Model-Based Displays for Satellite Ground Control*

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With the emergence of new technology for both human-computer interaction and knowledge-based systems, a range of opportunities exists to enhance the effectiveness and efficiency of satellite ground controllers. This presentation illustrates the use of models of operator function to represent operator activity in the context of changing system events and operator functions. Although there are many models, this research used the operator function model (OFM). Figure 1 depicts a generic OFM; Mitchell (1987) gives details about the model structure and the OFM modeling process.

In addition to representing operator activities, the OFM can be used to design 'intelligent' operator displays and, in real time control the displayed information so that the operator has the appropriate information, at the appropriate time, and at the appropriate level of abstraction. The operator function model was demonstrated in the context of a NASA Goddard Space Flight Center satellite ground control system (Figure 2). Figure 3 depicts a portion of the OFM for the Multisatellite Operations Control Center (MSOCC) application.

To evaluate the effectiveness of the model-based workstation, an experiment was conducted to compare system performance with a conventional operator workstation versus the model-based workstation. The conventional workstation consisted of three monitors and showed, in alpha-numeric form, hardware status and equipment and satellite support schedules. The conventional display had more than 150 display pages that the operator could query (Figure 4a).

Two monitors comprised the model-based workstation, one to support monitoring and fault detection, the other to support fault compensation (Figure 4b). The workstation design included qualitative icons and model-based windows. A faucet icon represented hardware status and data flow; the icon was qualitative and depicted the worst case for each equipment network supporting a satellite link. The faucet icon was hierarchical; if the operator wanted more detailed information, a display showing the configuration of the network and status of each equipment was available. The high-level mission icon supported monitoring; the more detailed representation of the equipment network supported fault detection. Fault compensation entailed the selective display of hardware and satellite schedule information. Schedule information was linked to a set of likely operator fault compensation activities derived from the OFM. For each activity the operator could ask for "help" to carry out the function. For example, if component RUP3 failed, the operator could say "Help Replace RUP3", and the model would search the hardware and satellite support schedules to identify a set of possible replacement components that were currently available and not scheduled to support another satellite for the time in question. For both the monitoring/fault detection task and the fault compensation task, the model provided the intelligence to enable the displays to adapt to changing operator and system requirements in real-time.

The experiment comparing the conventional versus model-based workstation demonstrated the effectiveness of the OFM-based design. The model-based workstation enabled operators to effectively handle real-time control with workload that quintupled normal Goddard workload. Figure 5 summarizes the experimental data.

Related Journal Papers

Mitchell, C. M. (1987). GT-MSOCC: A research domain for modeling human-computer interaction and aiding decision making in supervisory control systems. *IEEE Transactions on Systems, Man, and Cybernetics*, SMC-17, 553-570.

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Conference Presentations with Proceedings

Forren, M. C. and Mitchell, C. M. (1986) Multi-model interfaces in supervisory control. *Proceedings of the Human Factors Society 30th Annual Meeting*. Dayton, 317-321.

Saisi, D. L. and Mitchell, C. M. (1986). Model-based window display interfaces in real time supervisory control. *Proceedings of the 1986 IEEE International Conference on Systems, Man, and Cybernetics*, 885-889.
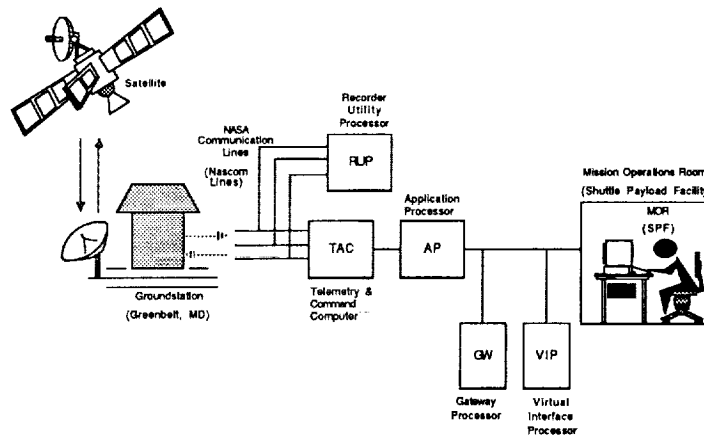
Jones, P. M., and Mitchell, C. M. (1987). Operator modeling: Conceptual and methodological distinctions. *Proceedings of the Human Factors Society 31st Annual Meeting*, 31-35.

Jones, P.M. and Mitchell, C. M. (1989). Operator models for supervisory control systems. *Proceedings of the Human Factors Society 33nd Annual Meeting*, 291-295.
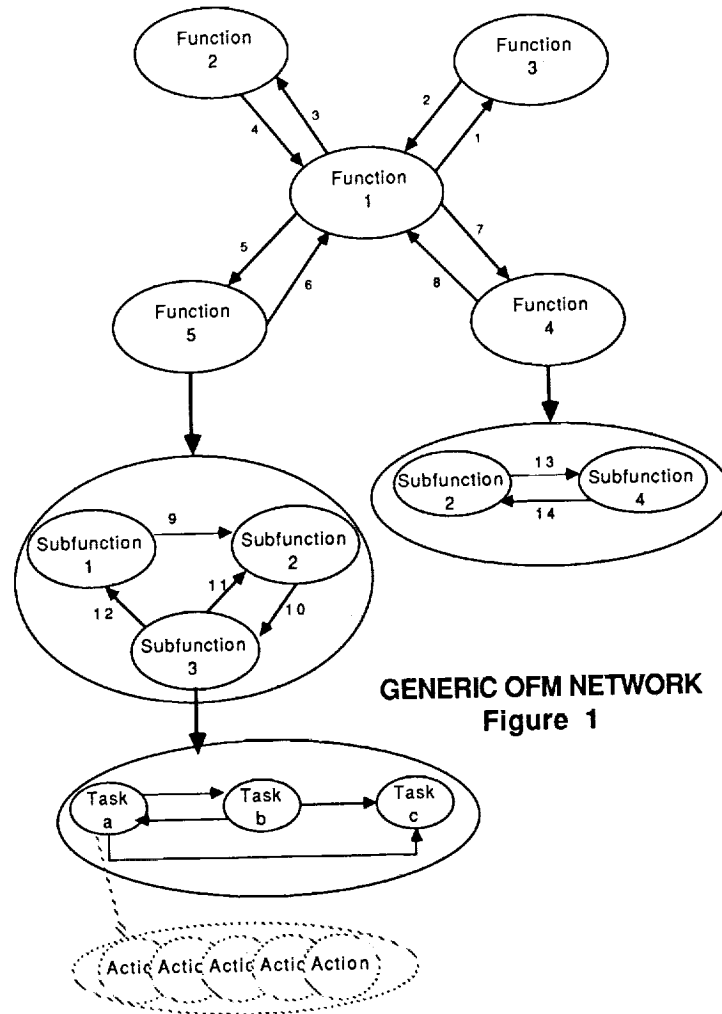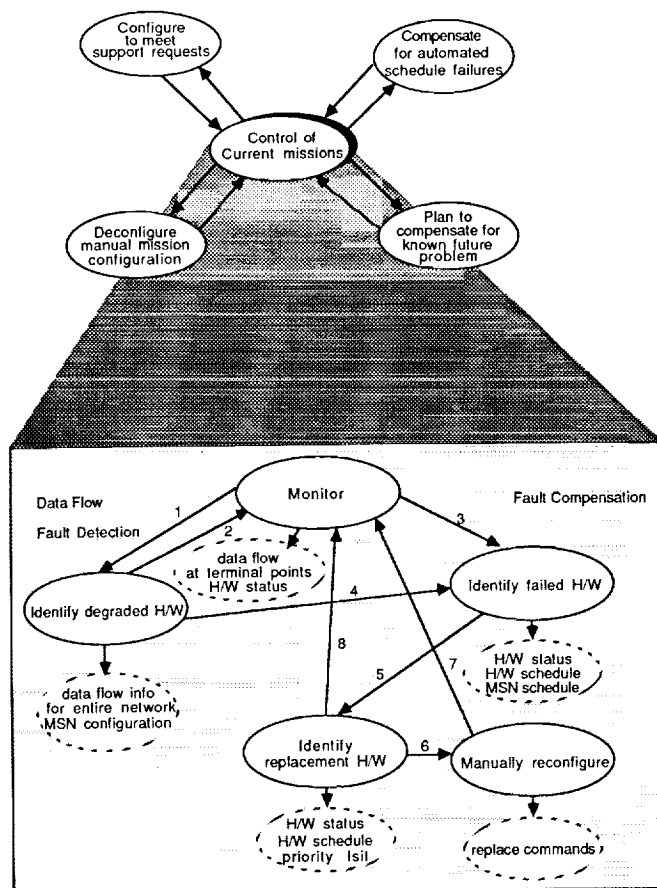
GENERIC OFM NETWORK
Figure 1

Multisatellite Operations Control Center
Figure 2

GT-MSOCC OFM
Figure 3

Measures	Model - based	Keyboard	Windows
Time to detect hardware failures	42.5s*	56.4s	88.0s*
Time to detect SW no flow	56.9s*	312.4s	369.4s
Time to detect SW decreased flow	71.2s*	398.9	438.9s
Time to detect high error count	206.0s*	356.7s	391.7s
Time to deconfigure	11.1s*	22.6s	28.0s
Time to compensate for automated schedule problems	46.5s	75.9s	82.9s
Number of operator-caused schedule conflicts	.16*	.70	.93

* indicates significance at p < 0.01

Mean Scores Per Session
Figure 5
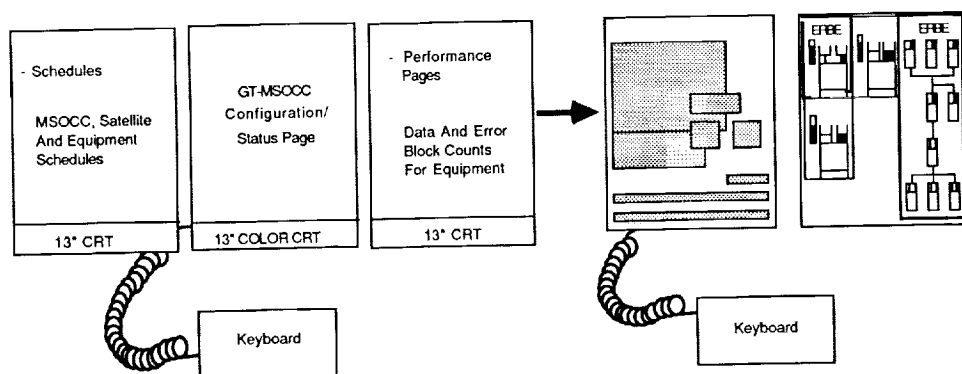
Conventional Vs. Model-Based(OFM) Workstation
Figure 4