Human Factors Techniques for Designing the Virtual Mission Operations Center

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1. INTRODUCTION

The objective of this paper is to illustrate how multiple human factors techniques are being successfully applied during the development of a new, state-of-the-art, satellite command and control system called the Virtual Mission Operations Center (VMOC). The VMOC is a NASA project to experiment with and develop new technologies and operations concepts, which increase the efficiency and effectiveness of satellite control centers. The primary goal of this project was to maintain the high levels of quality and efficiency of data in an environment where reduced US Federal budgets require a dramatic reduction in the size of a satellite's Flight Operations Team (FOT). The members of the FOT are the people that continuously staff the mission control centers. Their activities include commanding the satellites, monitoring the health and safety of the satellites, and planning future work. This work is funded by the Data Systems Technology Division (Code 520) of the Mission Operations and Data Systems Directorate at NASA Goddard Space Flight Center (GSFC).

Instead of following the current standard approach of building fixed and custom resources (hardware, software, and facilities) for each satellite and providing a 24 hour/day dedicated FOT, the VMOC concept calls for a dynamic, distributed collection of people and resources that can operate at any time in any place. Under this paradigm, a satellite control center will run autonomously to command and monitor satellites, to log and document the operations, and to notify on-call operators and engineers when anomalies occur. When anomalies occur, a response team is assembled to analyze, resolve, and take corrective actions [1].

To ensure the success of the VMOC project, the development team involves the user community whenever applicable to help create the new operations concept and the tools to support it. Thus, the team utilized the operators' domain knowledge and lessons learned from

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current operations as a basis for designing the VMOC system. The development team consists of one human factors engineer/user interface designer, a NASA program manager, and several software engineers.

2. TECHNIQUES

This paper will discuss multiple human factors methods being used in the VMOC design. The more common methods are only mentioned briefly so that more focus can be applied to several of the more innovative techniques.

The design team began by developing a working knowledge of the current process of spacecraft operations. First, a literature review was conducted of previous studies of operations at Goddard and at other centers. Several reports were quite beneficial because they included workflows of various levels of detail and completion [2, 3, and 4]. Next, the team began a more formal task analysis to better define interactions, workload, job organization, and skills and knowledge requirements. Data were collected via direct observation of FOTs in control centers during their shifts and during structured interviews. In all, five FOTs were observed. These ranged from a small mission like the Gamma Ray Observatory (GRO) to a large mission like the Hubble Space Telescope (HST).

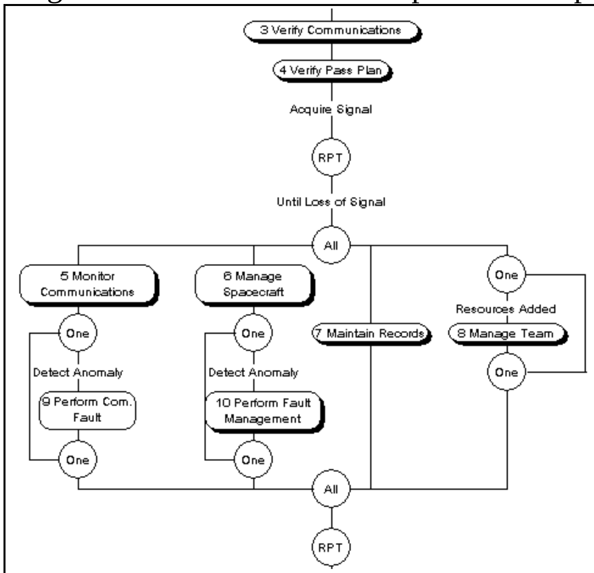

Figure 1. Sample composition graph

Once the data were collected, they were represented using Composition Graphs. A composition graph is a formal method for modeling task activities [5]. Composition graphs hierarchically break down user operations into activities, sub-activities, tasks, and task elements. A sample composition graph that represents a portion of a high level view of is shown in Figure 1. One of the unique attributes of this technique is that it provides a mechanism for representing parallel (concurrent) activities, such as monitoring communications, managing spacecraft, maintaining records, and managing the team.

This technique also provides convenient mechanisms for recursive activities through the use of the repeat (“RPT”) operators. In Figure 1, the activities in between the two repeat symbols are performed by the FOT until they lose contact with the spacecraft. Each of the numbered activities shown in the shadowed ovals are linked to more detailed graphs that break those activities into sub-activities, tasks, and task elements. A graph was developed for current operations, and a new graph was created to represent the VMOC operations concept.

Following the construction of the composition graphs, three scenarios were developed. As recommended by Carroll [6], the scenarios were developed to provide: (1) a more concrete representation of how the system would operate; (2) a basis for communication among the members of the design team, the client, and the end users; and (3) a starting point for the follow-on prototyping effort. As the scenarios were constructed, the initial rough operations concept solidified into a more comprehensive and realistic plan. As the scenarios were developed and reviewed, it was necessary to modify the composition graphs upon which the scenarios were based. Iteratively, over several months, the graphs and scenarios were modified until a cohesive story was constructed.

The original graphs and the new operations concept graphs were reviewed by a "steering committee" of satellite operators, engineers, and specialists at a series of project meetings. The goals of assembling the review committee were to ensure accuracy of the model and to get input into the practically and feasibility of various aspects of the new concepts. The VMOC concept was explained primarily by walking through the scenarios and stepping through the composition graphs as the scenarios progressed. This proved to be an excellent technique. The use of scenarios and graphs together allowed the operations end-users to understand some complex new ideas and it also allowed the software engineers to understand the needs of the users. A significant amount of feedback on what may and may not work was collected at these meetings. The feedback was then used to further modify the graphs, scenarios, and ultimately the operations concept itself.

At this point, the team began prototyping key aspects of the system. The development team continued to involve users in this process through cooperative prototyping. In this technique, as new features are added to the design, they are demonstrated to the users for feedback. That feedback is used to modify the design and to plan for follow-on prototyping. More detailed information on the prototyping is described in Bane and Fox [7].

3. IMPACTS

Involving the users has had significant positive impact on the development effort. The more important impacts are listed below.

- More realistic design -- through the many iterations of the compositions graphs and scenarios, more realistic constraints, requirements, and opportunities were identified.

- Better relationships -- by involving the users from the beginning, operators have been willing, and even enthusiastic, to devote their time to us in developing new tools. In the past, it was extremely difficult to have access to the end-users. Previously, operations staff often thought that the researchers were not interested in their needs.

- Increased usability -- through the feedback collected during demonstration of prototypes, many design changes were made to the prototypes. With each revision of the design, the users felt more comfortable with the new VMOC tools and concepts. In fact, this past April, a mission that will launch later this year (TRACE, Transition Region and Coronal Explorer) committed to using VMOC-based software.

- Changed priorities -- based on user feedback and observations of FOTs, the entire focus of the VMOC development changed. Initially, the focus of the project was on developing a state-of-the-art expert system that would monitor and diagnose problems with the spacecraft, thus reducing the number of operators required to fly a spacecraft. As it turned out, most of a FOT member's time is spent on routine tasks, such as planning, performing administrative duties (e.g., filling out paperwork), and managing computers and data. Based on this knowledge, the team decided to shift focus away from an expert system toward groupware that can assist or completely automate many of these tasks.

4. CONCLUSIONS

In conclusion, user-centered design techniques have formed the backbone of the VMOC development effort. Users (operators) have been involved through the concept definition and initial design phases. The results of this approach have been very beneficial. The concept is more detailed and realistic; the prototype tools are more usable, the focus of the project is now on assisting operators; and there has been more cooperation among the researchers, developers, and users. It is anticipated that such a user-centered focus will be used for future development projects.

5. REFERENCES

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