Examination of the Effectiveness of the Enroute Decision Point Concept for Minimizing Low Visibility Accidents in Helicopter EMS Operations

Preliminary Research Proposal By

Patrick R Veillette, PhD

In cooperation with

National EMS Pilots Association
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ABSTRACT

Inadvertent IMC continues to be a large contributor to fatal HEMS accidents. The likelihood that a HEMS pilot will inadvertently enter into deteriorating visibility conditions remains significant, and the human factors studies and accident investigation records indicate this often ends in tragedy as the pilot continues into worsening conditions. It is hypothesized that a formal decision making tool can decrease the risk of these weather-related accidents. Properties of such a proposed decision making tool would include rapid pattern recognition, prompt trigger of a condition-action-rule response prior to the aircraft entering into an undesired aircraft state, and minimal risk of misinterpretation by flight or medical crew. Initial field testing of the “En-route Decision Point (EDP)”, which specifies a corrective decision to land, turn-around or proceed under IFR if the rotorcraft slows 30 knots below cruise speed or descends to less than 300 feet Above Ground Level, has shown the potential to reduce the risk of Controlled Flight Into Terrain (CFIT) or Loss of Control (LOC) as EMS helicopter pilots encountered degraded visibility while in flight. The objective of this project is to rigorously test the effectiveness and the parameters of the EDP concept in a full-motion helicopter simulator. This will be a controlled double-blind experimental study utilizing current and qualified HEMS pilots. During a simulated HEMS mission, the cloud ceiling and visibility will be progressively decreased. Pilot actions will be recorded, to include aircraft control along with flight parameters such as airspeed and height above ground. An expert observer will evaluate non-technical skills to include Co-operation, Leadership and Management, Situation Awareness and Decision Making. If validated, the EDP protocol can decrease the risk of CFIT or LOC accidents, be easily implemented by any HEMS operator, adapted into CRM programs to include medical crew members thereby changing safety cultures, and readily monitored via Flight Operations Quality Assurance (FOQA) software.
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ASAP</td>
<td>Aviation Safety Action Program</td>
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<tr>
<td>ASRS</td>
<td>Aviation Safety Reporting System</td>
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<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
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<tr>
<td>CAA</td>
<td>United Kingdom Civil Aviation Authority</td>
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<tr>
<td>CFIT</td>
<td>Controlled Flight Into Terrain</td>
</tr>
<tr>
<td>DOI</td>
<td>United States Department of Interior</td>
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<tr>
<td>EMS</td>
<td>Emergency Medical Services</td>
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<tr>
<td>FAA</td>
<td>U.S. Federal Aviation Administration</td>
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<tr>
<td>FOQA</td>
<td>Flight Operational Quality Assurance</td>
</tr>
<tr>
<td>GAO</td>
<td>United States General Accountability Office</td>
</tr>
<tr>
<td>GPWS</td>
<td>Ground Proximity Warning System</td>
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<tr>
<td>HEMS</td>
<td>Helicopter Emergency Medical Services</td>
</tr>
<tr>
<td>IGE</td>
<td>In Ground Effect</td>
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<tr>
<td>IMC</td>
<td>Instrument Meteorological Conditions</td>
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<tr>
<td>LOC</td>
<td>Loss of Control</td>
</tr>
<tr>
<td>LOSA</td>
<td>Line Operations Safety Audit</td>
</tr>
<tr>
<td>LTE</td>
<td>Loss of Tail Rotor Effectiveness</td>
</tr>
<tr>
<td>NASA</td>
<td>U.S. National Aeronautics and Space Administration</td>
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<td>NTSB</td>
<td>U.S. National Transportation Safety Board</td>
</tr>
<tr>
<td>NVG</td>
<td>Night Vision Goggles</td>
</tr>
<tr>
<td>OGE</td>
<td>Out of Ground Effect</td>
</tr>
<tr>
<td>RPD</td>
<td>Recognition Primed Decision Making</td>
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<tr>
<td>SMS</td>
<td>Safety Management System</td>
</tr>
<tr>
<td>SWP</td>
<td>Settling With Power</td>
</tr>
<tr>
<td>TAWS</td>
<td>Terrain Awareness Warning System</td>
</tr>
<tr>
<td>VMC</td>
<td>Visual Meteorological Conditions</td>
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</table>
I. Introduction

The helicopter has been recognized for its unique ability to reach remote areas, often in difficult terrain, to quickly provide emergency medical services (EMS) to injured patients and to expeditiously transport the patient to trauma centers. The helicopter has also proven itself as a valuable tool in densely populated urban areas with large metropolitan traffic jams for expeditiously transporting a patient to a hospital, or for hospital-to-hospital transfers. The EMS helicopter routinely operates around-the-clock, in poor weather and at night, and usually single pilot. Landing and taking off areas are often unimproved confined landing areas surrounded by obstacles. Flight requests come in with little or no advance notice. The average EMS mission entails high pilot workloads, complex communications requirements, life-saver mission pressures, in-flight distractions, and stressful flight/duty conditions for pilots and crewmembers. Additional factors of time pressures, poor human-system interface, insufficient automation and inadequate risk assessment often combine to produce task overload in a very hazardous environment that is very unforgiving of errors.

When such missions must be conducted in conditions of reduced visual cues due to darkness or weather, or both, the risk potential for an aircraft accident due to Controlled Flight Into Terrain (CFIT) or Loss of Control (LOC) can be very high. This research project is designed to evaluate and validate the parameters for a simple, effective, low-tech protocol that helicopter pilots can employ to mitigate the risks associated with operating in such conditions.

Following the description of the design of this project are sections which present more extensive details regarding the challenges and hazards that are associated with helicopter air medical transport operations and the need to control the risk associated with those hazards, as well as descriptions of various models for researching pilot performance.

II. Objectives

It is hypothesized that a formal decision making tool can decrease the risk of weather-related accidents. Properties of such a proposed decision making tool would include rapid pattern recognition, prompt trigger of a condition-action-rule response prior to the aircraft entering into an undesired aircraft state, and minimal risk of misinterpretation by flight or medical crew.

This proposed study will evaluate the En-route Decision Point (EDP) protocol, which specifies a corrective decision to land, turn-around or proceed under IFR if the rotorcraft slows 30 knots below cruise speed or descends to less than 300 feet Above Ground Level rather than continuing into deteriorating weather conditions. Initial field testing of this concept for several years provides substantial anecdotal evidence of the EDP’s potential to reduce the risk of Controlled Flight Into Terrain (CFIT) or Loss of Control (LOC) as EMS helicopter pilots encountered degraded visibility while in flight. It is important to note the initial field testing was conducted in a region with adverse mountainous topography, rapidly changing weather conditions and lack of weather reporting stations. In this difficult mission environment flight crew response to the concept was strongly affirmative.

The objectives of this research project are to:
1) determine the effectiveness of the EDP protocol to induce a definitive change in the course of the rotorcraft (land, turn, or go IFR) rather than continue into unknown and/or deteriorating weather;

2) validate and refine the parameters of the proposed EDP protocol (rotorcraft slows 30 knots below cruise speed or descends to less than 300 feet Above Ground Level) as an effective trigger point to keep the rotorcraft’s safety margins from further deterioration.

III. Methodology

Experimental Subjects

Phase One of this study is designed as a one-factor experiment divided into two independent groups. Participants will be blinded to the study hypothesis and study design. Pilot participants in the control will be asked to behave as they would in real life as the pilot in command of a mission, with the reason “to provide candid comments on the training value of the scenario for future training.” Pilot participants in the experimental group will receive the supplemental instruction “Fly as if your operator applies the Enroute Decision Point protocol at any time during the LOFT that the airspeed decays below “X” knots or the height above ground level becomes less than “Y” feet AGL.”

Aircrews evaluated in this study will be chosen by the sponsor’s crew scheduling department based upon the need for annual training required by Federal Aviation Regulations. The investigator has no control over aircrew scheduling. All participants will have a minimum of a commercial pilot certificate with rotorcraft-helicopter rating and employed by a single major helicopter operator. A total of 48 subjects will be evaluated. All subject aircrew members will have a minimum of one year experience in the respective rotorcraft.

Voluntary participants will be EMS pilots undergoing recurrent flight training in the EC 135 simulator training program. Participants will be “current and qualified” in type. Pilots attending the FAA-approved “Recurrent” curriculum experience 16.0 hours of ground school, 2.0 hours of System Integration Training, 4.5 hours of Briefing/Debriefing, and 6.0 hours of simulator time over a four day period. A “Line Oriented Flight Training” (“LOFT”) scenario will be added to the end of this curriculum for purposes of this investigation.

Demographic data to include initial training background (military, civilian), total rotorcraft time, experience in make/model, and rotorcraft flight time in past 12 months will be collected and subsequently evaluated using standard descriptive statistics.

Subsequent phases to the study will be added as project funding becomes available. Subsequent phases will expand the experiment to include conditions such as dark night, flat light, complex topography, rapid vs gradual degradation in visibility, NVG’s, etc.

Experimental Device

This investigation will utilize a full-motion-visual helicopter simulator of the Eurocopter EC-135. The Level D, six-degree-of-freedom simulator is equipped with a high fidelity graphics package to include a 60 x 200 degree field of view, continuous high-resolution imagery displaying a full range of environmental conditions. This high quality visual field is produced using three calligraphic projectors, each driven from three computer-generated image channels. The visual package is capable of photo-realistic scenes such as urban landscapes, offshore oil rigs, brownout and whiteout conditions, to
include realistic VMC to IMC with deteriorating conditions. The simulator cabs are equipped with 60-inch electrically actuated control loaders, programmed to give the desired dynamic force-feel characteristics of each rotorcraft during the takeoff and landing phases of flight.

The aural cues consist of the mechanical, aerodynamic and environmental (weather) sounds normal to the in-flight environment. All sounds are summed prior to power amplification, and mixing is introduced to achieve the required directionality of the simulated sounds. Loundspeakers are arranged around, above and below the simulated flight deck to achieve a high-fidelity polyphonic environment.

Motion cues are provided by a six-post motion system which carries the simulator cockpit. The platform is supported at each of three points by a pair of cylinders. These pairs of cylinders are in turn attached to the floor at three points, each cylinder of a pair being attached at either plus or minus approximately 60 degrees away from its attachments at the other end. Proper commanding of the extension or retraction of the cylinders can produce both translation of the motion platform along three mutually perpendicular axes and rotations about these axes. The servo performance of these systems can be characterized as second order systems with a natural frequency of about 2 Hz.

The simulator utilizes a mainframe (host) simulation computer and satellite computer. The host computer is the controlling computer for the satellite computers which in turn provide motion, visual, instructor's facilities and control loading. In addition, the main computer drives all of the utility general purpose peripherals as well as the dedicated flight deck peripheral. For example, a force applied to the control column is processed in the control loading computer, passed to the main computer, where, after considerable computation, it is converted to the necessary signals to drive the appropriate flight deck instruments, and provide the motion and vision cues.

Data is available to modules and to the hardware via an area of memory assigned for this purpose termed the global data area. Subsequently, this data is transferred by a separate task dedicated to the input/output activity.

The input/output console is directly linked, in parallel with the operator console, to the control loading computer. The output console consists of a video terminal with keyboard in the simulator cab, and a printer located outside of the simulator cab.

**LOFT Scenario**

A “LOFT” scenario added to the end of the recurrent training curriculum will be utilized to measure pilot performance. Initial conditions for the scenario will be: simulated flight to a hospital 20 miles distant, cloud ceiling 1,200 feet OVC, visibility 5 sm, and winds calm. Instructors will then progressive reduce the ceiling and visibility after the pilot reaches cruising altitude to determine pilot actions as the visibility and/or ceiling decrease. The route of flight will include obstacles such as poorly-labeled high power electrical cables. At the pre-determined point during the LOFT scenario, the simulator operator will initiate an algorithm in the simulator's software to record the rotorcraft and pilot inputs onto hardcopy for later analysis.

The simulator instructor will play the role of air traffic control and medical crew member for the scenario. The instructor will not give feedback or assist in any way other than helping to operate the simulator as necessary.

**Dependent Variables**

Crew performance will be assessed to include technical and non-technical areas. Technical skills used for evaluating individual pilot performance will include rotorcraft state variables and pilot control inputs, including the following
• rotorcraft pitch and bank attitude,
• rotorcraft indicated airspeed, heading and altitude,
• rotorcraft height above ground, and
• pilot control inputs (cyclic, collective, anti-torque pedals.)

Non-technical skills will be evaluated by simulator instructors. The four non-technical categories to be evaluated are: Co-operation, Leadership and Management, Situation Awareness and Decision Making. To assist with inter-rated reliability, three to four elements for each of the above categories will be selected. For each element a number of exemplar behaviours were included. These were phrased as generic (e.g. closes loop for communications), rather than specific (e.g. reads back to ATC), to give an indication of type, and to avoid specifying particular behaviors which should be observed. Simulator observers will grade each category on a 5-point Likert scale. All simulator instructors utilized in this experiment will be trained and standardized in the observation and grading of non-technical skills using the protocols described in a subsequent section.

Subject anonymity

All information will be double-blinded and immediately coded for security reasons so that no one set of data could be traced back to an individual. The databases will be secured and personal identifiers removed before publication and release of any findings. No information regarding any individual crewmember will be released and individual information is maintained only with coded identification numbers.

Test of Statistical Significance

Given the nearly unlimited range and complexity of possible actions by the subject pilots, and because no one single parameter is adequate at accurately describing pilot performance nor the safety of the rotorcraft, this experiment will include a combination of analysis of pilot technical and non-technical skills as well as rotorcraft state variables.

Analysis of the rotorcraft state data will include the extent to which the pilot allowed the rotorcraft to enter into an undesired aircraft state, as measured by deterioration of distance to an object or ground, progression into a Settling-With-Power condition (SWP), or progression into portions of the flight envelope conducive to Loss of Tail Rotor Effectiveness (LTE) as prescribed by the rotorcraft’s flight manual.

Analysis will include comparisons of deviation (duration and magnitude) of rotorcraft state beyond limits specified by the FAA’s Practical Test Standards for the Commercial and Airline Transport Pilot license.

Comparison of rotorcraft state and pilot control input variables between the two groups will use the 2-tailed, unpaired t-test as the measure of statistical significance. The experimental null hypothesis for this study will assume no difference between the two population means. Specifically, this tests the following hypothesis:

\[ H_0 : \mu_1 = \mu_2 \]

Using the Cochrane-Cox method, the value of \( t \) required for an \( \alpha = 0.05 \) level of significance is 2.069. An observed value of \( t \) greater than 2.069 is grounds to reject the null hypothesis.
Analysis of Variance (ANOVA) will be used to compare demographic background data (pilot IFR-flying recent experience, total rotorcraft flight experience, previous training background, etc.) to performance.

Analysis of the flight crew non-technical skill areas using Likert scale data will utilize standard descriptive statistics as well as inferential techniques, to include ANOVA techniques such as the Mann Whitney or Kruskal Wallis tests variations.

IV. PRINCIPAL INVESTIGATOR (PI) BACKGROUND

EDUCATION:

1995: Ph.D. Aerospace/Civil Engineering, University of Utah, Salt Lake City, UT
1992: M.S., Mechanical Engineering, University of Utah, Salt Lake City, UT

EXPERIENCE:

- Analyzed the effects of cockpit automation on pilot performance and pilot error at a major international airline as part of a doctoral program of study co-sponsored by United Air Lines, the Air Line Pilots Association and the NASA/Ames Research Center.
- Analyzed suitability of implementation of cockpit automation for use by a major short-haul airline.
- Studied the effects of checklist usage, procedures, flows, and standardization for a major airline as part of a post-doctoral program of study sponsored by the FAA, ALPA and USAir.
- Provided guidance and testimony to the U.S. General Accountability Office on accident prevention methodologies, review of other special studies, review of industry and government regulatory proposals of helicopter EMS safety.
- Provided guidance and testimony to the U.S. General Accounting Office on suitable methodologies for the collection and analysis of data on public-use rotorcraft safety.
- Consulted with the U.S. Dept. of Homeland Security on the safety of airborne law-enforcement operations.
- Presented advanced instruction on Crew Resource Management to EMS pilots, smokejumpers, military special forces, military aviation units, international rescue teams, aerial fire fighters, and to emergency response teams in conjunction with the 2002 Winter Olympics.
- Conducted and published research findings in international journals on the safety analyses of aerial fire-fighting, emergency medical service, and Part 135 operations.
- Conducted various conference workshops on minimizing human error in high risk environments.
- Guest lecturer for graduate level courses in injury prevention and systems safety in interdisciplinary medical/engineering programs at the University of Utah and University of Southern California.
Validating EDP
Research Proposal

- Was awarded international recognition by the Royal Aeronautical Society, Transportation Research Board (a branch of the National Academy of Sciences), the American Institute of Aeronautics and Astronautics and the National Business Aircraft Association.
- Consulted by international broadcasting corporations for documentaries on the air traffic control system and airspace congestion.
- Consulted by the U.S. Secretary of the Air Force’s Scientific Advisory Board on the human factor risks involved with remotely piloted vehicles.

SELECTED PUBLICATIONS
by the Principal Investigator

In the Fields of Helicopter Operations and Human Factors: (full list available upon request)


"Aviation Accident Report: Bell 47G Soloy, Intermountain Region, Fishlake National Forest, 29 Oct 96."


“Distraction management.” Business and Commercial Aviation March 06.
“Procedures.” Business and Commercial Aviation May 06.
“Accident prone pilots.” Business and Commercial Aviation Sep 06.
“LOSA.” Business and Commercial Aviation Jan 08.
“Fair Treatment of Aging Pilots.” Business and Commercial Aviation Feb 08.
“Checklist Design.” Business and Commercial Aviation August 08.
“Helicopter EMS.” Business and Commercial Aviation August 08.

Awards and Honors
2008: National Business Aviation Association’s “Gold Wing” Award
2007: Royal Aeronautical Society and l’Aero Club de France ‘s Aerospace Journalist of the Year
1994: National Research Council/Transportation Research Board, Graduate Research Award
1994: American Institute of Aeronautics and Astronautics William T. Piper Award
1992-National Research Council/Transportation Research Board, Graduate Research Award.
1985-Federation Aeronautique Internationale Silver Medal #4799
1983-Distinguished Military Graduate, U.S. Air Force Academy
V. Tentative Schedule and Budget

Preliminary Work

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<tr>
<th>Activity</th>
<th>Status</th>
<th>Date</th>
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<tbody>
<tr>
<td>Meeting of Interested Parties – Concept of Project</td>
<td>Complete</td>
<td>Feb 2013</td>
</tr>
<tr>
<td>Discussion of the Problem, Possible Solutions</td>
<td>Complete</td>
<td>Mar 2013</td>
</tr>
<tr>
<td>Discussion of Resources Needed and Available</td>
<td>Complete</td>
<td>Mar 2013</td>
</tr>
<tr>
<td>Review Accident Cases</td>
<td>Complete</td>
<td>Mar 2013</td>
</tr>
<tr>
<td>Review Past Literature</td>
<td>Complete</td>
<td>May 2013</td>
</tr>
<tr>
<td>Draft Research Proposal;</td>
<td>Complete</td>
<td>May 2013</td>
</tr>
<tr>
<td>Present Research Proposal to Possible Donors (Industry, NASA, trade groups)</td>
<td>Ongoing</td>
<td></td>
</tr>
<tr>
<td>Solicit Respected Members of Government, Academia, Research Laboratories, Trade Industry into a formal “EDP Advisory Group”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present Preliminary Research Proposal to EDP Advisory Group for review, comment, additions, and changes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present Research Proposal to EDP Advisory Group for approval and recommendation</td>
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Travel Activities, Preliminary Work:

Trip #1 to NASA-Ames Research Center, Human Factors Division
Personnel Involved: NEMSPA board member, NEMSPA HEMS SME, PI
Objectives/Activity: Present Preliminary Research Proposal to EDP Advisory Group
Budget Costs:
- Hotel: 3 nights hotel (average hotel cost: $220/night) $660 per person
- Travel: Airline, round-trip, SLC to Mountain View, Calif $350 per person
- Location Transportation: Car Rental or Taxi $250 for team
- Per Diem: 4 days per diem (based on govt per diem rate, $56) $224 per person

Trip #2 to NASA-Ames Research Center, Human Factors Division
Personnel Involved: NEMSPA board member, NEMSPA HEMS SME, PI
Objectives/Activity: Present Preliminary Research Proposal to EDP Advisory Group for formal approval
Budget Costs:
- Hotel: 2 nights hotel (average hotel cost: $220/night) $440 per person
- Travel: Airline, round-trip, SLC to Mountain View, Calif $350 per person
- Location Transportation: Car Rental or Taxi $250 for team
- Per Diem: 3 days per diem (based on govt per diem rate, $56) $168 per person

Month 1 and 2 (tentative January and February, 2014)
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<tr>
<th>Activity</th>
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<tr>
<td>Present Project to Simulator Staff (data collection methods, security, scheduling, etc)</td>
<td></td>
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<tr>
<td>Incorporate Training Center Staff recommendations</td>
<td></td>
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<tr>
<td>Formalize LOFT scenarios consistent with the capabilities of the simulator and objectives of the experiment</td>
<td></td>
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<tr>
<td>Present revision to all interested parties for final input</td>
<td></td>
<td></td>
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<tr>
<td>Conduct standardization training of simulator instructors</td>
<td></td>
<td></td>
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<tr>
<td>Begin drafting Powerpoint Presentation for Heli-Expo</td>
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</table>

**Travel Activities, Month 1 and 2:**

**Trip #1 to Metro Aviation Training Center, Shreveport, Louisiana**  
Personnel Involved: NEMSPA board member, NEMSPA HEMS SME, PI  
Objectives/Activity: Present Project to Simulator Staff, Incorporate Their Suggestions/Changes  
Budget Costs:  
- Hotel: 3 nights hotel (average hotel cost: $150/night)  
- Travel: Airline, round-trip, SLC to Shreveport  
- Local Transportation: Car Rental or Taxi  
- Per Diem: 4 days per diem (based on govt per diem rate, $46)  
  $350 per person  
  $750 per person  
  $200 for team  
  $184 per person

**Trip to NASA-Ames Research Center, Human Factors Division**  
Personnel Involved: NEMSPA board member, NEMSPA HEMS SME, PI  
Objectives/Activity: Present Modifications Learned from initial trip to Simulator Center, Review hardcopies of the simulator data output, Review/Modify LOFT scenarios  
Budget Costs:  
- Hotel: 2 nights (average hotel cost: $220/night)  
- Travel: Airline, round-trip, SLC to Mountain View, Calif  
- Location Transportation: Car Rental or Taxi  
- Per Diem: 3 days per diem (based on govt per diem rate, $56)  
  $440 per person  
  $350 per person  
  $250 for team  
  $168 per person

**Trip #2 to Metro Aviation Training Center, Shreveport, Louisiana**  
Personnel Involved: NEMSPA HEMS SME, PI  
Objectives/Activity: Present Amended Project to Simulator Staff, Train Simulator Data Collectors  
Budget Costs:  
- Hotel: 3 nights (average hotel cost: $150/night)  
- Travel: Airline, round-trip, SLC to Shreveport  
- Local Transportation: Car Rental or Taxi  
- Per Diem: 4 days per diem (based on govt per diem rate, $46)  
  $350 per person  
  $750 per person  
  $200 for team  
  $184 per person

**Man-Hour Commitment, Month 1 and 2:**  
PI: Approximately 30 hours/week .75 FTE  
HEMS SME: Approximately 20 hours/week .50 FTE
Month 3 and 4

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<tr>
<td>Run a “Beta Test” to determine what aspects of data collection need revision</td>
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<tr>
<td>Revise research project to implement these “lessons learned” and gather approval from EDP Advisory Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finish Powerpoint presentation for Heli-Expo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present “EDP” to Heli-Expo</td>
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</tbody>
</table>

Travel Activities, Month 3 and 4:

Trip to Metro Aviation Training Center, Shreveport, Louisiana  
Personnel Involved: NEMSPA HEMS SME, PI  
Objectives/Activity: Observe “Beta Test”, Collaborate with Simulator Instructors on any additions, changes to data collection methods  
Budget Costs  
- Hotel: 3 nights hotel (average hotel cost: $150/night) $350 per person  
- Travel: Airline, round-trip, SLC to Shreveport $750 per person  
- Local Transportation: Car Rental or Taxi $200 for team  
- Per Diem: 4 days per diem (based on govt per diem rate, $46) $184 per person

Trip to Heli-Expo, Santa Anna, California  
Personnel Involved: NEMSPA HEMS SME, PI  
Objectives/Activity: Present this project in formal educational sessions open to conference attendees and representatives from major organizations within the helicopter industry  
Budget Costs  
- Hotel: 4 nights hotel (average hotel cost: $250/night) $1,000 per person  
- Travel: Airline, round-trip, SLC to Santa Anna, California $500 per person  
- Local Transportation: Car Rental or Taxi $200 for team  
- Per Diem: 5 days per diem (based on govt per diem rate, $71) $355 per person

Man-Hour Commitment:  
- PI: approximately 30 hours/week  .75 FTE  
- HEMS SME: approximately 20 hours/week .50 FTE

Month 5, 6, 7 and 8

<table>
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<tr>
<th>Activity</th>
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<tbody>
<tr>
<td>Collect Data from “Day” and “Night” LOFT</td>
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<tr>
<td>Begin Initial Data Analysis</td>
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Travel Activities, Month 5,6,7, and 8:
Trip to Metro Aviation Training Center, Shreveport, Louisiana
Personnel Involved: NEMSPA HEMS SME, PI
Objectives/Activity: Monitor Sample of Simulator Sessions to Assure Compliance With Research Proposal, Assure Inter-Rater Reliability; Receive Feedback from simulator instructors on trends they are noticing in subject performance that we may want to examine during data analysis
Budget Costs:

- **Hotel:** 3 nights hotel (average hotel cost: $150/night) $350 per person
- **Travel:** Airline, round-trip, SLC to Shreveport $750 per person
- **Local Transportation:** Car Rental or Taxi $200 for team
- **Per Diem:** 4 days per diem (based on govt per diem rate, $46) $184 per person

Trip to NASA-Ames Research Center, Human Factors Division
Personnel Involved: NEMSPA board member, NEMSPA HEMS SME, PI
Objectives/Activity: Review Early Data Outputs (looking for early trends, possible modifications or refinements in data collection or analysis, etc). Communicate simulator instructor’s early observations and examine their perspectives for early trends.
Budget Costs:

- **Hotel:** 2 nights hotel (average hotel cost: $220/night) $440 per person
- **Travel:** Airline, round-trip, SLC to Mountain View, Calif $350 per person
- **Location Transportation:** Car Rental or Taxi $250 for team
- **Per Diem:** 3 days per diem (based on govt per diem rate, $56) $168 per person

Man-Hour Commitment:
- **PI:** approximately 40 hours/week 1.0 FTE
- **HEMS SME:** approximate 20 hours/week 0.5 FTE

### Month 8, 9 and 10

<table>
<thead>
<tr>
<th>Activity</th>
<th>Status</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyze Data from “Day” and “Night” LOFT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Submit Initial Report of the “Day” and “Night” LOFT results to Participating Organizations and EDP Advisory Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Begin Development of LOFT scenario for Flat Light, Dark Night, NVG, Fatigue, Complex Terrain conditions</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Travel Activities, Month 8,9 and 10:

Trip to NASA-Ames Research Center, Human Factors Division
Personnel Involved: NEMSPA board member, NEMSPA HEMS SME, PI
Objectives/Activity: Collaboration on Data Analysis
Budget Costs:

- **Hotel:** 2 nights hotel (average hotel cost: $220/night) $440 per person
- **Travel:** Airline, round-trip, SLC to Mountain View, Calif $350 per person
- **Location Transportation:** Car Rental or Taxi $250 for team
- **Per Diem:** 3 days per diem (based on govt per diem rate, $56) $168 per person
Trip to Air Medical Transport Conference, Oct 21-23, 2014
Personnel Involved: NEMSPA board member, NEMSPA HEMS SME, PI
Objectives/Activity: Present Preliminary Results to HEMS community

Budget Costs:

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Cost Details</th>
<th>Amount Per Person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hotel</td>
<td>4 nights hotel (average hotel cost: $220/night)</td>
<td>$880</td>
</tr>
<tr>
<td>Travel</td>
<td>Airline, round-trip, SLC to Virginia Beach, VA</td>
<td>$500</td>
</tr>
<tr>
<td>Location Transportation</td>
<td>Car Rental or Taxi</td>
<td>$250</td>
</tr>
<tr>
<td>Per Diem</td>
<td>5 days per diem (based on govt per diem rate, $56)</td>
<td>$280</td>
</tr>
</tbody>
</table>

Man-Hour Commitment:

<table>
<thead>
<tr>
<th>Role</th>
<th>Hours/Week</th>
<th>FTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI</td>
<td>40</td>
<td>1.0 FTE</td>
</tr>
<tr>
<td>HEMS SME</td>
<td>20</td>
<td>0.5 FTE</td>
</tr>
</tbody>
</table>

**Month 11 and 12**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Status</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finalize 12-month Progress Report to the EDP Advisory Group and Supporting Organizations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If deemed appropriate by the EDP Advisory Group, begin drafting formal paper(s) of the preliminary results for peer review to respected aeromedical journals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present Draft of LOFT scenarios involving other combinations of terrain and lighting conditions to NASA scientists and simulator instructors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble Presentation of Project’s Preliminary Results for trade group conferences</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Travel Activities, Month 11 and 12:

| Hotel: 3 nights hotel each trip | $XXX each trip                                      |
| Travel: Airline, round-trip, SLC to National Conference | $XXX each trip                                      |
| Per Diem: 4 days per diem each trip | $XXX each trip                                      |

Man-Hour Commitment:

<table>
<thead>
<tr>
<th>Role</th>
<th>Hours/Week</th>
<th>FTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI</td>
<td>30</td>
<td>.75 FTE</td>
</tr>
<tr>
<td>HEMS SME</td>
<td>20</td>
<td>0.5 FTE</td>
</tr>
</tbody>
</table>

**Month 13 and 14 (tentative January and February, 2015)**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Status</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorporate NASA and Simulator Training Center Staff recommendations on LOFT scenarios involving other</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Travel Activities, Month 13 and 14:

Trip to NASA-Ames Research Center, Human Factors Division
Personnel Involved: NEMSPA board member, NEMSPA HEMS SME, PI
Objectives/Activity: Review/Modify LOFT scenarios involving combinations of terrain and lighting
Budget Costs:
- Hotel: 2 nights (average hotel cost: $220/night) $440 per person
- Travel: Airline, round-trip, SLC to Mountain View, Calif $350 per person
- Location Transportation: Car Rental or Taxi $250 for team
- Per Diem: 3 days per diem (based on govt per diem rate, $56) $168 per person

Trip to Metro Aviation Training Center, Shreveport, Louisiana
Personnel Involved: NEMSPA board member, NEMSPA HEMS SME, PI
Objectives/Activity: Incorporate LOFT scenarios involving combinations of terrain and lighting
Budget Costs:
- Hotel: 3 nights hotel (average hotel cost: $150/night) $350 per person
- Travel: Airline, round-trip, SLC to Shreveport $750 per person
- Local Transportation: Car Rental or Taxi $200 for team
- Per Diem: 4 days per diem (based on govt per diem rate, $46) $184 per person

Man-Hour Commitment:
- PI: approximately 40 hours/week 1.0 FTE
- HEMS SME: approximate 20 hours/week 0.5 FTE

**Month 15 and 16**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Status</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Begin data collection from LOFT’s using combinations of terrain and lighting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Begin Data Analysis of Incoming Data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble Powerpoint presentation for Heli-Expo 2015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present “EDP” to Heli-Expo 2015</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Travel Activities, Month 15 and 16:
Trip to Metro Aviation Training Center, Shreveport, Louisiana
Personnel Involved: NEMSPA HEMS SME, PI
Objectives/Activity: Monitor Sample of Simulator Sessions to Assure Compliance With Research Proposal, Assure Inter-Rater Reliability
Budget Costs:
- Hotel: 3 nights hotel (average hotel cost: $150/night) $350 per person
- Travel: Airline, round-trip, SLC to Shreveport $750 per person
- Local Transportation: Car Rental or Taxi $200 per team
- Per Diem: 4 days per diem (based on govt per diem rate, $46) $184 per person

Trip to Heli-Expo, Orlando, Florida
Personnel Involved: NEMSPA HEMS SME, PI
Objectives/Activity: Present the preliminary findings from the first year of the project in formal educational sessions open to conference attendees and representatives from major organizations within the helicopter industry
Budget Costs
- Hotel: 4 nights hotel (average hotel cost: $250/night) $1,000 per person
- Travel: Airline, round-trip, SLC to Orlando, Florida $500 per person
- Local Transportation: Car Rental or Taxi $200 for team
- Per Diem: 5 days per diem (based on govt per diem rate, $56) $280 per person

Man-Hour Commitment:
- PI: approximately 20 hours/week .75 FTE
- HEMS SME: approximately 10 hours/week .50 FTE

Month 17, 18, 19, and 20

<table>
<thead>
<tr>
<th>Activity</th>
<th>Status</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collect Data from LOFTs involving differing lighting and terrain combinations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continue Data Analysis</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Travel Activities, Month 17, 18, 19 and 20:

Trip to NASA-Ames Research Center, Human Factors Division
Personnel Involved: NEMSPA board member, NEMSPA HEMS SME, PI
Objectives/Activity: Review Data Outputs. Continue data analysis.
Budget Costs:
- Hotel: 2 nights hotel (average hotel cost: $220/night) $440 per person
- Travel: Airline, round-trip, SLC to Mountain View, Calif $350 per person
- Location Transportation: Car Rental or Taxi $250 for team
- Per Diem: 3 days per diem (based on govt per diem rate, $56) $168 per person

Trip to NASA-Ames Research Center, Human Factors Division
Personnel Involved: NEMSPA board member, NEMSPA HEMS SME, PI
Objectives/Activity: Review Data Outputs. Continue data analysis.
Budget Costs:

Hotel: 2 nights hotel  (average hotel cost: $220/night)  $440 per person
Travel: Airline, round-trip, SLC to Mountain View, Calif  $350 per person
Location Transportation: Car Rental or Taxi  $250 for team
Per Diem: 3 days per diem (based on govt per diem rate, $56)  $168 per person

Man-Hour Commitment:

PI: approximately 40 hours/week  1.0 FTE
HEMS SME: approximate 20 hours/week  0.5 FTE

Month 20, 21 and 22

<table>
<thead>
<tr>
<th>Activity</th>
<th>Status</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continue Data Analysis from LOFT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Begin Drafting Final Report</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Submit to Participating Organizations</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Travel Activities, Month 20, 21 and 22:

Trip to NASA-Ames Research Center, Human Factors Division
Personnel Involved: NEMSPA board member, NEMSPA HEMS SME, PI
Objectives/Activity: Collaboration on Data Analysis
Budget Costs:

Hotel: 2 nights hotel  (average hotel cost: $220/night)  $440 per person
Travel: Airline, round-trip, SLC to Mountain View, Calif  $350 per person
Location Transportation: Car Rental or Taxi  $250 for team
Per Diem: 3 days per diem (based on govt per diem rate, $56)  $168 per person

Man-Hour Commitment:

PI: approximately 40 hours/week  1.0 FTE
HEMS SME: approximate 20 hours/week  0.5 FTE

Month 23 and 24

<table>
<thead>
<tr>
<th>Activity</th>
<th>Status</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorporate Feedback from Participating Organizations</td>
<td></td>
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</tr>
<tr>
<td>Draft Final Report</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present Final Report to EDP Advisory Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepare Report(s) For Peer-Review Journals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble Draft Presentation of Project’s Final Results for trade group conferences</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Travel Activities, Month 11 and 12:

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XX trips to National Conferences
   Hotel: 3 nights hotel each trip  $XXX each trip
   Travel: Airline, round-trip, SLC to National Conference  $XXX each trip
   Per Diem: 4 days per diem each trip  $XXX each trip

Man-Hour Commitment:
   PI: approximately 40 hours/week  1.0 FTE
   HEMS SME: approximate 20 hours/week  0.5 FTE

Project Budget Summary:

<table>
<thead>
<tr>
<th>Budget Item</th>
<th>Amount</th>
<th>Sub-Total</th>
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<tbody>
<tr>
<td>A. Personnel</td>
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<td></td>
</tr>
<tr>
<td>Direct Salary of PI, CY 2014</td>
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<td></td>
</tr>
<tr>
<td>Direct Salary of PI, CY 2015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fringe Benefits of PI, CY 2014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fringe Benefits of PI, CY 2015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salary of HEMS SME, CY 2014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salary of HEMS SME, CY 2015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Travel</td>
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<td></td>
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<tr>
<td>Domestic Travel, CY 2014</td>
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<td></td>
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<tr>
<td>Domestic Travel, CY 2015</td>
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<td></td>
</tr>
<tr>
<td>C. Advertising</td>
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<td></td>
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<tr>
<td>D. Recruitment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. Total</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Budget Explanation

Summary: We request a total of $ XXX to undertake the study described.

Personnel: The Principal Investigator will be responsible for the successful execution of the project, to include the role of coordination, planning, study implementation and supervision of data analyses. The majority of funds will go towards personnel expenses ($ XXX) for the essential but time-consuming activities of coding and analyzing simulator data. The data analysis for this dynamic project will be complex, requiring the use of advanced forms of flight control modeling. A HEMS SME with over 40
years experience as a helicopter expert will assist with development of the LOFT scenarios and analysis of the data. It is estimated that the time commitment to this project is the equivalent of XXX FTE for the PI and XXX FTE for the HEMS SME. Significant time has already been invested in conducting the extensive literature review and experiment design.

Travel: The estimated travel costs of $XXX include XX trips to meet with staff at the Metro Aviation Training Center to introduce the study, train the expert observers, oversee a “beta test”, confer with initial observations and provide monitoring. XX trips to the NASA Ames Research Center are planned to conduct reviews of the research plan, extensive coordination for analysis of data, formulation of the LOFT scenarios for year #1 and year #2, and preparation of intermediate and final reports. Four trips are planned to present the results of the research at national professional conferences (two to Heli-Expo, two to aeromedical conferences). The amounts are estimated to include domestic airfare, lodging and government per diem rates for meals.

The NASA Ames Research Center Human Factors Division has planned for a multi-year budget equivalent of 0.2 FTE to provide human factors, experimental design and data analysis support. Metro Aviation has pledged usage of their training simulators, contingent upon grant funding, needed to implement this project. No other funding has been received. Additional funding from other sources will be sought to support subsequent data analysis and expansion of the project to include other conditions (for example: flat light, dark night, NVG, complex terrain, rapid transition to IMC, fatigue, etc.).

VI. Background

A series of IMC-related fatal EMS helicopter accidents between May 1978 and December 1986 led to the NTSB’s first special study on HEMS (Helicopter EMS) safety. The NTSB examined 59 EMS accidents between May 1978 and December 1986 and concluded that many areas of EMS operations needed improvement, including weather forecasting, operations during instrument meteorological conditions (IMC), personnel training requirements, and EMS operations management. (NTSB, 1988)

The following includes a review of the special studies on HEMS safety, an analysis of ASRS reports by HEMS pilots, a discussion of the weather minimums required for dispatch of a HEMS flight, and applicable human factors associated with the safe operation of a helicopter in reduced visibility conditions.

Review of Major HEMS Studies

The NTSB’s 1988 study determined that the single most common factor in fatal EMS helicopter accidents was unplanned entry into instrument meteorological conditions, with most of these accidents occurring at night. The FAA’s Aeronautical Decision Making for Air Ambulance Helicopter Pilots states, “the real killer lurking in the night sky is the unseen cloud. Clouds disappear easily in the dark, and you can fly into one without seeing it coming.” Spatial disorientation, unreliable en route weather information and interpretation, and pilot judgment were frequently found to be associated factors in reduced-visibility accidents.

In 1987, authors Adams and Thompson (“Learning from Past Mistakes”) found that 67% of HEMS accidents were weather related, 48% occurred at night in marginal weather, and 19% occurred during daytime marginal weather.

In 2001 the Flight Safety Foundation published an in-depth study on EMS safety. This study
examined 87 helicopter accidents and 59 rotary-wing EMS incidents that occurred during commercial EMS operations from January, 1987 through December, 2000. The significant findings from the accident analysis produced the following major findings: 47% of the accidents occurred during cruise flight. Eighty-one percent of all fatalities occurred during cruise. Sixty-three percent of the accidents in cruise flight resulted in fatalities. Night conditions accounted for 44% of the fatal accidents during cruise. IMC accounted for 34% of the fatal accidents during cruise. Thirty percent of all accidents involved low visibility or instrument meteorological conditions. Sixty-nine percent of all fatal accidents occurred in low visibility. (Flight Safety Foundation, 2001)

Of the 27 fatal HEMS accidents in the NTSB’s 2006 study, 21 occurred during night operations. Of the 21 night accidents, 16 of the operations originated under visual flight rules (VFR) and inadvertently flew into IMC conditions resulting in CFIT. (NTSB, 2006) Air ambulance accidents were more often associated with weather conditions compared with other helicopter accidents. While 4 percent of other helicopter accidents are associated with bad weather, air ambulance accidents were nearly four times more likely (15 percent) to be attributed to adverse weather. (NTSB, 2006)

The GAO’s special study of EMS safety in 2007 found a predominance of limited-visibility risks. More than half of all air ambulance helicopter accidents took place at night, compared with 9 percent of non-air-ambulance helicopter accidents. The GAO report indicated that even though 38 percent of all helicopter EMS flights occur at night, 49 percent of accidents during a 20-year period occurred during nighttime hours. Data of helicopter accidents occurring between 1998 and 2005 show that factors related to flight environment (such as light, weather, and terrain) underlie 70 percent of all EMS accidents, compared with 40 percent of accidents for other helicopter accidents. (GAO, 2007)

A study by the Bell Helicopter manufacturer (Fox, 2008) found over a 10 ½ year period that 54% of the HEMS accidents occurred at night. The Bell study also found 16% of day-time accidents occurred in poor visibility due to weather conditions, whereas 35% of night-time accidents occurred in such conditions (twice as high at night). The Bell study found 55.3% of the 114 fatalities occurred in the 37.5% of the accidents which occurred as a result of inadvertent IMC, spatial disorientation, and CFIT accidents.

**Analysis of HEMS ASRS data**

A comprehensive search of the NASA ASRS database for reports anonymously submitted by HEMS crews was conducted using keywords in the narrative such as EMS, medevac, flight nurse, flight paramedic, patient, hospital. A total of 369 reports were extracted from the database and evaluated using the Threat and Error Management model. [Note: A “threat” is an external event or an error outside of the flight crew’s influence but requiring the active management of the crew to prevent it from impacting safety. An “error” is a deviation from organizational or crew expectations that can result in an “Undesired Rotorcraft State” that places the flight at increased risk. ]

<table>
<thead>
<tr>
<th>Threat</th>
<th>Percentage Present</th>
<th>Percent Mismanaged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mission Preparation/Pressure</td>
<td>93%</td>
<td>57%</td>
</tr>
<tr>
<td>Excessive Workload</td>
<td>84%</td>
<td>68%</td>
</tr>
<tr>
<td>Communication Difficulties</td>
<td>75%</td>
<td>35%</td>
</tr>
<tr>
<td>Adverse Lighting Conditions</td>
<td>54%</td>
<td>38%</td>
</tr>
</tbody>
</table>

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On-Scene Operations | 53% | 42%
Adverse Weather Conditions | 45% | 34%
Confined Area Operations | 29% | 14%
Distractions | 28% | 24%
Pilot | 17% | 9%
Helicopter/Equipment | 16% | 15%

Mission Preparation/Operational Pressures were present in 93% of the ASRS reports. These included time pressures [67%], rapid mission preparation [63%], pressures from patient conditions [23%], and economic pressures (17%). Fifty-seven percent of the ASRS reports indicated that these threats had been mismanaged. An excellent example is contained in the following pilot narrative.

“The flight was flying from a hospital with a patient on board. The rain had picked up and the visibility was less than reported….I was able to maintain a couple of lights to the side but forward lights all disappeared….The problem is having a patient onboard and feeling the pressure to try to continue the flight in less than reported conditions. They had disconnected the autopilot so it was inoperative. I am ATP rated but not current IFR. We do have an IFR ship which should have been sent on the flight but we are closer by 18 mi (sic) and our ship is much cheaper to fly….It is too bad that we sometimes have to have less than favorable flight to get non-aviation people to realize closer and cheaper are not always the right thing to do. (ASRS #635667)

Time pressure is commonly cited in ASRS reports, and greatly increases the probability of human error. Dr. James Reason, professor emeritus at the University of Manchester and an expert on human error found that the perception of a shortage of time increases the probability of human error by 11 times. The following ASRS narrative is illustrative.

“I arrived at work for a shift change. After parking the car, I heard one of our hospital helicopters turning on the hospital helipad. I ran to the pad so I could relieve the night pilot and take the flight… We were responding to a multiple car accident with serious injuries incurred…. I remember glancing at my instrument gauges before lift off. Everything looked good. I made the appropriate calls and began the takeoff process….As we moved forward, my warning lights and horns for low rotor rpm came on. My rotor rpm’s began to drop and the rotorcraft slowly began to settle….I turned and was able to settle back on the pad and appeared to land without incident. I looked at the gauges and around the cockpit. Everything was normal again, except I noticed that my engine throttles were not full forward. I assumed that was the problem. I pushed the throttles forward completely, lifted off again and flew the flight to the accident scene as if everything was normal. Upon landing and shutting down at the scene, I discovered that approximately 2-3” of each tail rotor blade (2) was chopped off. I gave the remaining rotors a detailed inspection, checked the drive train from the engines to the rotors and found everything in place. The patient was brought to the rotorcraft, dying, and placed inside. I made the decision that I could make the 5 minute flight back to the hospital safely. The flight went back without incident.  

Problem areas: The quick EMS helicopter responses, the numerous interruptions of the EMS pilot during start-up and the pilot allowing this to happen. Plus, the added pressure of a dying person causing the pilot to make emotional decisions instead of safe ones.” (underlines added for emphasis) (NASA ASRS Accession Number 118240)

Excessive workload conditions were present in 84% of the ASRS reports. These included workload induced by single pilot operations, no copilot for cross-check and monitor, an operationally
difficult environment induced by congested airspace and/or multi-tasking, and unfamiliarity. 68% of the ASRS reports indicated that this threat had been mismanaged.

The EMS pilot works in a “very high threat” mission environment. The excessive workload faced by helicopter ambulance pilots is most clearly present in 84% of the ASRS reports. These included workload induced by single pilot operations in helicopters and the lack of a pilot monitoring for cross-checking. This is aptly stated by an EMS pilot in the following ASRS report.

“I was flying an EMS helicopter dispatched from XYZ hospital, in City A, to recover a patient at the mall, City B. The coordinates provided were incorrect and took me five nautical miles south of the City B airport before I recognized the error and reversed course. I was coordinating with dispatch, medic command (flight following/status reports) and an emergency vehicle on scene broadcasting position reports and intentions on unicom… the Approach Supervisor advised me that I entered his airspace and did not properly coordinate with his controller…. I was working four frequencies and receiving conflicting coordinates from the ground while searching for the landing zone. I was aware of my close proximity to the airport traffic area. I was preoccupied with the traffic avoidance while coordinating with the ground vehicles during the search for and subsequent approach and landing at the landing zone.” (NASA ASRS Accession Number 181754)

With very few exceptions, HEMS operations are conducted with single pilot crews. Single pilots lose the benefit of error management by cross-check and pilot monitoring.

Communication difficulties included working multiple frequencies simultaneously, troubles with access to ATC, and simultaneous inter-cockpit and intra-cockpit communications. 75% of the ASRS reports indicated this threat was present. Additional communication “threats” included missing information, miscommunication, and misinterpretation. 35% of the ASRS reports indicated this threat had not been adequately managed.

Adverse lighting conditions included night, brown-out, or white-out conditions. 54% of the ASRS reports indicated this was a threat present during the flight. 38% of the ASRS reports indicated this threat had not been adequately managed.

“On-scene” operations included lack of adequate information regarding weather and obstacles at a scene, proximity of obstacles, communication difficulties with first responders, inadequate identification and lighting of obstacles, etc. 53% of the ASRS reports indicated this was a threat during the flight. 42% of the ASRS reports indicated that the “on scene” threat had not been adequately managed.

Adverse weather conditions were present in 45 percent of the ASRS reports. This category included not only adverse weather such as limited visibility and cloud ceilings that create higher risks for helicopter operations, but also weather forecast reports with “chance of marginal conditions,” lack of definitive weather reports along the route or destination, un-forecast weather, and deteriorating weather. Thirty-four percent of the ASRS reports indicated this threat category was not adequately managed.

These factors combine to create an increased threat of inadvertent entry into instrument conditions, a factor cited in 18% of the sampled ASRS reports. Seventy-eight percent of these occurred at night. The NTSB’s 1988 study determined that the single most common factor in fatal EMS helicopter accidents was unplanned entry into instrument meteorological conditions. Inadvertent IMC (IIMC) should receive focused attention as it often results in a serious degradation of rotorcraft control [14% of the sampled reports] and a serious loss of safe clearance from the terrain [8% of the sampled reports.] Today, inadvertent IMC continues to be a large contributor to fatal HEMS accidents.
Confined area operations were a factor in 29% of the ASRS reports. Specific threats within this category included limited maneuvering room, proximity of obstacles, lack of information about the existence and proximity of obstacles, inadequate lighting for the operation to adequately detect the presence of nearby obstacles, adverse wind conditions for takeoff and departure from a confined area, and lack of guidance from other flight crew or ground crew members to maintain adequate separation from obstacles. Fourteen percent of the ASRS reports indicated this threat had not been adequately managed.

Distractions due to patient conditions, multi-tasking, and from crew were present in 28% of the reports. 24% of the ASRS reports indicated this threat had not been adequately managed.

Pilot factors included fatigue and lack of IFR currency/proficiency. In its 1988 study, the NTSB suggested that pilot fatigue could be a primary contributor to the industry’s poor safety performance. The topic of fatigue in EMS operations was revisited during the 2009 NTSB hearings on HEMS safety. This threat was present in 17% of the reports, and inadequately managed 9% of the time. The Safety Board believes “that EMS helicopter pilots work in an environment and operate on a schedule conducive to acute and chronic fatigue that can influence the pilot’s ability to operate the rotorcraft safely.”

Helicopter factors included the rotorcraft not being IFR capable, operating with inoperative components, and/or a mechanical failure. Sixteen percent of the reports indicated the presence of this threat; 15% of the ASRS reports indicated it was not properly managed.

<table>
<thead>
<tr>
<th>Table 2: Errors Cited in HEMS ASRS reports</th>
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<tbody>
<tr>
<td><strong>Percentage</strong></td>
</tr>
<tr>
<td><strong>present</strong></td>
</tr>
<tr>
<td><strong>Rotorcraft Handling</strong></td>
</tr>
<tr>
<td>Manual handling</td>
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<tr>
<td>Navigational error</td>
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<tr>
<td><strong>Procedural Errors</strong></td>
</tr>
<tr>
<td>Incorrect Execution</td>
</tr>
<tr>
<td>Checklist errors</td>
</tr>
<tr>
<td><strong>Communications</strong></td>
</tr>
<tr>
<td>Internal [crew]</td>
</tr>
<tr>
<td>External [dispatch, ATC, scene]</td>
</tr>
<tr>
<td>Decision Making</td>
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</table>

The most common error reported or observed in the ASRS sample was a decision-making error that resulted in an unnecessary increase in risk. This was present in more than half of all of the reports [54%], and mismanaged in 46% of the reports. For example, a pilot under time pressure rushes the preflight preparation, does not properly inspect the cockpit switches for correct positioning, attempts to takeoff with the throttles mistakenly at a low power setting, and continues the takeoff attempt with a warning horn blaring. The decision making errors subsequently resulted in an inadvertent encounter with IMC, degradation in rotorcraft control, or inadequate separation from terrain or from an obstacle, all of which are potentially serious “undesired rotorcraft states.”

The second most frequently reported error in the ASRS sample was a navigational error. There could be some reporting bias which would make aircrews more likely to report this type of error since most of these resulted in penetrating controlled airspace without a proper ATC clearance and could easily lead to an FAA notice of investigation and subsequent violation against the pilot’s certificate.
Manual handling errors occurred in 23% of the ASRS reports, and were mismanaged in 19% of the cases. These included degradations in control of the rotorcraft’s airspeed, rotor RPM, sink rate, airspeed, etc. All of these occurred in single-pilot rotorcraft.

Incorrect execution of procedures occurred in 20% of the ASRS reports, with 14% of the reports indicating the mismanagement of procedures.

Table 3: UNDESIRED ROTORCRAFT STATES:

<table>
<thead>
<tr>
<th>State</th>
<th>%</th>
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<tbody>
<tr>
<td>Inadvertent Penetration of Instrument Conditions</td>
<td>18%</td>
</tr>
<tr>
<td>Near Mid Air Collision</td>
<td>17%</td>
</tr>
<tr>
<td>Multiple &quot;Undesired Rotorcraft States&quot;</td>
<td>17%</td>
</tr>
<tr>
<td>Continued Flight with non-airworthy Rotorcraft</td>
<td>17%</td>
</tr>
<tr>
<td>Serious Degradation of Rotorcraft Control</td>
<td>14%</td>
</tr>
<tr>
<td>Course deviation</td>
<td>12%</td>
</tr>
<tr>
<td>Emergency declared with ATC</td>
<td>9%</td>
</tr>
<tr>
<td>Loss of Separation [Obstacle]</td>
<td>8%</td>
</tr>
<tr>
<td>Loss of Separation [Terrain]</td>
<td>6%</td>
</tr>
<tr>
<td>Unplanned/precautionary Landing</td>
<td>6%</td>
</tr>
</tbody>
</table>

“Inadvertent Penetration of Instrument Conditions” was cited in 18% of the sampled ASRS reports, of which 78% occurred at night. Of particular concern is that many of these resulted in a serious degradation of rotorcraft control [which occurred in 14% of the sampled reports] or a serious loss of separation with terrain [which occurred in 8% of the sampled reports.]

Weather Minimums and Accuracy of Weather Information

Since its first hearing on HEMS safety in 1988 the NTSB has held two more hearings urging the Federal Aviation Administration to mandate upgrades to equipment and operational practices. Given the frequency and severity, and the media focus on the increase in IMC-related accidents in 2007 and 2008, the NTSB in 2009 emphasized a concern about the established weather minimums for HEMS flights and recommended the development of visual flight weather minimums for individual helicopter programs based on local terrain and weather. The NTSB recommended that these weather minimums should be communicated to the pilots in writing, and that flight below the published minimums should be prohibited. The NTSB also recommended requiring that all EMS operators operate under Federal Regulations Part 135 on all flights with medical personnel on board (A-06-12), requiring all EMS operators to use risk evaluation programs and train in the evaluation of flight risks (A-06-13), require EMS operators to use formalized dispatch and flight-following procedures including up-to-date weather information flight risk assessment decisions (A-06-14), and requiring the installation of terrain awareness and warning systems on rotorcraft and training flight crews on the use of this equipment (A-06-15).

For Part 91 flights, which pertain to ALL flights, paragraph 14 CFR 91.103, “Preflight action,” states the following, “Each pilot in command shall, before beginning a flight, become familiar with all available information concerning that flight. This information must include - (a) for a flight under [instrument flight rules] or a flight not in the vicinity of an airport, weather reports and forecasts.”

Within Part 135 regulations, instrument flight rules allow for the use of instruments in guiding the rotorcraft in inclement weather. However, in order to utilize instrument flight rules equipment, weather reporting must be available for the destination location. According to Part 135 regulations, if
such weather reporting is unavailable flights must use visual flight rules. According to the GAO’s report, since many air ambulance flights are to remote landing sites or to hospitals that do not have such weather reporting available, air ambulances can be inhibited in their use of instrument flight rules equipment under Part 135.

The current weather minimums required for dispatch under Part 135 require that helicopter operators flying under 1,200 feet AGL (above ground level) have visibility of at least a half mile of visibility during the day and at least one mile at night. Additionally, Part 135 requires that all helicopter operators have visual surface reference during the day and visual surface light reference at night.

In addition, Operating Specifications A021, “Helicopter Emergency Medical Services Operations,” requires a minimum of 800-2 (800 foot ceiling, 2 sm visibility) for a “Local” flight in day conditions, and 800-3 for a cross-country flight in day conditions. At night, an operator without a Night Vision Imaging System or Terrain Awareness Warning System will require 1000-3 for local flights and 1000-5 for cross-country flights.

Veillette (2009) examined 55 limited-visibility HEMS accidents that occurred between April 1, 1988 to September 27, 2009 to examine whether the flight could have legally launched under the present and proposed Part 135 weather minimums. Only five of the 55 accidents would not have been allowed to dispatch using either the current or the proposed Part 135 weather minimums. The proposed amendments to the weather minimums would have prevented 25 of the flights from launching IF an important “loophole” in the Part 135 regulations were closed. The loophole would have required a definitive weather report or forecast of the weather at the destination. However, given that most HEMS flights are conducted to locations without official weather reporting, the pilot would still have been “legal” to launch due to the absence of an official weather report and allowed to use his own observations.

The lack of on-site weather reports also impacts the preflight go/no-go decision. Weather reports are often a significant distance from the destination making it difficult for EMS pilots to make an educated decision. Examining NTSB accident reports, the nearest weather reporting stations in ten accidents were 15 to 25 miles away, and in eight accidents the weather reporting was even more remote. One was 47 miles away. (Veillette, 2009)

Both the revised weather minimums and the current Part 135 weather minimums regulations fail to contain protection against several significant loopholes which allow a pilot to dispatch into weather conditions which contain a significant threat for an inadvertent IMC penetration. Specifically, for Part 135 flights, 14 CFR 135.213, “Weather/reports and forecasts,” states in part, “Whenever a person operating an rotorcraft under this part is required to use a weather report or forecast, that person shall use that of the U.S. National Weather Service, a source approved by the U.S. National Weather Service, or a source approved by the Administrator. However, for operations under VFR, the pilot in command may, if such a report is not available, use weather information based on the pilot’s own observations or on those of other persons competent to supply appropriate observations.”

The degradation of rotorcraft control upon entering limited-visibility-conditions should be of serious concern in the HEMS data. This author’s analysis of 369 ASRS reports found rotorcraft handling errors occurred in 23% of the ASRS reports. These included significant degradations in the rotorcraft’s airspeed, rotor RPM, sink rate, airspeed, etc. All of these occurred in single-pilot rotorcraft.

“Inadvertent Penetration of Instrument Conditions” was cited in 18% of the sampled ASRS reports. This number should receive immense attention. Clearly IMC-related accidents continue to be the most consistent fatal type of accident in the EMS industry’s safety records. Of particular concern is that many of these resulted in a serious degradation of rotorcraft control [which occurred in 14% of the sampled reports] or a serious loss of separation with terrain [which occurred in 8% of the sampled reports.]
A deeper look at the “inadvertent penetration of IMC” reveals some additional concerns. More than 84% of these involved un-forecast weather, localized weather phenomena or “probability of” weather forecasts. During the preflight planning stage pilots seldom had exact weather information for the destination. Pilot decision making was also complicated with weather forecasts containing “chance of localized weather” conditions. It is also interesting to note that in all of these reports, the flight could still have been dispatched under the more stringent weather requirements of Part 135.

Gaps within the Part 135 weather minimums would still allow a pilot to launch into weather hazardous to the flight. One of these “loopholes” is weather forecasts which contain “probability of ‘x’ conditions” or “temporary” weather conditions. For example, a weather forecast may state, “Ceilings better than 3,000 feet and visibilities better than 5 miles...with a 40% chance of rain showers and occasional visibilities below 1 mile and ceilings below 800 overcast.” Such a forecast would still allow a pilot to launch.

In actual operation, EMS pilots often fail to keep their weather assessment objective. A review of ASRS reports for the Flight Safety Foundation’s 2001 study found that 67% of the EMS pilot reports documented that knowledge of the patient’s condition influenced their decision making. A survey of flight paramedics conducted by the International Association of Flight Paramedics and presented at the NTSB’s special hearing on EMS safety revealed 30% of the respondents reported that the pilot is aware of the urgency of the flight request, despite attempts to shield that information to avoid pressuring the pilot to conduct the flight. Since weather and reduced visibility (including night flight) create additional risk, additional risk management is required on several fronts.

**Helicopter Human Factors**

Dr. Richard Adams, a noted aviation human factors researcher who consults to the FAA and US Navy Aviation Safety Center, stated in “Special Considerations For Helicopter Safety” in the book *Aviation Psychology*, “The basic handling qualities and stability characteristics make the task of flying helicopters significantly more demanding than fixed wing in VMC, and that task is compounded by the decreased visual cues inherent in night or IMC. In hovering flight with zero wind, the helicopter tends to be statically unstable. In forward flight, it is dynamically stable in the yaw axis, dynamically unstable in pitch and statically unstable in roll. These characteristics coupled with the sensitivity of the controls results in a vehicle that would most likely be unacceptable in many other commercial applications. The basic qualities and stability characteristics make the task of flying helicopters significantly more demanding than fixed wing flying in ideal VMC. When that task is compounded by the decreased visual cues inherent in night flying or IMC, the workload frequently exceeds the ability of the pilot to cope.” (Adams)

The NTSB’s 1988 Special Study stated, “Tests and experience have shown that non-instrument-trained pilots or non-proficient pilots are rarely successful in overcoming spatial disorientation. Most helicopters require some form of autopilot system in addition to appropriate navigation equipment and instrumentation in order to be approved and certificated for single-pilot flight into instrument conditions. Without this help, even if the helicopter has appropriate instrumentation, pilots will have a difficult time controlling the helicopter if they lose visual reference, since helicopters are unstable in flight and require constant input from the pilot to remain under control.” (NTSB, 1988)

Although some helicopters are minimally equipped for operations in IMC, the information provided is not sufficiently sensitive or accurate for the slow speeds flown (Verdi & Henderson, 1975). Typical attitude, altitude and airspeed indicators provide un-integrated information. Conventional instruments present two-dimensional information on these separate displays. These do not provide the three-dimensional visual representation of the immediate environment required for low level helicopter flight. This imposes considerably higher workload, especially in instrument flight. (Hart)
The visual demands imposed by the proximity of the rotorcraft to the ground and obstacles are particularly heavy. Pilots must not only keep their vehicle airborne but also maintain a safe distance from trees, wires, and obstructions. At low altitudes in good visibility, helicopter pilots use visual cues in the immediate surroundings to identify terrain features and determine their orientation, rate and direction of movement, height above terrain, and distance from obstacles for immediate flight path control, obstacle avoidance, and navigation.

Vision is more than a direct translation of incoming sensory data. Recognition and interpretation of incoming sensory information requires transformation and integration of retinal images based on expectations, information processing, previous experience, and knowledge of the current situation. (Hart)

Pilots use both dynamic cues (e.g., motion parallax, optic flow, and occlusion) and static cues (e.g., shading, texture gradients, perspective transformations, color and luminance contrasts, and surface contours) to identify objects and terrain features. While the information available with direct vision in good visibility is adequate, changes in the perception of dynamic and static cues with decreases in visibility and luminance contrasts interfere with accurate spatial and temporal resolution, thus increasing workload. (Lees, Kimball, Hoffman and Stone, 1976) Constant attention to the visual scene and a precise awareness imposes high visual, temporal, physical, and cognitive demands on two pilot crews, and unacceptable workload levels for single pilots. (Hart; Forbush, 1981)

Cockpit noise, vibration, heat/cold, poorly designed seats, instrument layout, and cockpit ergonomics are but a few of the added detractors to pilot performance in a rotorcraft. (Hart)

A review of 59 aeromedical accidents by Adams discovered that loss of attitudinal control and impact with the ground at cruise speeds or higher occurs within 34 seconds after loss of visual references. The median experience level of the pilots having these accidents was 5,500 flight hours. (NTSB, 1988).

A study by the Pennsylvania State University’s College of Medicine of the importance of helicopter instrument proficiency found that instrument-proficient pilots more safely managed an unexpected encounter with IMC. During a simulated EMS mission, cloud ceiling and visibility were decreased until IMC prevailed, and pilot actions were recorded. Data included the altitude at which the rotorcraft entered IMC, and whether the pilots maintained control of the rotorcraft, flew within aviation standards [i.e., bank angle, airspeed], and safely landed. Pilots considered “instrument proficient” lost control less often than those considered “non instrument proficient” [15% vs 67%], maintained instrument standards more often [77% vs 40%], and entered IMC at a higher altitude [689 feet vs 517 feet] compared with the non-proficient pilots. However, it is still worth noting that 15% of the “instrument proficient” pilots lost control. Instructor comments also indicated that the non-proficient pilots made more errors than did the instrument-proficient pilots.

Pilot Decision Making

Maintaining safe flight operations depends on assuring effective crew decision making, especially under threatening conditions. (Helmreich, et al, 2001). When HEMS pilots are surveyed on the leading threats, 92% of total respondents cite “pushing weather minimums” and 82% cite “pilot decision making” as the main reasons for crashes. (Dery, et al, 2005) This author’s analysis of 369 ASRS reports from HEMS pilots found the most common error was a decision making error that resulted in an unnecessary increase in risk. This was present in more than half of all of the reports [54%]. It is significant to note that almost all of these were mismanaged (46% of the reports) and the aircraft degraded into potentially serious “undesired rotorcraft states.” of inadvertent encounter with IMC (18%), degradation in rotorcraft control (14%), or loss of separation from terrain (8%) or from an
obstacle (6%).

This leads to a key question. How can HEMS crews be trained and supported to make the best decisions possible, especially under the high-risk deteriorating weather condition? To answer this key question, we should know, “What types of decision-making errors lead pilots to make unsafe decisions? Why have highly experienced pilots underestimated risk in potentially critical situations? What factors make decisions difficult and contribute to poor decisions? What constitutes effective decision making?”

Unfortunately the HEMS flight environment has an abundance of factors which hinder effective decision making. Orasanu & Connolly (1993) found the following eight factors as major hindrances to effective decision making: ill-structured problems, uncertain dynamic environment; shifting, ill-defined or competing goals; action/feedback loops; time stress; high stakes; multiple players; and organizational goals and norms.

HEMS operations occur in a high-risk consequential environment. Time for making a decision is limited. Badly needed information is incomplete, and conditions change dynamically, especially in regards to the deteriorating weather situation. Other operational factors that affect pilots’ ability to make reasoned decisions include high workload, distractions, time pressures, heavy traffic, last minute changes, etc.

Extensive research documents the deleterious effects of stress on cognitive functioning (Hancock and Desmond, 2001), including attention focus, working memory capacity and risk taking. Stress also may affect crew communication, which can interfere with building situation models, sharing information, contingency planning, and error trapping.

Fatigue can directly jeopardize flight safety. A survey of EMS pilots found that 25% believed that mission-related stress and 21% believed that pilot fatigue were significant factors in EMS helicopter safety. (Rau) In its 1988 study, the NTSB suggested that pilot fatigue could be a primary cause of the industry’s poor safety performance. (NTSB, 1988) Sleep loss and fatigue affect psychomotor skills, sensory-perceptual awareness, cognitive abilities, and affective state. More specifically, reaction times increase, leading to timing errors in response sequences, less smooth control and requiring enhanced stimuli. Reduced attention includes overlooked and misplaced sequential task elements, fixation on single tasks or elements, reduced audiovisual scan and less awareness of poor performance. Diminished memory leads to inaccurate recall of operational events, forgetfulness of peripheral tasks and reversion to old habits. Mood withdrawals due to fatigue bring about less communication, less likelihood to perform low-demand tasks, more distractions due to discomfort, more irritability and a “don’t care” attitude. (Graeber, 1988) Other researchers have found that fatigue is manifested in pilot decision making by carelessness, forgetfulness, sloppiness, slow reactions, inappropriate reactions, irritability, disinterest, loss of timing, tunnel vision and loss of situational awareness. Alertness, fine motor skills and judgment deteriorate when adequate rest is not obtained. The deleterious effect of fatigue on HEMS pilot decision making is significant.

It is generally assumed that a pilot’s knowledge, often acquired through many years of training and experience, plays a key role in the decision process. Expert knowledge facilitates rapid and accurate perception of cues and interpretation of problems (Cannon-Bowers, et al., 1990).

However, expert knowledge is not a shield against errors. Deep knowledge is responsible for efficient functioning, but sometimes has resulted in poor judgments. (Orasanu, 2000). If similar risky situations have been encountered in the past and a particular course of action has succeeded, the crew will expect to succeed the next time with the same response, a phenomenon Reason (1990) called “frequency gambling.” Given the uncertainty of outcomes, in many cases they will have been “correct” in the past, but not always in the future. Hollenbeck (1994) found that such past success can adversely influence risk-taking behavior.
FAA Advisory Circular 60-22, “Aeronautical Decision Making,” indicates that pilots, particularly those with considerable experience, try to complete flights as planned, please passengers, and meet schedules, which can compromise safety and impose an unrealistic assessment of piloting skills under stressful conditions. An organization’s emphasis on productivity may inadvertently set up goal conflicts with safety and negatively influence a pilot’s decision making. (Reason, 1997) Mixed messages can affect pilots’ risk assessment and the course of action to choose. Human performance researchers have noted that pilots tend to adhere to their original plan of action, which interferes with critical analysis processes that are needed to adequately reevaluate the suitability of the original plan and explore an alternate course of action.

The NTSB’s 1994 analysis of 37 crew-involved accidents revealed an emergent theme: about 75% of the decision errors involved continuation of the original flight plan in the face of cues that suggested changing the course of action. (Berman, 1995)

In addition to making it difficult to assess the situation, ambiguity (in the case of HEMS, a situation such as imprecise weather forecasts or weather reporting from distant weather reporting stations) can influence the decision indirectly. A crewmember may recognize that “something doesn’t seem right” but may find it difficult to justify a change in plan when cues are ambiguous.

Other research has demonstrated that individuals, when faced with a choice between alternatives, generally seek out information that confirms a chosen hypothesis and ignore or fail to fully consider contradictory information, particularly when workload is high and time constraints are imposed. (Wickens, 1992)

These contribute to a decision-making error common to pilots in weather accidents known as a “Plan Continuation Error.” It is an unconscious cognitive bias to continue the original plan in spite of changing conditions (Burbank, 2000). Examples include opting to press-on into deteriorating weather rather than revising the intended route of flight by changing course or altitude, deviating to an alternate airport, or returning to the departure airport. (Orasanu, 2000; Orasanu, 2001) This decision making bias appears stronger as one Near completion of an activity. It may prevent a pilot from noticing subtle cues indicating the original conditions have changed.

For aviation decisions, both rapid pattern recognition and diagnostic skills are needed. Recognition of danger cues and generation of appropriate responses to those cues should become automatic. Senders and Moray (1990) noted that pilots need training and decision making tools in “how to change one’s mind” and avoiding cognitive “lockup” which may play a role in plan continuation errors.

Research of decision making processes has found that Recognition Primed Decision making (“RPD”) is extensively used by experts in time-bound situations. (Bond, Cooper, 2006) The RPD model asserts that people use situation assessment to generate a plausible course of action and use mental simulation to evaluate that course of action. (Klein, 1993; Klein, 1986; Klein, 1989) Klein’s principal conclusion is that the decision makers assess the nature of the situation and, based on the situation assessment, select an action appropriate to it. The RPD process consists of three phases - situation recognition, serial option evaluation, and mental simulation. Klein’s research found that experts use situation assessment to generate a plausible course of action and use mental simulation to evaluate this course of action. This type of process lets the experienced decision maker focus on critical cues and identify causal factors which focus the decisions on the important issues and reduce the information overload (Lipshitz, 1993).

A broad class of decision making situations are non-routine, for which there are no complete written procedures. The deteriorating weather situation is such an example. The pilot not only has to identify the situation, which may be difficult in itself, but also to assess the parameters and the risks and then select an option or course of action. These kinds of decisions are less frequent and, although they
are not always emergency/crisis decisions, they are the types of decisions the crew will have to make under high pressure and workload.

Expert knowledge includes stored condition-action patterns. Once the situation reaches a “trigger point” then responses are clearly prescribed and highly procedural. According to Klein’s RPD work, single option cases are the simplest decisions because they require the least cognitive work. Defining the trigger point clearly is necessary to increase the likelihood of action.

Orasanu and Fischer (1997) found a crucial aspect of rule based decisions lies with accurate situation awareness and rapid recognition of the situation as a precondition for retrieving a matching rule from memory. They also found that high performing crews tend to make rule based decisions earlier (to give a greater safety margin) because they have attended to preceding cues (therefore have better situation awareness).

While the vast majority of HEMS operations are conducted single pilot, the presence of trained medical team members can expand the cognitive resources and help to overcome potential limitations of a single decision-maker. Team behaviors that characterize effective crew decision making include vigilance, and building shared situation models when threats arise. They assess and communicate the nature of the threat. Effective crews are adaptive, and adjust dynamically to evolving conditions and update plans as needed to avoid plan continuation errors. Effective crews check their assumptions, question missing information, consider what might go wrong, how likely it is, and how serious it would be.

As unexpected dynamic conditions arise, it is essential that team members communicate to build a shared model of the emergent situation and how to cope with it. Crewmembers must learn appropriate ways to bring problems to the attention of the PIC. These include being as specific as conditions allow, pointing out problems, suggesting solutions, and providing reasons for one’s concerns.

What is desired is explicit discussion of the problem to include its definition, plans, strategies, and relevant information. This includes questions such as, “What is the problem? What is our plan? Who does what and when? What contingencies must be planned for? What cues or conditions must we look out for and what will we do?” Only if all participants have a shared model will they be able to contribute efficiently to effective decision making.

Safety Culture

A safety culture promotes a questioning attitude, is resistant to complacency, is committed to excellence, and fosters both personal accountability and corporate self-regulation in safety matters (Reason, 1997). Part of an aviation program manager’s role within a safety culture is to obtain accurate information to identify, manage and reduce risks. An effective safety information system depends crucially on the willing participation of the workforce.

According to Reason (1997), there are five components of a Safety Culture: just, reporting, learning, informed and flexible. An informed culture is defined as “Those who manage and operate the system have current knowledge about the human, technical, organizational and environmental factors that determine the safety of the system as a whole.” In order for the front line work to come forward and report errors or mistakes, an organizational climate conducive to such reporting must exist. A reporting culture is an organizational climate in which people are prepared to report their errors and near-misses. A flexible culture is able to reconfigure themselves in the face of high tempo operations or certain kinds of danger, often shifting from the conventional hierarchical mode to a flatter mode. A learning culture must possess the willingness and the competence to draw the right conclusions from its safety information system and the will to implement major reforms.

A just culture is an atmosphere of trust in which people are encouraged (even rewarded) for providing essential safety-related information, but in which they are also clear about where the line
must be drawn between acceptable and unacceptable behavior. The Just Culture operates by design to encourage compliance with the appropriate regulations and procedures, foster safe operating practices, and promote the development of internal evaluation programs.

Every manager of an aviation operation should be asking the questions, “What are my flight crews really doing out there in line operations? Are there practices which are eroding the safety margins? How close have we come to having an accident? Are they following the procedures?” A properly designed and implemented SMS program can help answer these questions. A method successfully used within SMS programs to answer these questions is Flight Operations Quality Assurance (“FOQA”). It is a systematic method of accessing, analyzing and acting upon information obtained from flight data to identify and address operational risks before they can lead to incidents and accidents.

FOQA analysis provides two types of data events. These are “Triggered Events” and “Routine Operational Measurements.” “Trigger events” occur outside of normal operating envelopes. The acceptable limits for each parameter are pre-defined by the operator (some will be specific to make/model/type), and an exceedance of a parameter trips the “trigger”, thus putting a special label on the flight for subsequent review.

This type of information allows the operator to learn what is really happening out on the line. The added value of FOQA happens when the information loops are designed with the flight crews to change the safety culture. Communication of these events helps the pilots naturally learn from those experiences and increases awareness, thus contributing to a safety culture within the organization.

**Summary**

Inadvertent IMC continues to be a large contributor to fatal EMS accidents. Underlying threats which contribute to the reduced visibility accident include:

- Helicopters are less stable to fly;
- Helicopter instruments were not designed specifically for helicopter IMC flying;
- Pilot’s sensory, perceptual and cognitive processes are hindered by decreased visual environments, and the workload significantly increases;
- Precise weather information is difficult if not impossible to obtain;
- IFR flying “currency” is not the same as IFR flying “proficiency”;
- Slow speed and high maneuverability induces “we can always put it down somewhere” mindset;
- Working conditions (low altitudes, frequent landings, distractions, lack of weather, inadequate instruments) increase pilot’s stress and increase fatigue;
- Single pilot;
- Lack of adequate Low-Altitude IFR en route infrastructure; and,
- Plan Continuation Bias.

Given these risks the likelihood that a HEMS pilot will inadvertently enter into deteriorating visibility conditions remains significant, and the human factors studies and accident record indicate this often ends in tragedy.

Additional layers in the “safety net” are needed to break the error chain and prevent the helicopter from entering into an undesired state (degradation of rotorcraft control and/or decreased distance from terrain and obstacles.)

Desirable properties of a decision making tool to break the error chain would include: easy to interpret by flight and medical crew members; economy of mental effort for rapid recognition of
conditions/cue and retrieval of condition-action-rule; easily recognized “trigger” point; rapid pattern recognition; easy interpretation of the condition-action-rule; condition-action-rule “trigger” occurs prior to the aircraft entering into an undesired aircraft state; low chance that the cues may be misinterpreted, misdiagnosed or ignored; low chance of risk being incorrectly assessed; de-conflicts company mixed messages and clarifies condition-action policy; encourages shared mental model; enhances CRM; clearly specifies that a corrective course of action needs to be initiated immediately; consistent action between pilots regardless of experience differences; easily applicable between companies, with only minor modifications necessary for unique local circumstances (e.g., terrain); and less susceptible to the effects of stress or fatigue.

Additionally, future proposed safety protocols should be consistent with the philosophy and practices of an enlightened safety culture and should integrate well into an SMS program with active monitoring such as ASAP and FOQA programs.

VII. Pilot Performance Assessment in Simulators

The problem of pilot performance analysis continues to evolve as pilot examiners and researchers attempt to determine the skills that should be judged and the methods that are best for evaluating pilot performance. Among the difficulties still facing pilot examiners and researchers is the very subjective nature of pilot performance. While rotorcraft performance can be quantified into such state variables such as rotorcraft speed, altitude and heading, areas such as pilot judgment, planning, workload, and situational awareness remain difficult to quantify and measure, and yet these parameters are shown to be critical skills which a pilot must possess.

Methods Utilized To Study Pilot Performance

Four approaches for studying pilot performance have been utilized, with significant limitations to each. First and most straightforward is direct observation by skilled observers. This method can yield a wealth of information concerning the type, frequency, and cause of errors in flight operations. However, the presence of the observer may alter the behavior, and the observer cannot control all of the variables. (Nagel) Despite these drawbacks, direct observation continues to be one of the best ways to develop a systematic understanding of errors. In particular, Line Operational Safety Audits (LOSA) have proven invaluable at providing data-driven identification of threats and errors that occur during line flight operations. Unfortunately, numerous reasons, including space limitations and weight restrictions, prohibit the inclusion of a LOSA observer on the average HEMS helicopter.

Accident data and post-accident analysis can be useful, however the information recorded during accident investigations is often incomplete. What is typically missing from such analyses is any indication of WHY the errors were made. (Nagel) Veillette discusses the many limitations inherent in the use of accident data. Analysis of accident statistics should yield accurate information for accident prevention purposes. However, without consideration of the accuracy, completeness and original purpose of the database, trend analysis can yield overly simplistic and misleading recommendations. Current investigation methods tend to under-emphasize the stochastic, organizational and combinatorial nature of accidents. The limitations of using accident statistics for preventive measures are addressed using anecdotal examples in order to illustrate many of the practical and statistical shortcomings of such methods. Other limitations include the probabilistic nature of accidents, oversimplification of causal methods, the sources of human bias introduced into investigation findings, and statistical limitations of accident data. (Veillette, 1997)
The third method is the self-report. In the United States, the Aviation Safety Reporting System (ASRS) fulfills this function and its equivalent, the Aviation Safety Action Program (ASAP). Data from ASRS has proven to be a practical and indispensable source of info. Reported incidents in ASRS are representative of those under which unusual and unfortunate circumstance underlie accidents. Incidents are kept from turning into accidents because of the many redundancies and other safeguards that are built into our aviation systems. The voluntary reporting feature is a drawback as reports are not made on a random basis. Certain individuals (more safety conscious ones) may report more often, and certain operational conditions may induce people to report more frequently. This makes quantitative analysis of the incident record difficult.

Error may also be studied in the laboratory and simulators. A distinct disadvantage of the laboratory and simulator is the tightly controlled environment, as errors often only become apparent in the complex and high-workload conditions that reflect actually operating conditions. Smith showed convincingly that operational conditions must be reproduced very carefully for trained pilots to begin to reveal the kinds of errors which lead to accidents. (Smith)

**Limitations of Aircraft State Data**

Past simulator research has evaluated digital data such as the state of the rotorcraft and pilot control inputs. Rotorcraft state descriptors include altitude, airspeed, navigational location, pitch, roll, and yaw rates, etc. These variables can be measured through time, which is useful for the point in time and length of time that the parameter deviated from a baseline value.

The rotorcraft moves in three-dimensional space, and has six degrees of freedom (linear translation and angular rotations.) The motions of the rotorcraft are actually determined by the action of a variety of aerodynamic, gravitational, and thrust forces and moments which can be controlled using the four basic controls (collective, governor, cyclic and anti-torque pedals). In rotorcraft motions there is inevitable coupling among all six degrees of motion. Some interactions are quite strong while others may be negligible. The response of translation variables to control inputs is typically slower than that of rotation variables. There tends to be a separation of responses by time (and frequency) into fairly rapid (high frequency) motions associated with rotation about the center of mass and significantly slower (low frequency) motions associated with translation of the center of mass. (Baron)

Objective data has often been relatively insensitive to experimental design. For example, in Wiener's DC-9/MD-80 study, no significant differences in aircraft control were observed, yet over half of the MD-80 aircrews were unable to navigate the transport aircraft to the holding fix. Wiener's investigation was unable to draw any inferences about the effects of cockpit automation on the aircrew's ability to fly a difficult mission due to insignificant differences in aircraft state variables. (Wiener) Yet clearly, confusion, disorganization, and loss of situational awareness occurred in these instances.

Attempts by others to rely exclusively on aircraft state variables in previous studies have yielded inconclusive results. Sammonds and Stinett's attempt to define wake vortex hazard relied upon the roll control ratio, the ratio of roll acceleration due to the vortex induced rolling moment to the roll acceleration possible with maximum aileron deflection. Sammonds and Stinett found considerable variation in the data depending upon the pilot's immediate evaluation of the hazard and subsequent control inputs. Subjects also varied in determining which rotorcraft state parameters were most important in determining the hazard. A well-defined boundary between hazardous and non-hazardous conditions was not found for either roll rate or roll acceleration. Later evaluation of the degree of hazard required a subjective judgment of the maximum roll angle with respect to ground proximity by the pilot subjects (Sammonds).
Baron asserts that measures of control input, such as root-mean-square control deflections could be measured routinely. However, Baron also states that these measures are not sufficiently sensitive to the changes in pilot response behavior that accompany changes in rotorcraft configuration or other variables of interest. Moreover, these measures do not, in themselves, reveal the pilot’s strategy of the way in which information is being processed. It is frequently necessary to compute additional metrics of response behavior. (Baron)

**Evaluation of Non-Technical Skills**

Past studies have shown that aircraft state variables do not always accurately reflect important performance parameters, such as judgment, communications, workload management, situational awareness and planning. To effectively evaluate the crew's overall performance and how they translate knowledge into action, Helmreich and Foushee assert that we must distinguish between the different areas of crew performance, of performing the technical activities, understanding and motivating individuals and groups, and coordinating all activities and interests of the team toward a common objective. (Foushee)

After several decades of research, the human observer in the form of an instructor/evaluator continues to be the primary medium for the measurement and assessment of aircrew performance, to include non-technical skills. Non-technical skills usually refer to pilots' attitudes and behaviours in the cockpit not directly related to the technical skills of aircraft control, system management and standard operating procedures. Classic examples of non-technical skills are cockpit authority, crew co-ordination and co-operation, communication and collective decision making, human errors and conflict management, stress and workload management, attention, vigilance and confidence.

Pilot evaluators must necessarily possess an extensive base of skills and knowledge to judge adequacy in these areas. Unlike rotorcraft state data, pilot evaluators can take into account the effects of externalities which change the nature of the difficulty of piloting. The experience and judgment of expert human observers are indispensable components of most, if not all, systems for the measurement and assessment of aircrew performance. (Hubbard) If one accepts this position, then the major issue is not one of finding ways to eliminate the human element in aircrew performance measurement systems in a futile quest for complete "objectivity." Rather, the real issue is one of determining the optimal allocation of functions between "man" and "machine" for given measurement and assessment situations and designing systems to capitalize on the unique capabilities of the expert human observer/evaluator. Non-technical skills are better evaluated by cockpit observers who are trained and qualified in such areas to make subjective evaluations.

For research purposes, it is necessary to create standardization and inter-rater reliability when evaluating non-technical skills. There is also a requirement to develop improved techniques (e.g., job performance aids) to support the real-time collection of such data in order to reduce the task loading on expert observer/evaluators during the course of simulator and flying missions.

A special report jointly carried out by DLR, IMASSA, NLR, and the University of Aberdeen upon a request of the JAA Project Advisory Group on Human Factors studied potential methods to assess multi-pilot aircrew on their Non-Technical Skill proficiency. (Van Avermaete, J.A.G., Kruijsen, E.A.C., 1998)

The JAA/NLR special report analysed four existing non-technical skill training and evaluation systems, namely those in use at Air France, British Airways, Lufthansa German Airlines and KLM Royal Dutch Airlines. Additionally, two research systems were included in the discussion: a system used for diagnostic and data-collection purposes developed by the NASA/University of Texas/FAA Aerospace Crew Research project, and a system developed under auspices of the Dutch Civil Aviation Authorities.
for future use during flight exams. The special report merged the “best practices” of each method into a proposed single method. This study will draw upon that proposal based on its universal applicability.

The four primary categories effectively subdivide into two social skills categories (Co-operation; Leadership and Management) and two cognitive skills (Situation Awareness; Decision Making). The category ‘Communication’ is featured in a number of systems but is not included here as a separate category. This is because communication skills are inherent in all four categories and the listed behaviours all involve communication. Three to four elements for each category were selected. For each element a number of exemplar behaviours were included. These were phrased as generic (eg. closes loop for communications), rather than specific (eg. reads back to ATC), to give an indication of type, and to avoid specifying particular behaviours which should be observed.

**Category: Cooperation**

Elements of Cooperation: Team Building and Maintaining, Considering Others, Supporting Others, Conflict Solving

Behaviours for Team Building and Maintaining:
- Establishes atmosphere for open communication and participation
- Encourages inputs and feedback from others
- Does not compete with others

Behaviours for Considering Others:
- Takes notice of the suggestions of other crew members even if he/she does not agree
- Take conditions of other crewmembers into account
- Gives Personal feedback

Behaviours for Supporting Others:
- Helps other crew members in demanding situation
- Offers assistance

Behaviours for Conflict Solving:
- Keeps calm in conflicts
- Suggests conflict solutions
- Concentrates on what is right rather than who is right

**Category: Leadership and Managerial Skills**

Elements of Leadership and Managerial Skills: Use of Authority/Assertiveness, Providing and Maintaining Standards, Planning and Coordinating, Workload Management

Behaviours for Use of Authority/Assertiveness:
- Advocates own position
- Takes initiative to ensure involvement and task completion
- Takes command if situation requires
- Motivates crew by appreciation and coaches when necessary
Behaviours for Providing and Maintaining Standards:
- Ensures SOP compliance
- Intervenes if task completion deviates from standards
- With crew being consulted deviates from standards if situation requires

Behaviours for Planning and Coordination:
- Encourages crew participation in planning and task completion
- Clearly states intentions and goals
- With crew being consulted, changes plan if necessary

Behaviours for Workload Management:
- Distributes tasks among crew; checks and corrects appropriately
- Secondary operational tasks are prioritized to retain sufficient resources for primary flight duties
- Allocates enough time to complete tasks

Category: Situation Awareness

Elements of Situation Awareness: System Awareness, Environmental Awareness, Anticipation

Behaviors of System Awareness:
- Monitors and reports changes in systems states
- Acknowledges entries and changes to systems

Behaviors of Environmental Awareness:
- Collects information about the environment
- Contacts outside resources when necessary
- Shares information about the environment with others

Behaviors of Anticipation
- Discusses contingency strategies
- Identifies possible/future problems

Category: Decision Making

Elements of Decision Making: Problem Definition/Diagnosis, Option Generation, Risk Assessment/Option Choice, Outcome Review

Behaviors of Problem Definition/Diagnosis:
- Gathers information and identifies problem
- Reviews causal factors with other crewmembers

Behaviors of Option Generation:
- States alternative choice of action
- Asks crewmembers for options
Behaviors of Risk Assessment/Option Choice
- Considers and shares risks of alternative choice of action
- Talks about possible risks for choice of action in terms of crew limitations
- Confirms selected choice of action

Behaviors of Outcome Review
- Checks outcome against plan

Additional Implications for Simulator Studies
Foushee and Helmreich’s (Foushee) findings from past research indicates several important implications:

1) Studying pilots outside their organizational context seriously limits the generality and understandability of findings
2) An optimal research strategy should attempt to capture and relate the multiple influences on performance
3) To draw valid inferences from observed behavior, large sample sizes and multiple organizations must be investigated
4) Given imperfect measurement, multiple indicators of relevant constructs should be employed

There is no single experimental source or methodology which satisfies every scientific requirement. Maher points out that decision making under the high stress of emergency conditions and/or high workload is often suboptimal. Line Oriented Flight Training (LOFT), however realistic the scenario and execution, does not reproduce conditions when crews find themselves in extremis. While the flight simulator satisfies the experimental need to strictly control as many variables as possible, true environmental fidelity, such as high density traffic operations and radio congestion in the terminal area or around an EMS “site”, the typical pressures and distractions associated with having an EMS crew and patient on board, etc., are not accurately replicated in typical training simulators.

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