Recommendations for the U.S. Coast Guard Survival Prediction Tool.

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INTRODUCTION

The U.S. Coast Guard (USCG) is responsible for maritime search and rescue (SAR) operations within its area of responsibility. During the five-year period from 2004 to 2008, the U. S. Coast Guard (USCG) conducted, on average, more than 28,000 Search and Rescue (SAR) cases and rescued more than 5,300 people annually. These statistics do not include the USCG's response to Hurricane Katrina, in which it rescued 33,544 people alone. Not all cases are successful, and the USCG Search and Rescue (SAR) Mission Coordinator (SMC) must at some point consider whether to continue or suspend the search, "Active Search Suspended Pending Further Developments" (ACTSUS). This decision is a critical juncture for the victim, their families, and the USCG.

Predictions of the survivor's deteriorating physiological condition and future survival time are essential to the SAR planner during the search. The SMC uses these predictions to optimize the search resources, and for consideration along with other aspects of the search to make the ACTSUS decision. The survivors addressed here include victims who are either immersed (e.g., treading water) or afloat in emergency craft (e.g., life raft, surf board) on the ocean. The ultimate goal is to provide improved decision support on the survival aspect of the search and rescue case picture so that the SMC and senior SAR staff can make informed decisions based upon the best information available during this critical time.

The USCG Research and Development Center (R&DC) was tasked by the USCG Office of Search and Rescue (CG-534), with facilitating new approaches that would improve the quality on the existing survival prediction capability.

METHODS

The R&DC's goal was to incorporate the best available guidance tools into a product that would meet the information needs of operational users. In March 2006 a group of technical experts from universities and government research laboratories at a two-day workshop to explore current scientific understanding of human survival in the marine environment. The workshop discussed the processes affecting survival (hypothermia, heat exposure, fatigue, circadian rhythms, etc.) and recommended a roadmap for the R&DC. The recommendation of the workshop was that with current scientific knowledge, the R&DC should pursue a model framework that factored victim core hypothermia and dehydration. The R&DC tasked the U.S. Army Research Institute of Environmental Medicine (USARIEM) Biomedical Modeling Division with adapting an

existing physiological model to calculate the influences of environmental conditions (e.g. temperatures, turbulence) and victim properties (e.g. height, weight, and clothing) on survival. The USARIEM Probability of Survival Decision Aid (PSDA) [1] simulates the heat and water balances of potential victims. Victim survival is based on the time required for the modeled body core temperature or weight loss due to dehydration to reach critical values (25^{o} C and 20%, respectively). These values are considered to be protective of human life in that they represent levels that most survivors would not reach.

The two-day workshop also concluded that any improvement in knowledge was impeded by a general lack of case data involving victim immersion and survival. Familiarization with the UK National Immersion Incident Survey (UKNIIS)[2], which documents the survival of immersed victims in the UK and recommended that the UKNIIS be further analyzed. The R&DC contracted the University of Portsmouth, UK to digitize the UKNIIS, which was in paper form, and to develop an Empirical Survival Model from relationship in the data set. The Empirical Survival Model[3] model employed a statistical approach (based on reliability theory of aging and longevity) to create an empirical model of victim survival probability, a family of equations based on the Weibull distribution that estimate victim survival probability with elapsed time as functions of the victim's description, the surrounding water temperature, and other variables. The curves also provide estimates of survival probability for the general population during the first hour.

We used the UKNIIS data in combination with USCG case data to develop a maximum survival time guideline for victims in the water. The R&DC then added data from USCG SAR cases and the open literature to expand the temperature range of the data available for analysis. The purpose of the guideline was to provide information on the longest expectation of victim survival as a function of ambient water temperature. We examined approximately 400 incidents in which the victim had survived immersion for more than an hour, focusing on a small set of cases with the longest survival times that spanned a range of water temperatures between 2º C and 29º C. We found that the longest survival times reasonably fit an exponential function of ambient water temperature. We developed a functional relationship based on the upper 95% confidence interval of this relationship to account for the variability seen in the cases. The result, called the Maximum Observed Immersed [victim] Survival Time (MOIST), is based on all known data for surviving immersion incident victims, and is functionally equivalent to the classic Molnar curve[4], which has long served as the basis for survival time guidance.

The R&DC's final task was to propose requirements and functionality for new a USCG Decision tool for survival guidance, and conditions for its use. The R&DC developed operational requirements for the features and functionality of the survival guidance following USCG guidance. The process incorporated a review of existing USCG operational policies regarding search suspension followed by interviews of SAR controllers at several district and area command centers to identify how they interpreted policy and the existing tool in their decision-making. The requirements were refined during two additional workshops. The first workshop involved a review of the products' technical suitability for their intended use that involved external physiology reviewers and USCG operational medicine staff. At the second workshop, a strawman proposal for the functionality of the new system was presented to USCG operational watchstanders and SAR Program staff. The R&DC and its technical support contractor, Science Applications International Corporation (SAIC) then refined final recommendations for guidance

tool requirements and developed a final recommendation for the functionality of the guidance, which is presently being implemented into an application with a graphical user interface (GUI) by the Office of Search and Rescue.

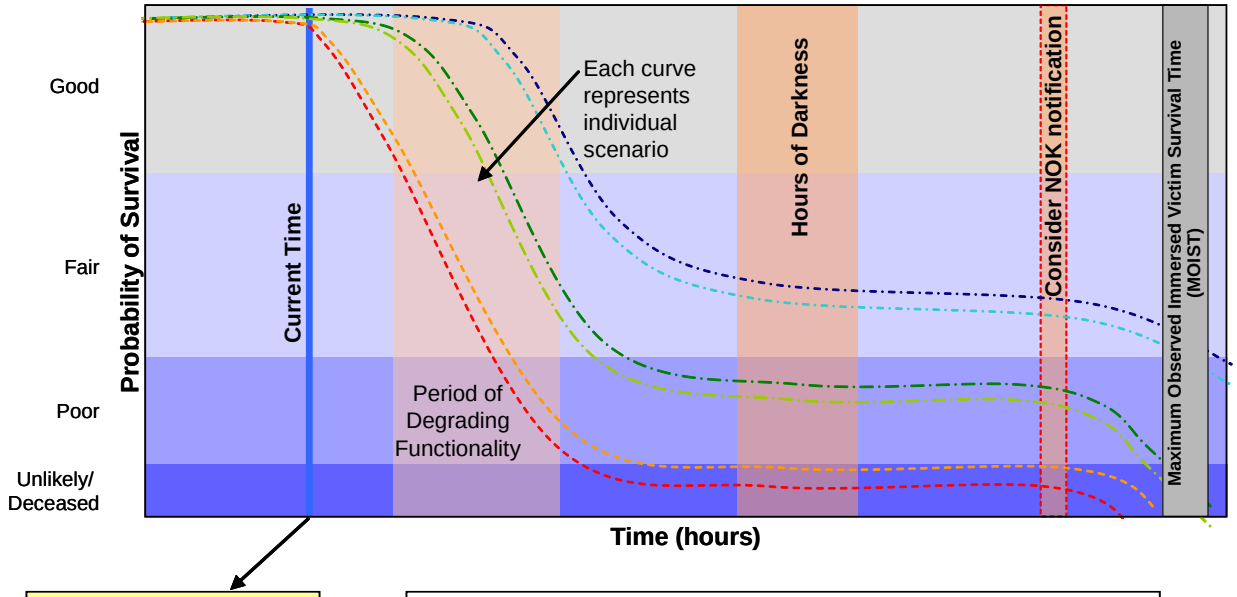
RESULTS

The system recommended by the R&DC uses the USARIEM PSDA model as its central element to predict long-term survival as a function of victim core body temperature and dehydration. The University of Portsmouth Empirical Survival Model is factored into the probability of survival at temperatures below 15 ºC (59 ºF) during the first hour of immersion. The R&DC MOIST is intended to provide guidance at water temperatures above approximately 15°C (59 ºF) where the PSDA model may predict that the victim has reached thermal equilibrium with the environment without reaching either a fatal core temperature (at <120 hours) or a fatal dehydration level (at <240 hours).

Ease of use and functionality were considered to be important to the success of the system. The key features that we sought were the ability to input descriptions for multiple victims in a short period of time to keep the SAR planners' focus on the search. Our solution uses the GUI to select whether (1) individuals, (2) groups, or (3) pre-set mass casualty scenarios are being considered. From these three group types, the software the software will develop a larger pool of (~ 100) victims whose features (height, weight, sex) are randomly varied around those in the group selected. The SAR planner may also select multiple clothing or immersion (e.g. treading water vs. in a survival raft) scenarios to consider simultaneously. In this case, the initial pool of 100 victims would then be dressed in each of the clothing or immersion scenarios.

A graphical mockup of the GUI in development is show in Figure 1. Its features include the following:

- Times referenced to Greenwich Mean Time (Z).
- The time (origin of the graph) referenced to the estimated start time of the incident.
- A sliding vertical line or bar representing the present time that may be moved into the future or past to describe future or past conditions.
- An area depicting the time range when the victim's condition is deteriorating for each immersion (e.g. neck, partial, dry) scenario. The deterioration time will start when the core temperatures of individuals in the group drop to the 34 °C (93 °F) threshold.
- A depiction of night and day periods.
- Environmental data automatically ingested from the USCG Environmental Data Server (EDS) as a default option to represent the ambient environment. The parameters will include SST, air temperature, relative humidity, wind speed, and wave information.
- A vertical time bar to prompt the user that next of kin notification may be appropriate.
- Summaries of victim group survival probabilities for each clothing and immersion combination; alternately, the software will provide the user with the option of selecting a subset of curves to display.
- A vertical time bar associated with the MOIST. Reference to this time will state that it represents the time beyond which the recovery of survivors has not recorded in the past.



AOI Source

SAROPS ☑ Manual Entry

Environmental Conditions in AOI

Automatic Ingest from EDS ☑ Manual Entry

Avg Sea Surface Temp ___
Air Temp ___
Wind Speed ___
Local Sea State ___
Humidity ___

Victim Description

INDIVIDUAL

Victim1 Height ___ Weight ___ Fat ___
Victim2 Height ___ Weight ___ Fat ___

GROUP

%male ___ % female ___

MASS CASUALTY

Physiological Parameters Affected at this Time

- Unconscious
- Moderate Hypothermia
- AV Fibrillation Likely
- Shivering Inefficient

Survival Time Summary

$P_{Survival}$ < 50% at: 0200 Z
$P_{Survival}$ < 10% at: 0500 Z
CG Guideline Search window ends at: **0945 Z Sept 20**

MISLE #: _____
File Name: _____
Scenario: Life Raft + Nude
Run #: 1

Export | Case Closeout | Save | NOK Version | New Scenario

Selected Scenario Legend

- Life Raft + Nude
- Life Raft + Summer Ensemble
- Partial Flotation + Nude
- Partial Flotation + Summer Ensemble
- Complete Immersion + Nude

Immersion Level

☑ Life Raft
☑ Partial Flotation
☑ Complete Immersion
Land

Victim Clothing

☑ Nude/Swimsuit
☑ Summer Ensemble
Fall/Winter Ensemble
Winter Snowmobile
Partial Wetsuit
Light Full Wetsuit

Figure 1: The USCG Survival Guidance System Graphical User Interface

CONCLUSIONS

The R&DC Survival of distressed Mariners Project has developed new information and models that incrementally improve our understanding and the decision process for immersed and stranded victims. The guidance uses a combination of models and analyses to provide what we believe are the best available science. These tools are contained in a GUI that is easy to use and will provide SAR planners with the flexibility to examine multiple scenarios concurrently.

This system is designed to be compatible with the Coast Guard's Search and Rescue Optimal Planning System (SAROPS). The inclusion of this victim survival module into SAROPS is expected to improve the USCG's success at finding survivors. This guidance is recommended for incorporation into SAROPS as time and resources permit.

This study raises issues regarding victim survival that remain to be addressed:

- The lack of information on the human element in SAR cases, primarily of the physiological impacts of exposure and the outcomes of SAR cases represented the principal obstacle to our ability to improve the CG's survival guidance tool. We recommend that the Office of Search and Rescue address the information gaps by implementing processes to collect **victim exposure time and victim outcome**, **victim medical condition at time of rescue, with concurrent environmental data.** This information should be collected as circumstances permit, in a manner that does not interfere with care provided by the responders. This information should be collected and recorded before the victim is delivered to other responders by the CG. The USCG should also seek to set up agreements and protocols with other countries for the sharing of case data.

- Significant uncertainty exists regarding the conditions that may be used to represent the set point for maritime death due to hypothermia. Is a setpoint of 25^{o} C too low? Should death be calculated in a manner similar akin to dosage as a time below a higher core temperature? Does death occur with Loss of conscious in the maritime survival environment?

- Little information exists to support the assumption that death occurs at the 20% loss of body mass.

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