USER AND TASK ANALYSIS OF THE FLIGHT SURGEON CONSOLE AT THE MISSION CONTROL CENTER OF THE NASA JOHNSON SPACE CENTER

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Final Report

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ABSTRACT

Astronauts in a space station are to some extent like patients in an intensive care unit (ICU). Medical support of a mission crew will require acquisition, transmission, distribution, integration, and archiving of significant amounts of data. These data are acquired by disparate systems and will require timely, reliable, and secure distribution to different communities for the execution of various tasks of space missions. The goal of the Comprehensive Medical Information System Project at Johnson Space Center Flight Medical Clinic is to integrate data from all Medical Operations sources, including the reference information sources and the electronic medical records of astronauts. A first step toward the full CMIS implementation is to integrate and organize the reference information sources and the electronic medical record with the Flight Surgeons' console. In order to investigate this integration, we need to understand the usability problems of the Flight Surgeon's console in particular and medical information systems in general. One way to achieve this understanding is through the use of user and task analyses whose general purpose is to ensure that only the necessary and sufficient task features that match users' capacities will be included in system implementations.

The goal of this summer project was to conduct user and task analyses employing cognitive engineering techniques to analyze the task of the Flight Surgeons and Biomedical Engineers (BMEs) while they worked on Console. The techniques employed were user interviews, observations and a questionnaire to collect data for which a hierachical task analysis and an information resource assessment were performed. They are described in more detail below. Finally, based on our analyses, we make recommendations for improvements to the support structure.

INTRODUCTION

Astronauts in a space station are to some extent like patients in an intensive care unit (ICU). Medical support of a mission crew will require acquisition, transmission, distribution, integration, and archiving of significant amounts of data. These data are acquired by disparate systems and will require timely, reliable, and secure distribution to different communities for the execution of various tasks of space missions. The goal of the Comprehensive Medical Information System Project at Johnson Space Center Flight Medical Clinic is to integrate data from all Medical Operations sources, including the reference information sources and the electronic medical records of astronauts. A first step toward the full CMIS implementation is to integrate and organize the reference information sources and the electronic medical record with the Flight Surgeons' console. In order to investigate this integration, we need to understand the usability problems of the Flight Surgeon's console in particular and medical information systems in general. One way to achieve this understanding is through the use of user and task analyses whose general purpose is to ensure that only the necessary and sufficient task features that match users' capacities will be included in system implementations.

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Our project supports the NASA Strategic Plan For Medical Informatics: Telemedicine and Telehealth, January 2000. According to the Executive Summary, the last several years have seen a rapid evolution in technology in communications, information systems, and medical care. The evaluation and ongoing efforts to integrate these three domains continue to be the focal point of NASA's telemedicine, telehealth, and medical informatics development. Medical informatics will become the center of medical care and not simply a tool for medical care.

METHODS

Review of Johnson Space Center Information

Johnson Space Center is like any large organization that has its distinct culture. In order to understand the background and the operations of the study subjects, the analysts started by reviewing the manuals and documents that the subjects use or are trained with. A description of these resources may be obtained from the researchers. Many of these documents have an acronym attachment due to the fact that many acronyms are context specific – i.e. the same acronym may be used in more than one area to mean different things. The document review provided the analysts with excellent views of the intricate procedures and diverse functions of the various aspects of space flight. In addition to the document review, the analysts gained background and context information by attending seminars, workshops, and tours of Johnson Space Center. This provided them with improved understanding and profound appreciation of the Mission, Vision, the monumental accomplishments, and the tremendous challenges of Johnson Space Center and NASA.

Task Data Collection Methods

Data collection is a prerequisite of any form of task analysis (Kirwan, & Ainsworth, 1992). We collected data by the following methods: Observation, Questionnaire, and Unstructured Interview.

Observation

The objective was to obtain data by directly observing the activity and behavior of the Flight Surgeons and BMEs while they were working on console. The analysts attended simulations of both shuttle missions and international space station missions and observed Flight Surgeons and Biomedical Engineers while they worked on console. One analyst would observe the Flight Surgeon in Mission Control while another analyst would observe the BMEs in the Multi-purpose Service Room. The subjects were informed that the analysts were there to observe unobtrusively. Questions could be asked of the subjects and the subjects would only respond if that did not interfere with their job performance.

Videotape was made of the BMEs while they worked on two shuttle mission simulations. These tapes were later reviewed for useful information. While this is generally a good data collection method, the particular simulations observed in this manner had sparse activity and so the videotapes provided no additional information over the notes taken during observation. Discussion of future use of this technique will be presented in the recommendations section.

Unstructured Interview

Unstructured interviews were used during all stages of information gathering. (Kirwan, & Ainsworth, 1992). The analysts performed some unstructured interviews during mission simulations. Additional interviews were scheduled with Flight Surgeons and BMEs to investigate specific issues such as a) what set of information resources is available in paper form; b) how are updates to the information resources performed; c) what electronic resources are available; d) what are the differences in resources between shuttle and ISS; and e) what is the current state of the electronic patient record.

Questionnaire

The questionnaire was designed for the Flight Surgeons and BMEs in order to determine which information resources are being used and what types of support might be useful. The information gleaned from the unstructured interviews was used to design this questionnaire. A copy of the survey may be obtained from the researchers. The criteria were:

- To make the questions direct and informative
- Use multiple choice questions with comment sections for adding information
- The answer selections must include a full range of significant alternatives

- The questionnaire must be anonymous; and must not require more than ten minutes to complete.

The questionnaire was distributed to Flight Surgeons in hardcopy form and collected during a regular meeting. Additional results were collected using a web-based survey form. The questionnaire was administered to BMEs through the web-based survey. Responses were obtained from 70% of the Flight Surgeons. Data collection has not yet been completed for the BMEs.

RESULTS

Information Assessment Index

The Information Assessment Index was utilized to organize the huge amount of information that was gathered (William Pena, 1979). There are two major components to this index: Function and Form. For each, the goals, facts, concepts, needs, and issues are listed. This may be obtained from the researchers.

Task Analysis of Flight Surgeon and Biomedical Engineer on Console

A hierarchical task analysis was performed. Results are presented here for the Flight Surgeon portion of the task analysis. Flight Surgeons and BMEs have intersecting task sets. The primary differences are:

1) The BME sets up the equipment and materials for the Private Medical Conference (PMC) and serves as a resource locator rather than performing the PMC which is the task of the Flight Surgeon.
2) The BME is the person who is primarily responsible for diagnosing medical equipment problems.

It should also be noted that there are differences in the resources available for Shuttle and ISS. Although many of the same types of resources are available, the terminology used is often different (e.g. EECOM for Shuttle versus ECLSS for ISS).

The hierarchical task analysis is displayed in two forms. Figure 1 shows a graphical representation of the task/subtask hierarchy. Following that, Table 1 gives the specific descriptions of the higher level tasks.

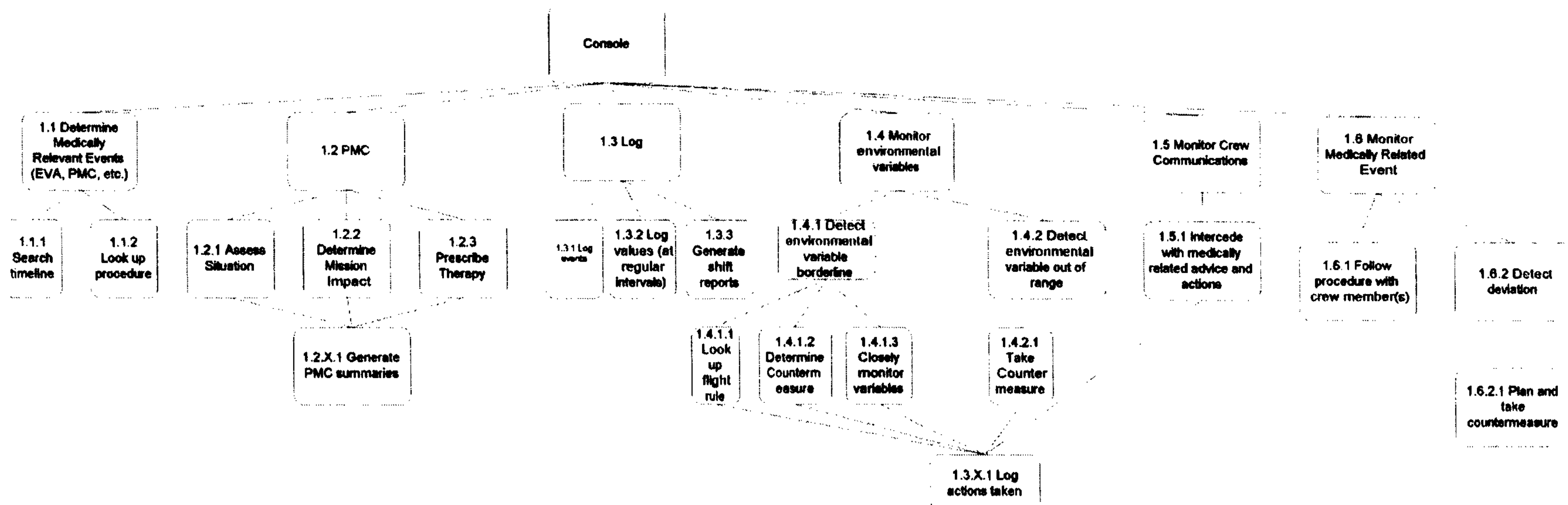

Figure 1: Flight Surgeon Task Hierarchy

Table 1 Task descriptions

Task Element	
1.1 Determine medically relevant events (EVA, PMC etc.)	**Purpose** To determine events that would fall within the purview of the Flight Surgeons and BMEs (i.e. have medical implications or use medical devices) These generally have the potential to develop into abnormal situations.
	Decision Alternatives Make knowledge based decision for actions.
	Displays Timelines on PC (ISS – interactive, STS – static)
	Actions Monitor Timelines. Look up procedures in flight rules and Missions Information Package
	Information Sources Timelines, Flight rules, Mission Information Package
1.4 Monitor Environmental Variables	**Purpose** To monitor environmental variables that have the potential to develop into abnormal situations
	Decision Alternatives Determine if environmental variables are near range boundaries or out of range. Locate in information materials the constraints or counter measures involved. Make knowledge based decisions.
	Displays Environmental variables on DEC Alpha Timeline on PC (ISS – interactive, STS – static) Procedures on PC
	Actions Take appropriate actions based on flight rules Log the actions taken
	Information Sources Flight Rules, Timelines, Flip File, DCS manual, Medical Record, Environmental Display, log, SOMS/CHeCS Reference, Medical References/texts, Toxicology Web Site, Toxicology Ref (TOMES), Radiation Web Sites, Mission Support Medical Operations JSC Web Site.
1.4.1 Detect environmental controls near range boundary	**Purpose** To make timely decisions and take appropriate counter measures to maintain crewmembers' health and safety. To prepare for the possibility that actions may become necessary due to environmental changes.
	Decision Alternatives Make decisions on whether to initiate counter measures to maintain crew members' health and safety

	Display Orange value in environmental display on DEC Alpha
	Actions Maintain close monitor of those environmental controls. Log values/times. Look up appropriate rules. Determine actions that may become necessary. Determine materials necessary to take countermeasures. Locate materials. Locate crewmembers procedures if necessary. (e.g. method for replacing CO2 filter).
	Information Sources DEC Alpha environmental displays, Flight Rules (hardcopy)
1.4.2 Detect environmental controls out of range boundary	**Purpose** To initiate counter measures.
	Decision Alternatives Make decisions to initiate counter measures to maintain crew members' health and safety
	Display Red value in environmental display on DEC Alpha
	Actions Take counter measure actions. Monitor crew performance. Continue to monitor/log values.
	Information Sources DEC Alpha environmental displays, Flight Rules (hardcopy)
1.5 Monitor crew communications	**Purpose** To keep abreast of the mental and physical conditions of the crew and detect any factors that may affect the health and safety of the crew members
	Decision Alternatives Decide when and where to intercede with medically related advice and actions
	Display Maintain open channels on DVIS between crewmembers and CAP COM, CAP COM and Flight Director and others as appropriate.
	Action Take actions to maintain the health and safety of the crew members
	Information Sources DVIS, DEC Alpha environmental displays
1.6 Monitor Medically Related Events: EVA, use of medical devices	**Purpose** To react promptly and efficiently and to act within Flight Rule Guidelines BME to detect and handle mechanical/device problems
	Decision Alternatives When deviations from planned procedures occur, decide on

	actions to safe guard crews' health and also impact on the mission.
	Display Timeline on PC. DEC Alpha bioenvironmental displays.
	Action Detect deviations. Follow procedures in Flight Rules. Take counter measures when indicated.
	Information Sources DVIS, DEC Alpha, Timeline on PC, Flight Rules (hardcopy), MIP (Mission Information Packet – hardcopy),
1.2 PMC routine (weekly in case of ISS)	**Purpose** To perform a checkup of a crewmember for various purposes including: routine physical (weekly on ISS), pre-EVA; post-EVA, or crewmember has requested one. To detect any deviations from the Astronauts' general health status.
	Decision Alternatives No change in daily schedule. Modification of work or exercise schedules. Prescribe the necessary medications. Determine mission impact.
	Display OCA communications. DVIS. Ku band
	Action Flight Surgeon go to MPSR to perform PMC. Modification of work or exercise schedules. Prescribe medications. Inform Flight Controller of Mission Impact. Generate PMC summary.
	Information Sources Flight Rules. Timelines. Flip Chart. DCS manual. Medical Record. Environmental Displays. Log. SOM/CHeCS References. Medical References/texts. Toxicology We sites. Toxicology Ref (TOMES). Radiation Web Sites.
1.3 Log	**Purpose** To keep records of events, environmental variables, decisions, results of actions, and generate shift reports..
	Decision Alternatives Make decisions to enter pertinent information into log
	Displays PC displays template for log or use paper log form.
	Actions Document events, decisions, and results of those decisions along with the times that they occurred. Document environmental variables at intervals. Generate shift reports.
	Information Sources Flight Rules, Timelines, Flip File, DCS manual, Medical Record, Environmental Display, log, SOMS/CHeCS Reference, Medical References/texts, Toxicology Web Site, Toxicology Ref (TOMES), Radiation Web Sites, Mission

	Support Medical Operations JSC Web Site.

Questionnaire Results

A preliminary analysis of the questionnaire data shows that Flight Surgeons do indeed use most of the resource materials that the analysts found and that the list of materials documented here is relatively comprehensive. There is also strong evidence that there are several areas of support that survey participants would like to see improved. 1) The majority of the respondents expressed a wish for the capability to automatically time stamp log entries. Although this capability can be used, it requires that the person know where to obtain the appropriate template and the reliability of the tool appears to be low. 2) An overwhelming majority of respondents indicated that a combination of electronic resources and paper resources would be beneficial. 3) Many respondents indicated that a key issue is finding reference materials more quickly. 4) Several respondents requested that the crewmember medical record be electronically available while on console

Issues Identified

The following key issues were identified during this project:

1) Not all participants have knowledge of the availability of all information resources and tools.
2) There is a lack of ease of access to information resources.
3) Manual copying of information is time-intensive and prone to errors. For example, logging the environmental variables is accomplished by reading the displays on the DEC Alpha and writing or typing the values into a log.
4) The organization of information material not task oriented. For example, the flight rules are organized by functional unit. If the oxygen concentration (an environmental variable) registers high, the person monitoring must look up the relevant flight rule. In this particular case, the flight rule is not dictated by Medical Operations but is instead a safety issue related to fire hazards. Thus the person monitoring has a difficult time finding the appropriate flight rule.
5) BMEs do not have clinical training but may be required to be the liaison between crew and the Flight Surgeon who may be off site during ISS mission.
6) There are few medical emergency scenarios during simulations.
7) There is a lack of communication of DEC Alpha with the PC. It is not possible at this time to send data between the two systems.
8) There is a mismatch between amount of information to display and screen real estate. There are 3 or 4 DEC Alpha screens (the number is different for ISS vs STS) and only one PC screen when most of the tools that the Flight Surgeon and BME use are on the PC.
9) The current console is designed for a person to actively monitor variables and events and requires that their eyes be looking at the screen and that the data to be monitored is displayed. Long uneventful periods can cause a lack of attention to the screen.

10) Much of the time spent on console is relatively slow. However, when a medical emergency does arise, the nature of the tasks becomes time-critical.

11) The crewmember medical record is currently a standardized summary of medical information presented on paper. Often this summary does not include previous mission data.

Potential Solutions

It is not within the scope of this project to identify the solutions to all of the issues raised above or even to identify the best solutions. However, some discussion of the potential solutions is worthwhile. The most beneficial support change would be a centralization of resources. There is already a very extensive web site that contains links to many of the resources; however, each resource must be searched individually. Further electronification and centralization would enable the addition of a search capability at a global level – not only searching an individual document, but searching all the documents that are potentially relevant. It would also enable alternate indices for the materials. It would be particularly useful to implement a task-based index as this would facilitate quick and accurate access to the appropriate information. This same area could also be used to centralize a description of capabilities for use both in training and while working the console. For example, the analysts found that it IS possible to receive an audio indication of environmental variables reaching threshold values. Enabling this capability would help to alleviate issue 9 above (inattention to values during uneventful periods). However, this capability is unknown to most Flight Surgeons and BMEs.

Time could be saved and more accurate information collected if there were a way to automatically log the environmental variables periodically. Also, it was apparent from some of the simulations that having access to recent unlogged values could be useful. For example, when it is noticed that an environmental variable reaches a threshold value, knowledge of exactly when the event occurred and how quickly the variable was changing is useful in determining the actions to be taken.

Integration of the electronic patient record into the console environment would provide easy access to the most recent data on a crewmember and would serve to consolidate and coordinate all the information collected. For example, a medical problem that occurs during an EVA may be better solved if the Flight Surgeon has access to logs about previous missions. In the current environment, this information may not be available in the paper patient record that is used on the console.

CONCLUSIONS

The console environment used by Flight Surgeons and Biomedical Engineers is very complex. There are numerous information resources including computer displays of information, web-based materials, paper documentation, personnel, etc. The tasks that the Flight Surgeons and Biomedical Engineers do can also be complicated and at times quite time-critical. There are clearly some areas where support for these users and tasks can be improved. We have identified what seem to be the most critical issues and have generated some potential solutions. Future work may include implementation and testing of some of these solutions.

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