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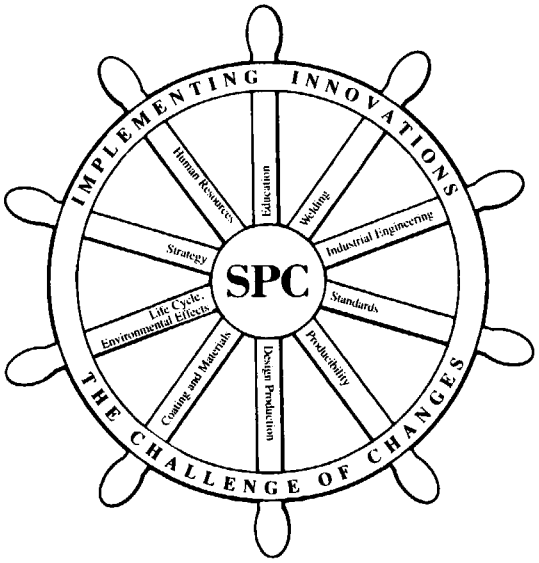

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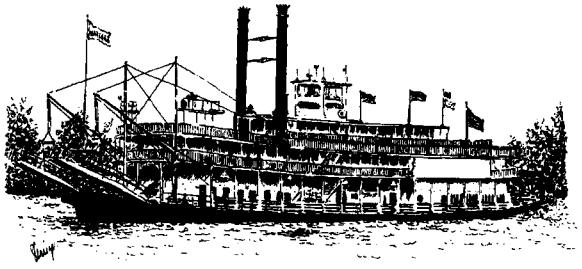

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Human Factors: An Initiative in the United States Coast Guard

No. 5A-2

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ABSTRACT

Although the concept of human factors is not new, it is new within the marine system. Ship design and operations are just a part of the marine system. The marine system is everything and anything associated with the marine community, environment, industry, etc.; whether it is public or private. Human factors is a means to improve and maintain a better quality of life in both the workplace and the home. Human factors is compatible and complimentary with good managerial practices, and is back by sound engineering. The aim of this paper is to expose the reader to human factors.

INTRODUCTION

Ships' machines can do a lot of the work required of humans. There are unmanned engine rooms, there can be bridge consoles that need only a single operator, and there can be damage control systems that provide decision support. Such systems, if designed and operated properly, can reduce the likelihood of mishaps. The engineering called for to build these systems is not complex by today's standards. The challenge is moving the marine industry to this technology. This requires a systems approach.

The current marine system is missing data. This is why there is a knowledge gap. From marine statistics kept by the Coast Guard, nearly 80% of commercial maritime casualties and nearly 80% of Coast Guard vessel mishaps have human related causes. However, these marine statistics do not capture the underlying causes of human error. Some examples are: improper training, under the influence of alcohol or drugs, fatigue, workload too high on the bridge, or the ship's design. The Coast Guard's taxonomy of human related causes of casualties has been changed, as much human factors' data can be entered into a Coast Guard database by investigating officers. This new taxonomy will enable the Coast Guard to analyze human error and eventually, focus near-term human factors efforts on the areas to be identified. For example, if the findings are that many casualties happen when the mariner is over-worked, then there is a need to examine the factors contributing to mental overload and physiological tasking, and perhaps consider changes to the appropriate regulations.

The need for marine specific human factors research was one of the main recommendations by the National Academy Sciences, Marine Board in a report entitled Crew Size and Maritime Safety. The Marine Board points out that human factor applications are not being addressed in the issue of minimum manning. The recommendations are to undertake: a reduced manning study, and more development and application be conducted on a variety of human factors issues, such as; an analytical tool that guides ship staffing decisions that accounts for human factors.

Global competition is the major hurdle for the marine industry. Keeping labor costs down would help make the United States Merchant Marine more

competitive. The manning requirements may be constraining. However, there are no manning alternatives that advocate a safe reduction in crew size. The Coast Guard is drafting its first Human Factors Plan. The plan is intended for the Office of Marine Safety, Security and Environmental Protection and has virtually tapped all aspects of the marine system. The Human Factors Plan contains a specific task of conceptualizing a manning model. In late 1992, the plan will be introduced. Although global competition is not part of the Coast Guard's mission, it is a recognized reality.

AN EXECUTIVE SUMMARY OF HUMAN FACTORS

Human factors and ergonomics are synonyms. A working definition for Human Factors is making machines such as computers, products. and places (e.g., ships, building, etc.) fit the user. Humans are part of the system. The system is the environment in which human behavior influences specific outcomes. Therefore, Human Factors Engineering (HFE) is a multi-disciplinary technology.

An objective of HFE is to enhance working conditions in a way that encourages productivity in the workplace. This can be accomplished by improvement of equipment design that will make it compatible with human use. Improvements in health, safety, satisfaction, and quality in the work places will be windfalls from a system designed with HFE. Other benefits will be accident reduction, increased productivity and extended equipment life. There are abundant benefits in using human factors.

Human .Factors can be simplified to four basic factors: perception, judgment, motor ability and internal stress.

Perception **is** the ability to be aware of objects, movements or changes of energy occurring outside the human body. One must be aware that an action is called for. This is done yia any of the natural senses. The perception ability involves consciousness. Perceptions are arbitrarily classified as high; medium and low, and based on the sense affect. The senses are not in direct contact with the events being sensed. However, they are a convincing basis to interpret the reality. The importance appears in failures versus successes attributed to difficulties using the correct control or understanding the correct signal. The designer's goal for the perceptual factor is to generate displays to ensure the most reliable interpretation of signals. Interpretation calls for vigilance, and humans are not ideal sensors. Machines can monitor, sense and control better than humans. However, humans have several advantages. Humans can adapt easily and are very efficient in detecting signals in the presence of high levels of noise. Lastly, training has an important role in enhancing the perceptual factors in humans. If an outcome requires a perception then training is required.

The second factor considered is judgment. After a human has perceived that an action is required, he or she must then decide what action is required. In essence, judgment is a cognitive voluntary activity. Humans learn from both created and prevailing data, commonly referred to as training and experience, to respond successfully to situations. Usually, the decision making process is based on choosing the best option, and often, choosing one option prevents choosing all others. The concept is based on the 'value of anticipated outcomes' multiplied by 'important weights.' This results in a numerical value for each choice. Obviously, the desired choice has the highest value. Outcomes do not necessarily result directly from the human decision. Several factors, usually not under human control, contribute to human decision making. Decisions count on memory ability. Many decision-making problems are memory related. A complete database required to make the right choice usually exceeds an individual's memory. Again, training will enhance the decision-making process in humans, but the training must be routine, frequent and thought provoking.

Motor Ability is the capacity to make the muscular contractions required to perform a task. Motor ability is included in areas of study in anthropometry and biomechanics. Many aspects of the human body are unmeasured, unclassified and unaccounted in human factors. Humans are limited by speed, force, displacement and accuracy. Human duty cycles are limited and life support in a hazardous environment is costly. The best advantage is the human ability to adapt to new situations. Instead of standards and guidelines, humans are required to adapt. The challenge is to provide guidelines regarding the best distribution of functions between operator and machine.

Internal Stress is internal conflict resulting from certain qualities of the task. Any of the other factors affecting human performance is considered a stress agent. The internal stress effects can be catastrophic, in the right place at the right moment. There are two arbitrary stresses, based on the source: psychological and physiological. The social environment at work and leisure are typical sources of psychological stress. The task itself has mental-loading and pacing. The organization has supervisor style, boredom, and motivation. The individual has personal attributes and preferences. The other source of stress is physiological. Age and lack of sleep are examples. Changes such as day-night, natural cycle, and physical fatigue are antecedents to physiological stress. Temperature, noise or illumination will effect performing a task. The task itself forces demand. There are myriads of sources. Prevention is difficult but management is attainable; such as physical exercise. Some level of physical activities will improve both, psychological and physiological stress. Stress levels are related to one's health, and can be related to the health or well-being of others.

One common mistake in the implementation of human factors is the methodology. Most people think one does not have to be a human factors specialist to implement this concept. Scientific methods must be used to validate human factors' data. The data is obtained under controlled conditions. Independent and dependent variables must be taken into account. Biomechanics and anthropometry are available for most applications. However, methods are needed to account for stress, judgment and perceptual factors in any part of the marine system, e.g., ship's operation, fleet operation, maintenance, standards, etc. The method must deal with vagueness in quantitative and qualitative ways.

HFE plays an important role in prevention and response. Human factors contribute to accidents and are the means of avoiding accidents. It is possible to quantify the combination of factors and sequence leading to an accident. It is more challenging to forecast the factors and events that would prevent the accident. Human factors are based on events, and prevailing or created data, including those using simulators. Poor design of equipment, fatigue, over-load, too much information required for a decision, vigilance and environment may be all in the critical path leading to an event. These factors can be foreseen. Checklists are used to ensure the correct action is taken. However, the improper use of checklists will increase the risk of failure. So, the ideas in this summary are an over simplification of a complex matter. To show the complexity a checklist of twelve domains follows. Linkage among the domains is not included and will be the topic of another paper.

A HUMAN FACTORS CHECKLIST

In 1991, a checklist was considered by members of the Coast Guard's Human Factors Coordination Committee (HFCC). The checklist was not all inclusive in nature, nor is the expanded version presented below. To develop a checklist for a specific situation, a discreet analysis of the related variables must be performed. Since the HFCC had a time constraint and variables were questioned, the HFCC checklist is not available. The checklist presented is the author's

attempt to foster human factors in the marine system. Several more questions from "The Biology of Work" (1) were added and several words and sentences constructions were changed as well. This is presented for the reader's consideration.

1. Physlcal capabilitles required for effective human performance
   a. Are there any physical conditions that will disqualify the individual?
   b. Are there any useful characteristics (e.g., strength or endurance) required to accomplish the task?
   c. Are any of the five senses a critical ability(ies)?
   d. Is the work space adequate?
   e Are the characteristics of the hand controls compatible with the forces required to operate them (e.g., shape, size, surface) and are the forces acceptable?
   f. Can the subject be seated for all or part of the time and complete the task?
   g. Are there provisions for the subject to sit, and is the available chair satisfactory in its design?
   h. Are hand tools used or required?
   i. Can the speed of the machine equipment or device be adjusted according to the skill of the operator dedicated to the task?
   j. Are personal protection devices required?
   k. Does the task impose excessive visual demands on the individual?
   l. Is high illumination required or local artificial light needed?
   m. Are there visual signals, and are they placed in a central area?
   n. Is color discrimination required?
   o. Does the task require tactile discrimination?
   p. Does the task require a good sense of balance?
   q. Does the task require a good sense of smell or taste?
   r. Does the task require high accuracy of movement?
   s. Is the muscular load dynamic or static?

2. Mental capabllitles requlred for effective human performance
   a. To what extent is alertness considered critical?
   b. To what extent is reaction time considered critical?
   c. To what extent is concentration considered critical?
   d. To what extent is ability to think under stress considered critical?
   e. How complex are the decision-making requirements (i.e., do the decisions require consideration of many variables to determine the most effective alternative)?
   f. What mental conditions should be considered disqualifying?
   g. Are high levels of motivations, alertness and power of concentration required?
   h. Is there any data to be processed before the required action can be taken?
   i. Are there different sets of data to be compared before action can be taken?
   j. Are standards of comparison available and used?
   k. Can signals be confounded?
   l. Are there any rest pauses during monitoring work?
   m. Are fear or repulsion evident?

3. Minimum required training or experience
   a. Is perception required?
   b. Are there any special training requirements related to the specific task?
   c. is on-the job experience required before an effective performance can be expected?
   d. Is supervision required during performance?
   e. What is the training period, e.g., one week, month, etc.?

4. **Critical information required for effective human performance**

a. Is essential data readily available when **needed?**

b. Must any data be located before proceeding with the task?
Must data be assessed before used?

c Is the rate of data likely to exceed the mental capacity of the operator and to overload the user?

e. Do identical or similar signals occur for a long time and are they frequently repeated?

f. Are all the factors applicable to a decision presented at the right time and sequence?

5. **Associated events related to workload**

a. Are several related events that require attention by the same individual taking place simultaneously?

b. Will other events continue to develop unattended?

c. Can a critical point develop if other events are permitted to proceed unattended? d Must other important tasks be postponed while attention is devoted to a task that the individual has determined is more important?

e. Do surrounding events distract the individual who must focus attention on a single task?

f. If any of the sensory channels is likely to be overloaded, can the load be more evenly spread?

g. Does the subject have to make a choice in response to a signal, and does he know immediately if the choice is wrong?

h. Can feed-back be given of the effects of adjustment to a system?

6. **Degree of precision required for effective human performance**

a. Do conditions normally allow for a wide margin or error?

b. Are some errors in the situation under study likely to undermine accuracy, reliability, validity of later events?

c. Does the task demand very fine visual judgment?

d. Can auditory signals be easily detected and distinguished from each other?

e. Is the accuracy of the instrument compatible with the required reading accuracy inherent on the task?

f. Are reading errors minimized by the design of the instrument?

g. Can signals from different sources occur simultaneously?

h. Can preferred signals be distinguished easily?

7. Communication skills

a. Does performance require an ability to read?

b. Does performance require an ability to communicate orally in a particular language?

c. Does performance require an ability to communicate by non-verbal means?

d. Does performance require an ability to use technical vocabulary or technical formulation?

e. Can lack of opportunities of communication with other individuals affect performance?

f. Is verbal communication needed in the task, and does noise level permit it?

8. Time-critical factors

a. Must judgment be exercised within specific time limits?

b. Must a series of interdependent steps or instructions be performed rapidly?

c. Does the event recur periodically?

d. Can the performance become so routine that the individual's level of concentrations begins to drop?

e. Can performance involve a response to emergency conditions (i.e.. is the individual likely to be confronted with unexpected situations requiring immediate attention to avoid major adverse consequences)?

f. Does performance significantly influence other events?

9. Is the time lag between changes in the system and indication of it in the dials optimized?

9. Procedural considerations

a. Can the entire process or sequence of events be accomplished by one person or machine?

b. Can it be commenced by one person and completed by others?

c. Does effective performance require more than one person to work together?

d. Must the process or sequence of events be completed in a specific series of steps?

e. Does performance depend on reliable performance of automated equipment?

f. Does the process include warning or imminent failure that requires immediate attention?

g. Does the process depend on accurate record-keeping?

h. Can the process be standardized?

i. Does the process include safeguards such as redundancy, review, observation or inspection by others?

j Are there any circumstances under which advancement to the net state of the process will be turned back if permission to continue is not granted by someone not involved directly with the task?

k. Does the process require a positive confirmation to be given to others and an affirmative acknowledgement that the performance has been effectively completed?

l. To what extent must individuals responsible for one part of the process be familiar with other parts of the process?

m. Are there any procedures so complex that they require frequent consultation with written instructions?

n. Are those instructions provided in a form that is adequately clear for those who are likely to consult them?

o. Is the task rigidly paced? (What are the pacing systems?)

10. Design Considerations

a. To what range is the distribution if instruments, equipment, machinery inflexible?

b. To what extent is physical access to equipment, controls, spaces, work station, etc., required?

c. Does effective performance require rapid or emergency access? d Does effective performance require random access?

e. Does effective performance require concurrent access to more than one location?

f. Does effective performance require concurrent access to more than one person?

g. Is there a wide variation in the available designs for performance capabilities?

h. Does the design arrangement allow for adjustment to accommodate individual preferences, abilities and physical characteristics?

i. Are instruments, equipment, machinery often installed as a modification to an existing arrangement?

j. Are security features or safeguards needed to discourage improper or unauthorized use?

11. Other relevant factors

a. What position does the practice or procedure under examination occupy as a component within a larger, more comprehensive system?

b. Are there any conventional standards in the maritime or other transportation industry that might apply to the practice or procedure?

c. Is any written guidance available on the above matters to assist decision makers who are responsible for implementing the particular practice or procedure most effectively and practical?

d. Is additional information needed to allow an assessment of the extent to which human ability or behavior may be involved in the practice or procedure?

e. How can reliable current information be collected most expeditiously?

12. Environment

a. Are conditions within the comfort zone?
b. Is the individual exposed to rapid environmental changes?
c. What is the noise level; does it interfere with performance; is there any risk of hearing loss?
d. Are personal protective devices needed?

This checklist is for insight and by no means totally inclusive. Furthermore, this checklist does not provide the linkage for the entire system/solution. A system's analysis is required that must include task and network analysis. The next step is to determine where in the design, maintenance or operation process the domains need to be considered.

SUMMARY

Though humans will make mistakes, there is a lot that can be done to minimize their short comings. Humans play an active role in the marine system and the maritime community needs to integrate human factors into the design, maintenance and operation of the marine system. Many came to realize there are methods and techniques that can be applied to the marine system that will improve human performance and reduce casualties and errors.

To ensure human factors principles are applied as widely as possible the United States Coast Guard is incorporating human factors considerations in its research and development, design, and operational efforts. The integration of human factors into these efforts will be a major undertaking for the maritime community. By understanding why humans err and understanding how to design systems to minimize human error the maritime community will have a safer marine system.

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