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# Application of Human Engineering Techniques for Assessing the Impact of System Design on the User

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The historical approach to marine safety has been to concentrate on ship structure and engineering design solutions. However, although marine systems are now highly reliable, casualty rates have not decreased demonstrably. Various sources have documented that 65 - 90 percent of marine casualties are caused by human error. These statistics demonstrate that regardless of how sophisticated the technology solutions may be, the performance and efficiency of systems is bound by the psychophysical constraints of the human operator. All to often, systems are designed with the assumption that the system user can be trained, and is flexible and robust enough to adapt to the system. While this assumption may have been acceptable in the past with less complex systems, rapid advances in technology are pushing the user tolerance envelope to unacceptable limits. To ensure that systems operate safely and efficiently, minimize human error, a more human-centered approach must be adopted during system design and development.

The human element is frequently referenced but often neglected during new system acquisition. For example, although human element issues are identified throughout the Coast Guard acquisition process, human factors assessments are typically limited to the Operational Test and Evaluation (OT&E) period during the Full Scale Development phase. The end result is that critical safety and efficiency issues are either ignored, or engineering change proposals must be generated to correct deficiencies. In either case, potentially significant amounts of time, money, and energies could be saved if human factors analyses are incorporated earlier, during the design phases, and throughout the acquisition process. Although opponents to human factors analyses during acquisitions cite cost and time constraints as reasons for the neglect of these analyses, numerous case studies of previous acquisitions clearly indicate that the investment in these analyses produce significant returns in economy, safety, and performance of the system. This paper presents some techniques for assessing the human element during system acquisition and where appropriate, the results of a recent evaluation conducted in support of a new boat for the Coast Guard.

The Coast Guard is in the process of replacing an aging fleet of 44-Foot Motor Lifeboats (44MLB) that have been the agencies' primary heavy weather rescue craft for the past 28 years. The replacement craft is a 47-Foot Motor Lifeboat (47MLB) that is self-righting and capable of operating in 25-foot seas. The 47MLB has many enhancements from its predecessor that are designed to make it a safer, less fatiguing, and more effective platform. The enhancements include: increased speed, better motion characteristics, an enclosed bridge to protect crew from the elements, a fly-bridge for better visibility, and seating for the entire crew. Although the 47MLB boasts some impressive technological and performance capabilities, system effectiveness is constrained by poor human/machine interface issues. During Preliminary Acceptance Trials (PAT) of the prototype vessel, it became obvious that a number of human factors deficiencies required significant attention. Specifically, crew performance was hampered by sub optimal instrument and control layouts and poor workspace configuration. Crew safety was compromised by poor ladder and hatchway design, and ineffective seating support. In response to these concerns, the Coast Guard Research and Development Center (R&DC) was tasked with the conduct of various human factors evaluations to support the OT&E of this vessel.

The request for human factors analysis support was to evaluate vessel design characteristics to ensure that human factors principals were not violated and crew safety and performance compromised. Specifically, concerns focused on two basic questions: (1) does the new system design produce any significant human/machine interface concerns that could compromise safety and performance, and (2) what are the user impressions concerning the "suitability and effectiveness" of the new design to fulfill mission requirements. Three human factors techniques were selected to address these questions: walkthroughs, mockups, and questionnaires. The walkthrough technique is an effective technique for familiarizing and understanding the operational environment, and identifying potential deficiencies between operational requirements and system characteristics. However, to address subtle differences in system design alternatives, the mockup technique is a more powerful technique where one can manipulate and objectively assess system design differences. These two techniques were used to assess the human/machine interface question. The questionnaire technique, which is ideal for collecting user impression data, was used to address the "suitability and effectiveness" question. The purpose of this paper is to introduce these three techniques and illustrate how they can be applied. Unfortunately, because of restrictions on the length of the paper, only the most salient points of each technique will be addressed. An effort is made to present the techniques, a process for implementing the techniques, and, where appropriate, the possible results of the current analysis.

The first step in the conduct of the present evaluation was to familiarize ourselves with the new boat and to identify and define the operational objectives and potential operational environments for the boat. This step is critical to orient and develop an effective protocol to measure the issues of concern. A visit to the boat and meetings with subject matter experts at the Coast Guard Motor Lifeboat School fulfilled this objective. The result of these efforts was a list of operational focal points (OFP) that identify the essential mission requirements for the boat (Table 1). In addition, lists of critical equipment components (Table 2) and relevant human factors issues (Table 3) were generated to orient and structure the data collection process. For each of the OFPs, equipment components were assessed and relevant human factor issues evaluated. For example, for heavy weather operations (Table 1), were there any controls, displays, etc. problems (Table 2), and if so, were they related to location and arrangements of the controls, the size and shape, the direct and force required to manipulate the controls, was the information being presented effectively, can the operator perceive (visual, tactile or auditory) the information, can the controls be used in the range of conditions encounter by these operations, and finally safety issues related to controls were evaluated (Table 3). This protocol provided a comprehensive and structured approach for identifying and assessing system deficiencies in components that could compromise crew safety and performance.

**Table 1 Operational Focal Points (OFP)s**

| |
|---|
| Heavy Weather Operations |
| Calm Weather Operations |
| Surf Operations |
| Towing (Aft) |
| Towing (Alongside) |
| Personnel Recovery |
| Piloting/Navigation |
| MooringAnchoring (Own Boat) |
| Anchoring (Other Boat) |
| Firefighting (Own Boat) |
| Firefighting (Other Boat) |
| Alongside Operations |
| Helicopter Operations |
| Maintenance (Underway) |
| Maintenance (In Port) |
| Mission |
| • Search |
| • Rescue |
| • Maritime Law Enforcement |
| • Port Safety and Security |
| • Marine Environmental Response |
| • Recreational Boating Safety |

**Table 2 Equipment Component Check lists**

| | |
|---|---|
| 1 | Controls |
| 2 | Displays |
| 3 | labels, Manuals, Markings |
| 4 | Workspace |
| 5 | Doors, Hatches, Passageways |
| 6 | Steps, Platforms, Railings |
| 7 | Accesses, Covers, caps |
| 8 | Lines, Hoses, Cables |
| 9 | Fasteners, Connectors |

**Table 3 Human Factors Consideration**

| | |
|---|---|
| 1 | Location/Arrangement |
| 2 | Size/Shape |
| 3 | Direction/Force |
| 4 | Information |
| 5 | Perception |
| 6 | Use Conditions |
| 7 | Safety |

The following section describes each of the techniques and provides examples of how they were used in this evaluation. Results of the analyses will be provided where appropriate.

## Walkthrough

The walkthrough technique involves an on-site physical review of the system to orient and understand the operational environment and evaluate the individual elements of the system (work environment, work procedures, tasks, and user characteristics) and their interaction, to identify and define potential misfits between and within the elements. The appeal of the walkthrough is it's versatility. The basic process is to visit and interact with system components to assess whether human factors principals have been incorporated into the design and development of the system. In most cases, the conduct of a walkthrough does not require sophisticated data collection tools, elaborate implementation procedures, or significant manipulations to the environment. The walkthrough can be as simple as giving a human factors professional access to the system without any additional support, or to intensify the process by providing resources so interaction can occur between the professional and the system. In most circumstance, the preferred approach is to have individual qualified to operate the system accompany the professional so they can describe the work environment and equipment, tasks to be performed, simulate task requirements, be measured for anthropometric data, and, above all, answer questions.

This approach is especially useful during developmental test and evaluation because an operational system is not necessary to conduct the analysis. A walkthrough can be conducted on a "static", non-operational, system. Through the use of role playing, simulation, or modeling, one can achieve a fairly accurate representation of equipment, tasks, or operating environments for evaluation. By conducting these analyses early in the acquisition process one can identify critical deficiencies that will compromise crew safety and performance. These deficiencies can be corrected prior to the system being operational. Although the "static" walkthrough can provide a valuable initial look, a "dynamic" evaluation, during the actual operation of the system, provides a more realistic look at how the system elements interact. The ideal process is to conduct a "static" walkthrough evaluation early in the development of the system and a "dynamic" evaluation when the system is operational.

In the present evaluation, the check lists generated from Tables 1-3 were used to structure the walkthrough. Both a "static" and "dynamic" walkthrough were conducted on the vessel. The "static" evaluation was conducted as the vessel was docked at the pier. A qualified 47MLB crew person for each of the systems and subsystems under consideration accompanied us and provided the necessary input. The "dynamic" evaluation was conducted during actual operations. When specific mission tasks were not observed, simulations were conducted. The simulations ensured that all the OFP tasks were observed in an operational setting. The results from the walkthrough evaluation were used to assess whether more specific and detailed evaluations were necessary to address potential problem areas. For example, it became obvious that the crew were experiencing transfer problems when alternating between steering stations. Specifically, while dials and displays were similar, their layout and arrangement were not consistent between the stations. In addition, display and control labels were not located in a consistent manner. Appropriate human factors design guidelines are available to correct the majority of the observed design deficiencies. However, although guidelines are available for design specification issues, operational requirements often necessitate specific configuration of the instrumentation. To assess these specific configuration issues, mockups of the control stations were fabricated and various alternatives tested.

## Mockups

A mockup is a three-dimensional representation of a system that can vary in fidelity, complexity, and expense depending on the issue under evaluation. Mockups can range from an individual control item, such as a throttle control for the bridge of a boat to the entire control station. In either case, the mockup should be full scale so that user characteristics, can controls be reached and actuated, and maintenance requirements be evaluated. Mockups are often misrepresented as complex and expensive measurement techniques. However, inexpensive materials can frequently be used to build adequate mockups to address concerns. For example, foam, paper, clay, and cardboard are common materials used to create mockups. Photographs and other depictions can be attached to add realism. However, these materials are not rugged and will not support an operator's weight. For full-scale mockups, where the operator's weight must be supported, the preferred material is wood. The fidelity and complexity of the mockup will depend on the issues under consideration and economics. However, regardless of the construction material for the mockup, the intent is to model the subject system and be able to manipulate the components so that alternative system design and arrangement configurations can be objectively assessed. For more detailed information on the mockup technique, please refer to Jacobs (1992).

Mockup techniques were used by Coast Guard naval engineers to assess human engineering issues during design and construction (Shepard, 1994). For the OT&E evaluation, mockups were designed to address specific human/machine interface problems encountered during

PAT and the walkthrough evaluation. Some examples of problems include controls and displays not clearly visible from a normal operating position, displays obstructed by the microphone cord, throttle controls directly in front of the operator that can be activated accidentally, and a jog lever that protrudes out beyond the face of the console and can be moved accidentally or impale the operator. Wood mockups were created of the control stations that included movable, actual size instrument panels, gauges, controls, seating, etc. The mockup provided a realistic environment were an individual crew person could interact with the control station and simulate actual mission tasks. The mockups were configured to address in detail, those areas, identified during the walkthrough process, as human/machine interface problems.

To objectively assess the impact of the control station design and consideration, baseline data were collected on the mockup with the original design and configuration. Operational scenarios were generated and crew performed the necessary tasks to accomplish the mission. Data were collected on how effective the tasks were performed (time to completion and number of error) as well as operator feedback. These activities were repeated with alternative design and configuration options. The performance data and operator feedback were analyzed to assess which configuration option provided the best alternative to fulfill the full spectrum of mission needs. This technique proved to be very successful for designing more efficient and effective control stations.

## Questionnaires

Because of it's subjective nature, the questionnaire is often not warmly received as a data collection option. However, this technique is frequently the only option available to quantify difficult-to-measure aspects of human factors in an economical and precise manner. Questionnaires are especially powerful for integrating system parameters and capturing data on subjective states such as knowledge, experience, satisfaction, and attitudes. A good questionnaire must consider the characteristics of the respondent pool to ensure that the questions capture the appropriate wording, terminology, and phrasing to reduce interpretation artifacts, and that the placement and order of the questions is such that presentation biases do not occur. A poorly design questionnaire may introduce irrelevant factors that will contaminate the accuracy of the responses and result in an unreliable measure. While specific rules and guidelines must be considered when developing questionnaires, their presentation and discussion are beyond the scope of this paper. For more detailed information on this technique refer to Charlton (1993).

The "suitability and effectiveness" question lends itself well to the questionnaire method. When we refer to operational effectiveness we mean "can the vessel perform its intended function over the expected range of operational circumstances in the expected environment?". Operational suitability refers to "when operated by typical fleet personnel in expected numbers and experience levels, is the vessel reliable, maintainable, operationally available, logistically supportable, compatible, interoperable and safe?"

While more objective means were available to capture data on some of these issues, time and economic constraints limited the data collection options. Moreover, the request for support asked that all possible 47MLB operators be solicited for response. Given the potentially large data collection sample (approximately 100 individuals), the questionnaire was deemed the most cost effective and precise data collection method at our disposal. For more detailed information on the research methods and results of the current analyses, the reader is referred to Bittner, et. al. (1995).

Prior to developing a questionnaire, some basic questions need to be addressed. These questions include, what are the issues or areas under question, what type of information are you attempting to capture (i.e., frequencies of occurrence, level of intensity, etc.), and how do you plan to use the information (i.e., make comparisons, establish system status, etc.). For the current effort, we were asked to assess how the 47MLB compared to the predecessor vessel (44MLB) on the OFP items. In addition, we were asked to assess how well the 47MLB fulfills OPF requirements. The first objective is obvious since both resources are known, but for the second objective, a comparison needed to be constructed. To accomplish the second objective, we asked crew members to compare the 47MLB to what they consider to be an "ideal" MLB vessel. A definition of the "ideal" MLB was deliberately not provided so as to not constrain the characteristics of the "ideal" vessel. Each crew member was asked to use their own perceptions of the "ideal" MLB to make their evaluations. These type of ratings represent a direct estimation method that has been valuable for rapid evaluation of responses to physical and other aspects of systems (Stevens, 1975). The comparison of the 47MLB against the "ideal" provided an *absolute* assessment of suitability and effectiveness while the comparison against the 44MLB was a *relative* assessment. The results from the *absolute* comparisons are useful for judging the potential for improving the current 47MLB design. The results from the *relative* comparison (47MLB v. 44MLB) are most important when judging suitability of the 47MLB to replace the 44MLB.

For absolute comparisons, crews were asked to evaluate, using a 100 point scale, the suitability and effectiveness of the 47MLB relative to an "ideal" MLB vessel for each of the OFPs. Crew members were instructed that " for each question, if the equipment and design of the current 47MLB are as good as they can be compared to the "ideal" MLB, then fill in the bubble for 100%. If the equipment and design are less than they can be, then choose a percentage that represents how close to the "ideal" you feel it is. For example, if you feel the 47MLB is only 75% of the "ideal" MLB on a certain OFP, then fill in the bubble that corresponds to 75% on the scale. Figure 1 shows a portion of the questionnaire using heavy weather operations, calm weather operations, and surf operations as examples.

For the relative comparison, crew members were asked to directly estimate the effectiveness and suitability of the 44MLB and 47MLBs with regard to each of the OFPs. The rating scale response range included a central neutral point (where the 44MLB and 47MLB are equal) with separate ranges to left and right of the neutral designating the relative superiority of the respective 44MLB or 47MLBs with respect to a specific focal point . Responses to the left of the neutral point indicated 44MLB superiority, and responses to the right of the neutral point indicated 47MLB superiority. The crew members were requested to consider each question and, " if you feel that both vessels are exactly the same, then fill in the midpoint bubble (equal) on the scale. If you feel that one vessel is more effective than the other, then fill in the appropriate bubble, to the left (44MLB) or the right (47MLB) to show which boat is more effective, and by what percentage." Figure 2 shows a portion of the complete questionnaire using heavy weather operations, calm weather operations, and surf operations as examples.

These ratings proved very successful at identifying global problem areas (OFPs). However, knowing more detailed information is required to correct the deficiencies. To accomplish this, thresholds were set for the global ratings that if exceeded would require more detailed questioning. The threshold value for the absolute comparisons was 75%. If an OFP was rated at or below 75%, crew members were directed to the appropriate section of the survey where more detailed questions were located. For the relative comparisons, the threshold value was 40% favoring the 44MLB. So, if an OFP was rated greater than (or equal to) 40% in favor of the 44MLB, crew members completed the detailed questions. For the sake of brevity the detailed questions are not presented. This detail was mentioned to illustrate that questionnaires are not constrained to global or general analysis but can be developed to systematically evaluate more detailed levels of a system. For details, refer to Bittner, et al. (1995).

Because questionnaires are economical and relatively easy to administer, they are often used as a preliminary data collection technique to identify and define potential problem areas that will require more detailed analysis. For example, maneuverability deficiencies were identified in a number of OFPs. Therefore, detailed engineering analyses were requested to specifically, and in detail, address this concern. In our case, small group discussions were conducted with the crew to address some of the more severe deficiencies identified by the questionnaire. These discussions were used to not only collect additional detail on the problem but to solicit potential corrective measures. This systematic use of approaches, using more economical techniques to identify and define deficiencies and using more costly approaches to conduct specific analyses, is a cost-effective approach to design analysis.

## Discussion

While the human element is often ignored in new system design and development, evidence is mounting that in order to improve marine safety, greater energies need to be directed at ensuring that the human element is incorporated more fully into the marine system. To accomplish this, appropriate human factors analyses must be conducted early and throughout the acquisition process to assure that human element constraints have been considered, and not exceeded, during the design and development of the new system. Although the analyses presented here were conducted during OT&E, these techniques can be used during any phase of the acquisition cycle.

The techniques presented here were successful in identifying and defining in excess of 150 human element deficiencies. Where appropriate, the results were used to generate engineering change proposals to correct or minimize deficiencies on existing vessels. In all cases, recommendations and support documentation were provided so that appropriate contract provisions could be incorporate into the Circular of Requirements (COR) to ensure that the observed deficiencies were not repeated in the final production run. Although the analyses were incorporated late in the acquisition cycle, they provided valuable insight and direction for improving safety and performance of this new system.

The argument that human factors analyses are costly and delay the acquisition process can no longer be accepted given the critical role the human element plays in the safety and efficiency of operations. An effort has been made to demonstrate that not only are techniques for assessing the human element available, they can be implemented in a cost effective and timely fashion. The consequences of continuing to emphasize the role and development of technology, without considering the implications on the user, can only result in the compromise of safety and performance.

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Heavy Weather Operations** | | | | | | | | | | | | | | | | | | | | |
| O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O |
| 0% | | 10% | | 20% | | 30% | | 40% | | 50% | | 60% | | 70% | | 80% | | 90% | | 100% |
| **Calm Weather Operation** | | | | | | | | | | | | | | | | | | | | |
| O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O |
| 0% | | 10% | | 20% | | 30% | | 40% | | 50% | | 60% | | 70% | | 80% | | 90% | | 100% |
| **Surf Operations** | | | | | | | | | | | | | | | | | | | | |
| O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O |
| 0% | | 10% | | 20% | | 30% | | 40% | | 50% | | 60% | | 70% | | 80% | | 90% | | 100% |

**Figure 1**
Example of the Absolute Rating Scale

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Heavy Weather Operations** | | | | | | | | | | | | | | | | | | | | |
| O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O |
| 100% | | 80% | | 60% | | 40% | | 20% | | Equal | | 20% | | 40% | | 60% | | 80% | | 100% |
| **44-Foot MLB** | | | | | | | | | | | | | | | | | | | | **47-Foot MLB** |
| **Calm Weather Operation** | | | | | | | | | | | | | | | | | | | | |
| O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O |
| 100% | | 80% | | 60% | | 40% | | 20% | | Equal | | 20% | | 40% | | 60% | | 80% | | 100% |
| **44-Foot MLB** | | | | | | | | | | | | | | | | | | | | **47-Foot MLB** |
| **Surf Operations** | | | | | | | | | | | | | | | | | | | | |
| O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O | O |
| 100% | | 80% | | 60% | | 40% | | 20% | | Equal | | 20% | | 40% | | 60% | | 80% | | 100% |
| **44-Foot MLB** | | | | | | | | | | | | | | | | | | | | 47-Foot MLB |

**Figure 2**
Example of the Relative Rating Scale

## Discussion

**David M. Shepard**
**U.S. Coast Guard Boat Engineering Branch**

Mr. Carvalhals makes some interesting points about the need for human engineering analysis during the design and construction of new vessels and for this he should be congratulated. However, he has used as an example the U.S. Coast Guard's 47 ft. Motor Lifeboat (47 MLB) and gives the impression that human engineering was not a considered early in the design and construction of the 47 MLB. This is unfortunate since an emphasis on human engineering has been a major part of the development of the 47 MLB starting at the earliest stages of design development. Mr. Carvallhas and the Coast Guard's Research and Development Center contributed to a portion of this human engineering process when they were asked to evaluate the Pre-Production 47 MLB.

The 47 MLB is designed to replace the 44 ft. Motor Lifeboat (44 MLB). The 44 MLB has been the primary asset for the Coast Guard's heavy weather search and rescue operations. While the 44 MLBs have performed admirably over the last 30 years, they have their shortcomings, particularly in the area of crew comfort. offering only an open steering station and having lively roll motions, the 44 MLB can be quite fatiguing in severe weather missions. It was for this reason that an emphasis has been placed on human factors in the development of a replacement motor lifeboat.

The 47 MLB incorporates a number of design features that are innovative in motor lifeboat design. These features include:

<u>Open and Enclosed Birdges</u> - The open bridge provides excellent visibility and communication with the crew working on deck or in the recess, while the enclosed bridge provides protection from the weather during long transits.

<u>Four Control Stations</u> - The multiple control stations allow for operational flexibility and are also useful in training. The consoles contain a full range of electronics and controls.

<u>Side Recesses</u> - The side recesses allow the crew to get close to the water for personnel recovery and working alongside smaller craft. The recesses are covered with a hinged grating which allows easy access around the decks under normal operations.

<u>Ergonomic Seating</u> - There are a number of seats onboard for the crew and passengers. Unlike the 44 MLB, there is seating for everyone onboard, and the seats all incorporate seatbelts. These have proven valuable in restraining the crew during extreme rolls in surf conditions. The seats were custom designed with input from the Coast Guard operators. Two of the seats in the in the enclosed bridge incorporate steering levers in the armrests.

<u>Handrails and D-Rings</u> - There are handrails throughout the boat to allow safe passage underway. External handrails have "D" rings to allow attachment of heavy weather safety belts.

<u>Stability and Seakeeping</u> - Although nearly twice as fast as the 44 MLB, the 47 MLB offers better seakeeping and stability for a less fatiguing ride.

The Coast Guard has taken a very conservative approach to the 47 MLBs development to ensure that the design was well proven before beginning a production run of approximately 100 boats. Human engineering has played a part in every step of design development, and will continue to play a part through the Coast Guards Boat Alteration process.

In order to ensure that all of the operational requirements were met prior to the start of a production run, a Prototype and five Pre-production 47 MLBs were constructed by Textron Marine Systems. The prototype was delivered in 1990 to a dedicated Test Team located at Cape Disappointment, Washington to allow testing on the Columbia River Bar. The Test Team put the Prototype through a battery of tests, and made numerous recommendations to improve the boat. Many of these, including a redesign of the control consoles, were incorporated into the 5 Pre-production boats.

The Pre-production boats were delivered to 3 East coast and 2 West coast stations beginning in 1993. The purpose of the Pre-Production boats was to evaluate the 47 MLB as an operational resource under a wide range of operating scenarios. During this time the Prototype also was used as an operational unit. Suggestions for changes were solicited from the crews of these boats, and many of these were incorporated into the design after review by a Configuration Control Board.

During the development process a number of human engineering tools were used. These included CAD design, full scale mock-ups for the preliminary design and for the Pre-production bridge arrangements, prototyping, numerous crew interviews, and independent reviews. The independent reviews were conducted by the U.S. Navy Biodynamics Laboratory as well and the Coast Guard's Research and Development Center. In addition, input was solicited from the Royal National Lifeboat Institution and the Canadian Coast Guard.

The suggested changes have greatly improved the 47 MLB. As an example, Mr. Carvalhais sites the use of a heavy door. What he failed to realize was that the correction of this problem was already in the works when he visited the Pre-Production 47 MLB. The door in question leads from the main deck to the deckhouse. It had been changed from a vertical door to a sloped door to eliminate a vestibule. This improved visibility aft from the enclosed bridge and visibility of the tow bitt from the open bridge. When the slope of the door was changed a gas strut was to be incorporated to compensate for the weight of the door.

Unfortunately, this change took a while to incorporate, and the strut was not in place at the time of Mr. Carvailhas's review. The struts were installed shortly thereafter, and the result is that it takes less than five pounds of force to open the door.

The use of human engineering tools such as CAD modeling, mockups, prototypes and feedback from operators and outside reviewers has resulting in numerous design improvements resulting in a boat that is not only superior in performance to its predecessor, but is more easily used by its crew. It is hoped that the 47 MLB project will be used as a baseline for future human engineering programs in the development of Coast Guard boats.