RAPID PROTOTYPING AS AN ACQUISITION STRATEGY OF THE AIR FORCE SATELLITE CONTROL NETWORK

L.K. Whipple T.J. Hoida
USAF Space Systems Division
Los Angeles Air Force Base, CA 90009-2960

ABSTRACT

The Air Force Satellite Control Network (AFSCN) processes on the order of a thousand separate requirements each year to enhance Network capability to meet the support needs of various satellites. Many of these individual requirements are translated into modifications or additions to the network assets. Rapid Prototyping has been utilized successfully for complex and urgent developments to meet many of these requirements. Rapid Prototyping has also been used for requirements definition and for defining man/machine interfaces. Through Rapid Prototyping, the AFSCN has successfully developed applications using new technology and has improved the process of defining requirements for operational satellite support systems. Rapid prototyping is proving to be an effective alternative to the traditional system acquisition process.

1. INTRODUCTION

The Satellite Control and Data Handling System Program Office (SPO) is responsible for engineering, development, and integration support to the worldwide assets of the Air Force Satellite Control Network (AFSCN). The Network operates around the clock, 365 days a year, providing various command and control services for most military satellites and for a selected group of non-military space programs. Many individual development requirements levied each year are implemented through relatively small efforts, but a significant number (approximately 10%) are translated into more extensive modifications to one or more of the Network's assets. It is a characteristic of these efforts that they are implemented on an operational system and cannot interfere with critical mission support activities.

The AFSCN is required to support a constantly-increasing satellite inventory. At the same, the experience and numbers of Mission Control Complex (MCC) operators are decreasing. Consequently, future satellite operators must have the effective tools to support more satellite passes, to process greater volumes of telemetry data, and to analyze more complex satellite systems. This trend is creating a need to develop more complex, "user friendly," systems more quickly.

The paper describes AFSCN applications of the rapid prototyping approach in the network's unique operational environment. Problems that yield best to the rapid prototyping approach are discussed, and examples of past successful prototypes are presented.

2. PROBLEM: COMPLEX REQUIREMENTS

The AFSCN worldwide assets include Mission Control Complexes, Range Control Centers, Remote Tracking Stations and the Network communications systems. These facilities support the daily operation of close to 80 communication, navigation, weather, surveillance, and scientific satellites. DoD satellite systems have many missions and within each satellite family are a variety of configurations. Additionally, the AFSCN assets are used to support sub-orbital tests and commercial launches. The variety of space assets requires a large number of support assets. Development of advanced computer workstations with automated data processing, expert systems applications, multimedia, and improved operator computer interfaces for satellite support activities are increasingly common throughout the satellite operations community. Some typical characteristics of AFSCN systems requirements are: a) an unclear or incomplete statement of requirements, b) developments encompassing new technologies, c) man-in-the-loop systems that require a heavy user interface, necessitating a high degree of experimentation to define optimum configurations for user control, input and data display, d) systems may have short acquisition lead time, e) the evolution of the AFSCN inherently requires evolutionary development of its components. To assure timely deployment of the most effective advanced systems, the AFSCN requires an acquisition process which promotes iterative definition and evaluation of requirements and a great deal of user involvement.

3. SOLUTION: RAPID PROTOTYPING

Prototyping is used to create either a model from which a system is copied or a set of technical parameters for incorporation into specifications. Prototyping systems during the acquisition process provides the following advantages:

- Provides a better definition of requirements
  - Avoids misunderstanding of requirements
  - Avoids over- or under-specification of requirements

- Assists in understanding operability and interface issues

- Helps to determine a realistic cost analysis
  - Defines development timelines
  - Assesses cost of workstation components and software development

- Provides a mechanism to develop and evaluate state of the art technology
- Provides a mechanism to develop and evaluate new standards
- Provides “insurance” - Prototype cost is 2-10 percent of the “real-thing”

Rapid Prototyping (RP) is an iterative method for developing prototypes of components, subsystems, or complete computerized systems, in which the time between successive versions of the prototype is short. RP integrates analysis, design and construction, and defines requirements during the process. RP produces a working model more quickly than conventional computer systems development approaches. The prototype focuses on communication between developers and users. RP lends itself to problems which are not well understood, and for developing user-system interfaces. The ill-structured system development problems that yield best to RP include: a) decision support systems in areas where system knowledge changes rapidly, b) systems whose users need to assess and organize data in ways not foreseen when the system is created, c) instructional or experimental systems, and d) user-system interfaces [1]. In the AFSCN, satellite operator workstations become prime candidates for RP. The two systems discussed here, ASTRO and ASW, represent some successes the Network has had in employing this methodology. ASTRO is a system which automates the time intensive, manual process of AFSCN resource scheduling and communication of schedule data. ASW is an operator support environment which provides tools for technical information access and management, and telemetry analysis. These prototypes are leading to the acquisition of operational systems.

3.1 ASTRO

The Automated Scheduling Tools for Range Operations (ASTRO) project was developed to explore the electronic representation of paper acquisition scheduling charts, and to design new approaches to the human computer interface (HCI) and automation of scheduling regular satellite contacts with the global network of satellite tracking and control facilities. On a given day, the nearly 1600 satellite network support events must be interpreted and used to make decisions that can be critical to the survival of our space missions. ASTRO is a semi-automated network scheduling system incorporating a synergystic HCI consisting of a Compaq 386/25 computer, Greyhawk 22" by 34" large screen color display, Verbex 5060 voice input/output system, Science Industries GP-8 Sonic Pen pointing device, Elographics touchscreen overlay on a color CRT, and a standard keyboard shown on Figure 1. ASTRO replaces a single paper chart, 36" wide by 144" long, with extremely high information density. Three types of schedules are maintained: seven day, 24 hour, and real-time. The engineering challenge of representing such a data intensive display in a useable format, while maintaining supervisory control of the scheduling task, was met by designing an optimized HCI for ASTRO.

The effective HCI was developed by involving the user early in the design phase. Instead of copious reports, documentation and design reviews, system demonstrations were given to representative users at frequent intervals during the development. Forty demonstrations were given to 320 people with space operations and scheduling background, over a three year period, to solicit suggestions and to guide the development process. Following this, ASTRO was installed at two major control nodes of the AFSCN: Falcon Air Force Base (FAFB) in Colorado Springs, Colorado, and Onizuka Air Force Base (OAFB) in Sunnyvale, California, where a four month extensive functional evaluation study was conducted, with an extremely favorable report. Areas evaluated were: Functional Requirements (Information Display, Operator Capabilities, Scheduling Functions), Performance Requirements (Display, Functional), Human Factors (Workspace, Displays, Pointing Devices, Keyboard, and Voice Input), plus an overall system rating. Later, ASTRO was given two weeks of full operational testing, and performed very well. Recent personnel reductions in Air Force Space Command have produced an urgent requirement to activate this research and development system, to reap benefits of increased efficiency of the electronic acquisition chart. The effectiveness of this prototyping activity is demonstrated by the readiness of the prototype to be activated on very short notice.

3.2 ADVANCED SATELLITE WORKSTATION

The Advanced Satellite Workstation (ASW) was developed to improve the definition of requirements for automated satellite support systems and to gain technology transition experience though evaluation in an operational environment. The ASW is a prototype integrated data processing and display environment. The central mission of ASW is to provide an intelligent decision support and training environment for operators and analysts of complex systems such as satellites. There have been other workstations developed which incorporate graphical telemetry displays and expert systems. ASW is a considerably broader look at intelligent data access and integrated toolsets. The ASW hardware consists of a Sun 3/470 workstation connected to a Apple Macintosh IIcx via ethernet network, Sony Laser Disk System, Optical Storage System, and DEC PDP Telemetry Data Interface shown in Figure 2. The Sun provides the operators primary interface to the telemetry data and analysis tools including an expert system for anomaly analysis, automated pass planner for scheduling vehicle support activities, and an architectural modeler for hierarchical simulation and analysis of satellite vehicle subsystems. The Macintosh provides access to multimedia-based information systems that provide intuitive and easy access to Orbit Operations Handbooks and other relevant support documentation (text, graphics, and animation) on the CD ROM and Laser Disk. The Sun-based data analysis architecture integrates user modifiable telemetry display systems and expert systems for background data analysis. It also provides an interface to the multimedia system. The Macintosh multimedia workstation is connected via ethernet and is automatically oriented to the proper documentation page based on analysis being performed on the Sun workstation.

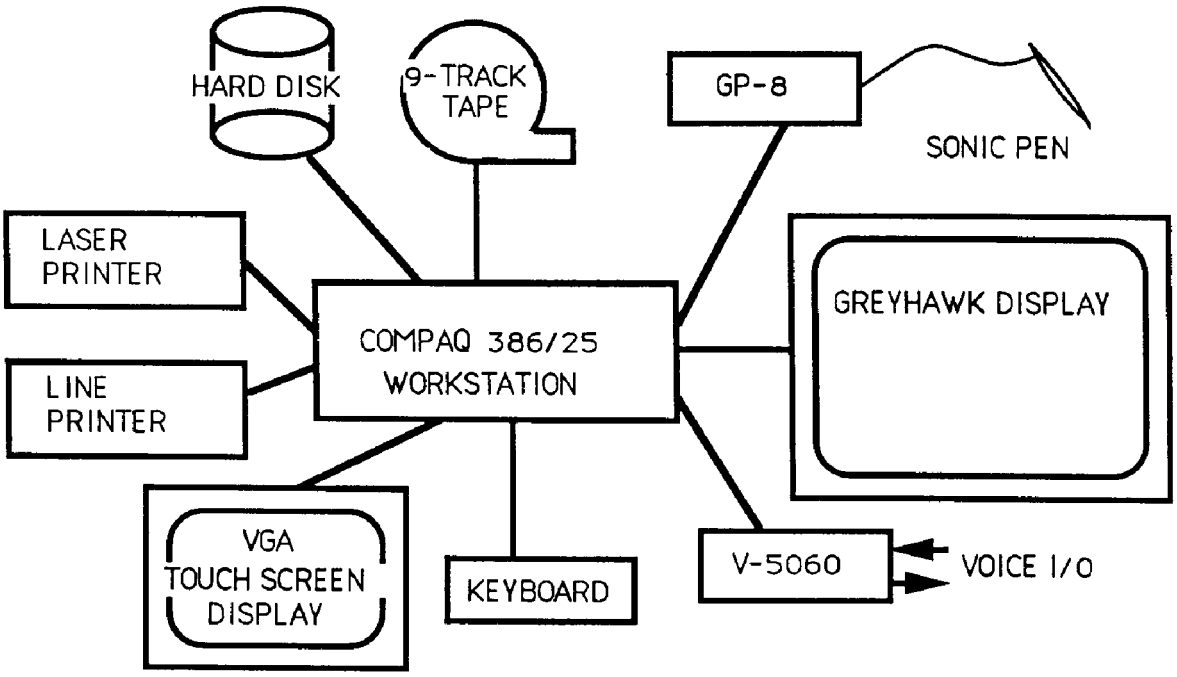

FIGURE 1. ASTRO BLOCK DIAGRAM

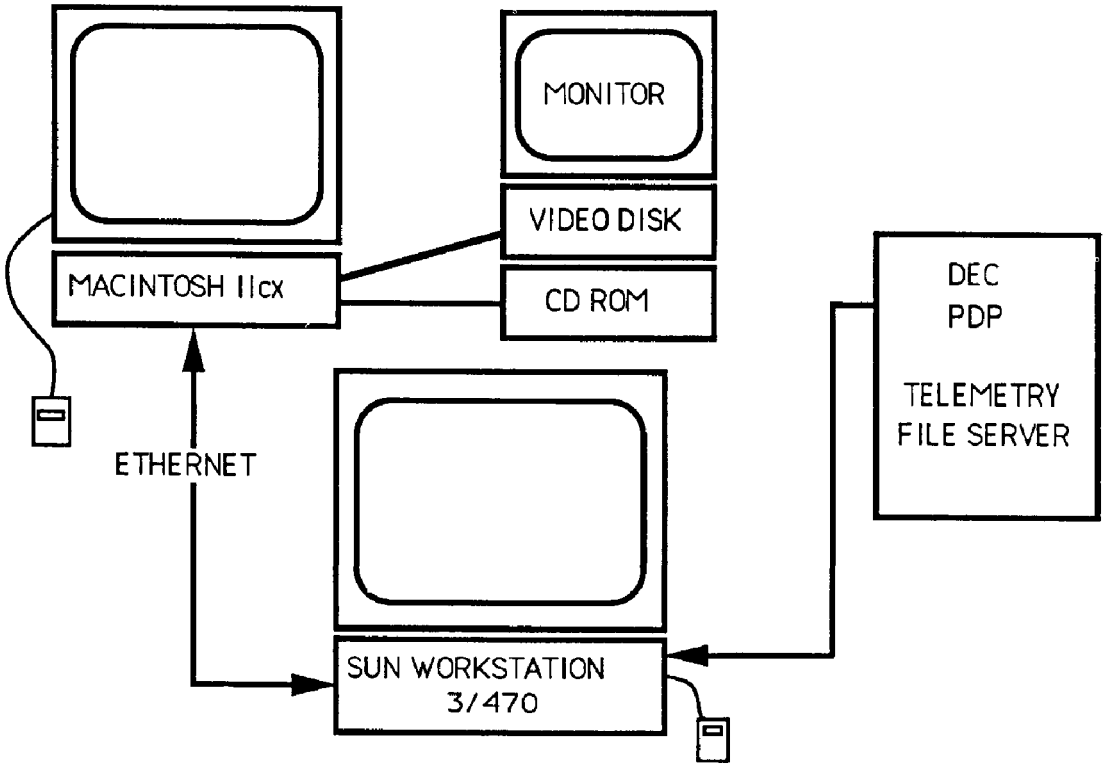

FIGURE 2. ASW BLOCK DIAGRAM

Operational experience with the ASW prototype is providing a method of exploring operational questions relating to satellite support activities. The following areas are being explored as part of the ASW prototype activity:

a) Utility of Automation and General Design: Using on-line documentation, automated display and analysis of telemetry, automated Pass Planning and scheduling, can the operator work-load be reduced, can errors be reduced, can automation save time, can operations costs be reduced? Which operators benefit from automation? What training is required to effectively use the system? Can the workstation system be easily modified for customization for each user? Are messages displayed clearly and understandably? What is the best configuration of control buttons, time and status displays? What "Icons" are most descriptive and unambiguous?

b) Expert Systems (E.S.) Applications: What areas of satellite support are best suited toward implementation of E.S.? Can experience on a specific subsystem for one program improve efficiency of development of another E.S. for a different program?

c) Telemetry Processing and Display Systems: How can the clarity and control efficiency of the TLM display system be maximized? Is graphic display of TLM an improvement over numeric display of measureands? What are the most effective user interfaces and control mechanisms for a TLM display and workstation? What are the performance tradeoffs of batch vs. local TLM processing?

d) Hypermedia and Multimedia Systems: Can an interface be developed that it is intuitive to all users of the system? Does having access to as-built photographs of the satellite vehicle assist the operator in normal operations or during anomaly resolution procedures? How should multimedia data be structured to provide scalable systems with efficient user and programmed data access and query capabilities? What procedures will streamline development of electronic multimedia data systems?

e) Modeling and Visualization: What modeling and simulation techniques can be used most effectively in an operational environment? How can advanced visualization techniques be used in conjunction with modeling to improve operator understanding?

The development of ASW was tailored to meet the operational requirements of a scientific program, following many demonstrations. ASW has elicited positive comments from many satellite program offices and operators at both Air Force Systems Command at Onizuka AFB, and Air Force Space Command at Falcon AFB. ASW-like environments are being developed for other satellite programs at this time. [3]

4. CONCLUSIONS

Rapid prototyping methodologies are proving to be successful in meeting the challenges of the AFSCN acquisition process, helping to develop computer technology, and to define and evaluate unique and complex system requirements. The ASTRO and ASW satellite operations support tools show Rapid Prototyping with extensive user interaction has been instrumental in the creation of useful products and acceptance of new technology.

ACKNOWLEDGEMENTS

This material is based upon work supported by the USAF Space Systems Division under various contracts. The authors would like to express their appreciation to the following: John List and his associates at Unisys for their efforts developing ASTRO; to Dr. M.J. Hamilton and his staff at The Aerospace Corporation for their efforts developing ASW; and to the project officers of the AFSCN and their counterparts at the Aerospace Corporation for their assistance in preparing this paper.

REFERENCES

[1] ASTM (American Standards for Testing and Materials) E 1340-90, “Standard Guide for Rapid Prototyping of Computer Systems,” Philidelphia, PA, 1990

[2] C.H.G. Wright and D.J. Aitken, “A Human Factors Approach to Range Scheduling for Satellite Control,” USAF Space Systems Division, Los Angeles Air Force Base, Los Angeles, CA, 1990

[3] M.J. Hamilton and S.A. Sutton, “Advanced Satellite Workstation”, Proceedings 1990 International Telemetering Conference. San Diego. CA. October 1990