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GRTS Operations Monitor/Control System

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ABSTRACT

An Operations Monitor/Control System (OMCS) was developed to support remote ground station equipment. The ground station controls a Tracking Data Relay Satellite (TDRS) relocated to provide coverage in the tracking system's zone of exclusion. The relocated satellite significantly improved data recovery for the Gamma Ray Observatory mission. The OMCS implementation, performed in less than 11 months, was mission critical to TDRS drift operations. Extensive use of Commercial Off The Shelf (COTS) hardware and software products contributed to implementation success. The OMCS has been operational for over 9 months with no significant problems. This paper will share our experiences in OMCS development and integration.

INTRODUCTION

An increase in tape recorder error rates onboard the Gamma Ray Observatory (GRO) spacecraft necessitated alternative approaches to data gathering for the GRO mission. The project resorted to collecting science data using full period, in view, Tracking and Data Relay Satellite (TDRS) return link services. The TDRS system could not track the GRO spacecraft in the zone of exclusion. In addition, view periods are frequently restricted by spacecraft body blockages. Using the two available spacecraft, TDRS West and TDRS East, the project could retrieve only 50% of its science data.

To increase GRO viewing opportunities, NASA decided to implement a Southern Hemisphere TDRS ground station and move a TDRS over the Indian Ocean. The GRO Remote Terminal Subsystem (GRTS) Operations Monitor/Control System (OMCS) was developed in response to the requirement to provide means to remotely control and monitor the Southern Hemisphere ground station located at the Canberra Deep Space Communications Complex (CDSCC) at Tidbinbilla in the Australian Capital Territory.

The driving requirements for the OMCS were:

- Equipment monitor and control - The main function of the OMCS is to monitor the remote ground station equipment and provide status updates within 5 seconds. It was also required to control all critical functions for the ground station equipment for configuration and fault detection/failure.

- Provide operator workstations at geographically diverse locations - The main TDRS system control center is located in White Sands, New Mexico. It was decided that the TDRS satellite controllers would operate the station in Australia remotely from the United States with CDSCC personnel providing on site operations support for the first year. The White Sands locations was designated the Extended TDRS Ground Terminal (ETGT) and the CDSCC location was designated the Remote Ground Relay Terminal (RGRT).

- Minimize operator workloads - The OMCS should provide a simple graphical user interface to reduce the amount of operator keyboard type-ins. It should also provide preloaded configurations to allow one button operation to reduce operator workload since the operator would also be the TDRS satellite controller with other operational responsibilities.

- State vector to the antenna subsystems - The OMCS was required to provide a method of entry, verification, and transmission of the TDRS and GRO state vectors to antenna control computers at RGRT since there was no other method of obtaining the vectors.

The factors that would act as constraints were:

- Multiple interfaces - Most of the equipment purchased for the ground station had never been integrated by ATSC before. About 20 new interfaces had to be documented, developed, and tested.

- Real time integration - Due to the intense development schedule, equipment was to be shipped directly to Australia and integrated at the site.

In summary the OMCS had to be implemented in less that 7 months from project start using equipment to be dropped shipped to its final destination. Quite a challenge.

DEVELOPMENT APPROACH

Meeting the very aggressive schedule required a new approach to developing the system. The decision was made to use COTS products to the maximum extent possible. Several COTS approaches were investigated, but Allied Signal Technical Services Company (ATSC) had implemented a monitor and control system for another customer using an industrial control system. A trade study of current industrial control systems was currently being performed for another project and the results were used to aid in the selection. The advantages of most industrial control systems is a well defined man-machine interface (MMI) and configuration simplicity, i.e. it does not require programming, but uses a database to support the equipment interfaces. The real advantage of an industrial control system was that it allowed rapid development which was key to the success of the OMCS implementation.

The product chosen was the TIS4000 system developed by Tate Integrated Systems located in Owings Mills, MD. The TIS4000 is a distributed data acquisition and control system. The TIS4000 system is database driven and has been designed with a flexible architecture and a modular, distributed construction. This allows it to be configured for a wide range of applications. The basic architecture is based on a "client-server" structure with Motorola 68000 series microcomputers performing the real-time control and processing operations and RISC workstations providing the MMI functions. All of these components are connected via high-speed LANs using TCP/IP networking. The advanced workstation MMI uses the UNIX operating system and the X-Windows environment. The MMI provides a full graphical operating environment for operators, as well as a programming and applications development environment for engineers.

The TIS4000 is database driven, i.e. parameters to be monitored or controlled are entered into a database. The database is downloaded into real-time computers, which perform all parameter gathering, limit checking, and alarm notification. The operator displays are created on the workstations using a graphics editor and then connected to the real-time parameters. This allows parallel development of the database and displays, reducing development time. Each equipment interface can be verified as it is completed and changes easily made. Many of the commercial systems evaluated were based on this type of architecture.

OMCS HARDWARE

Figure 1 provides an overview of the system architecture. At the CDSCC, two workstations were placed at Deep Space Station 46 (DSS46), where the equipment is located and one at Signal Processing Center 40 (SPC40), the main operations area. Two workstations were placed at ETGT, one in the TIC and one in the TOC. An additional workstation was located in the GSFC Network Control Center (NCC) for state vector entry, user services, and administrative functions. Two real-time computers referred to as Input Output Controllers (IOCs) were located in DSS46 and interfaced to the ground station equipment. The operational entities were connected locally by an Ethernet local area network and standard 9.6 kbps lines were used to interconnect the geographically diverse locations. Each workstation can see all of the data provided by the IOCs.

The workstations are standard SUN Sparc IPX workstations with 32MB of memory, an internal 425MB disk and 19" color monitor. During implementation an additional 425MB external hard disk was added. Hewlett Packard LaserJet IV printers were provided. Standard Motorola VME computer components including a 68030 CPU with 16MB of memory and four communications interface cards configured to meet the requirement of 16 serial lines on each. S band Telemetry, Tracking and Control (TTC) functions were allocated to one of the real-time computers. Ku band user services were allocated to the other real-time computers. This arrangement provided some fault tolerance. An Ethernet was installed in Australia and standard bridge/routers are used to extend the LAN to White Sands, NM and Washington, DC.

Figure 2 shows the interfaces to the various RGRT equipment.

OMCS SOFTWARE

Figure 3 illustrates the OMCS software architecture. The COTS products are 1.1, the real-time database processor; 1.2 and 1.3, TCP communications stacks; 1.4, the display manager; 1.5, the display editor; 1.9 and 1.10, device drivers; and 1.12, dBase IV used for building the real-time database and generating reports. The ATSC developed items are 1.6, the state vector entry and transfer; 1.7 and 1.8, configuration macros; 1.13 and 1.15; configuration processes; and 1.14; the checkpoint process.

The TIS4000 vendor developed, under subcontract, the serial driver required to interface the ground station equipment. Due to the schedule this appeared to be the most expeditious method of completing a critical portion of the work.

ATSC engineers working with NASA engineers developed the databases and graphics based on interface information provided by the vendors. Personnel from White Sands provided operations input to the process. Some pieces of equipment were staged at the ATSC facility before shipment to Australia. When the OMCS was shipped in June 1993 confidence was high that successful on site integration would be possible. Two ATSC engineers spend three months on site in Australia completing integration. Additional testing was carried out remotely using the workstation in the NCC, reducing travel

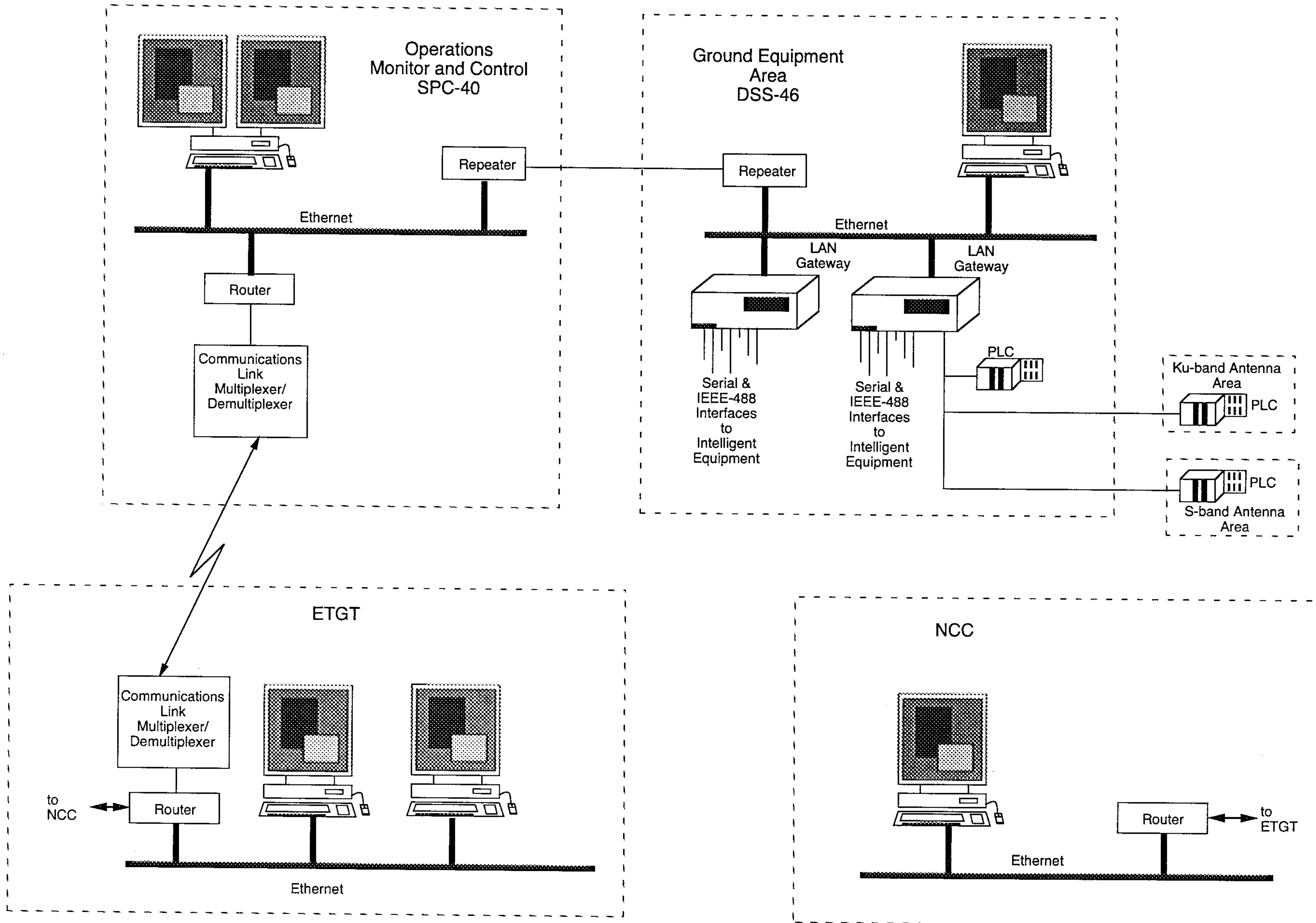

Figure 1: OMCS Systems Architecture

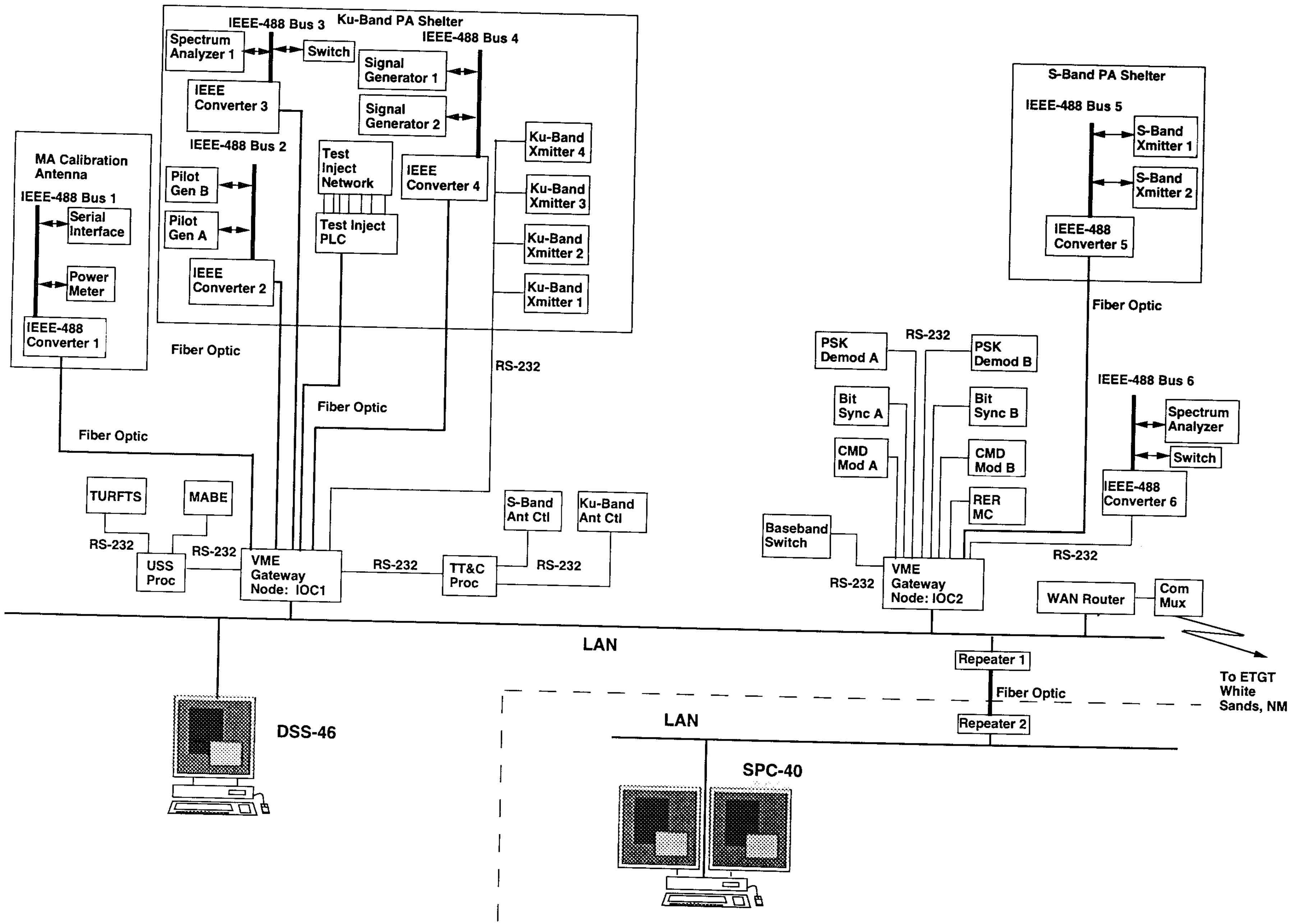

Figure 2: OMCS Equipment Interfaces

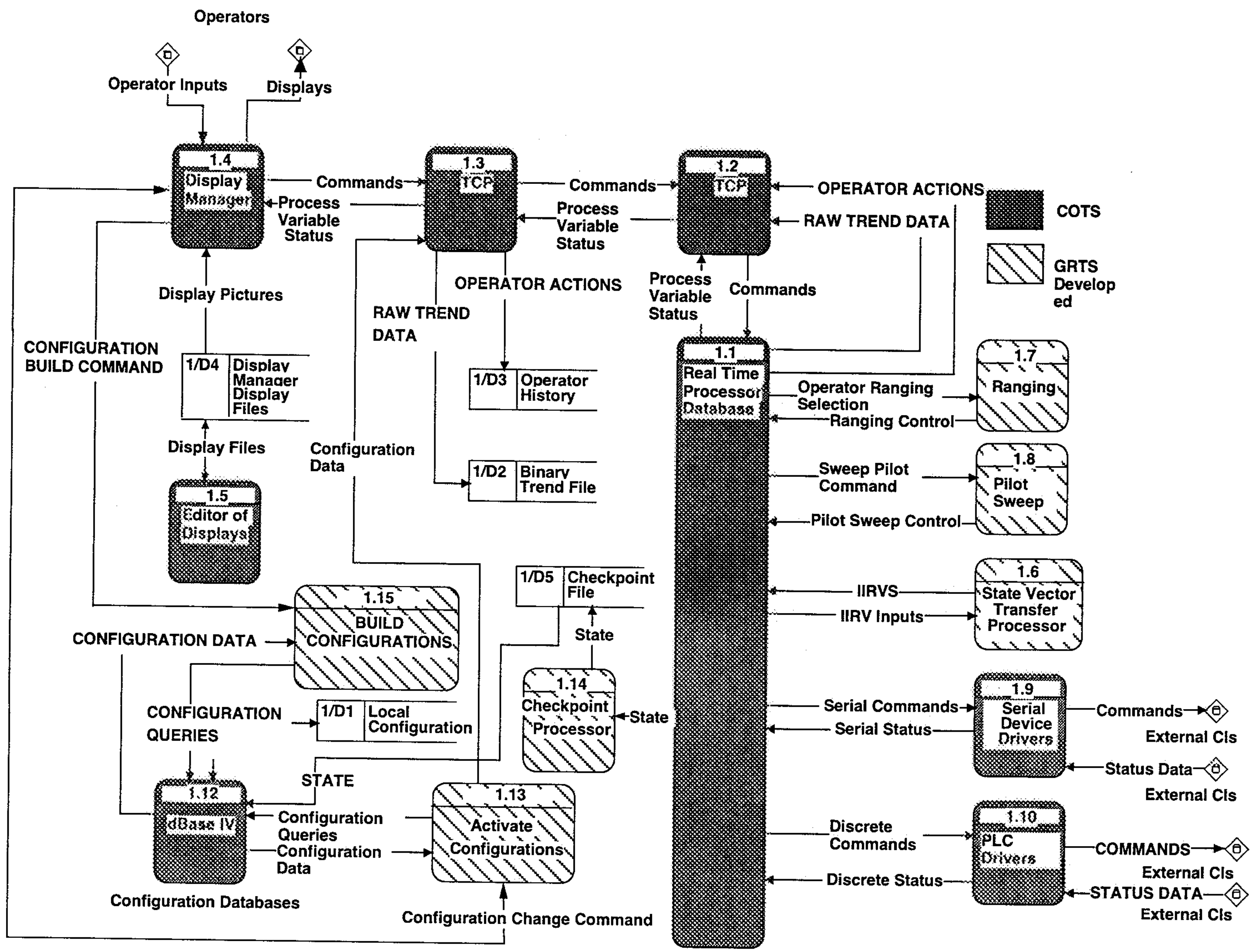

Figure - 3: OMCS Software Context Diagram

requirements. Currently, software upgrades are performed remotely from the NCC workstation.

OMCS CAPABILITIES

The OMCS presents operators with a window into the station. The system works by a point and click method, with operator keyboard entries reduced to the absolute minimum. Normal operations can be performed from a single station overview screen, but the operator has the ability to move to lower levels of detail on any specific piece of equipment if the need arises. Most detailed equipment screens mimic the actual front panel of the equipment, so there is no need for operator retraining on the equipment. If a user can operate the equipment from the front panel, he can operate the equipment from the OMCS.

The OMCS is not a fully automated system, nor is it schedule driven. It requires an operator to initiate and approve activities. A decision was made early in the development program not to attempt full automation until more operational experience was acquired. Therefore, the operator is required to acknowledge alarms and take corrective measures, configure for TTC by selecting active and backup strings, start and stop the uplink carrier, start and stop ranging, and switch in redundant equipment if necessary. The operator also must configure user services and perform Multiple Access (MA) system calibrations. These operator interactions are not burdensome for such a small TDRS ground station .

Automatic configuration sequences referred to as "macros" were developed to reduce operator workload. All normal configurations are performed by the use of "macros". These are predefined routines that set the station up in a predetermined configuration. The use of the macros allows one-button operation. Typically a macro does nothing more than duplicate all steps an operator would perform if configuring the system manually. It checks the appropriate equipment status and initiates control actions in the correct sequence. The macro informs the operator if a piece of equipment is not available, incorrectly configured, or faulted. The operator can then take the appropriate action.

Since the major configuration functions have been "automated" in the form of macros, this provides the first steps towards higher levels of automation if desired. Nothing in the current implementation of the OMCS precludes expanding to full automation or even adding an expert system helper.

CONCLUSIONS

The implementation of the OMCS was a success, but not a trivial undertaking. Many problems had to be conquered. Some caused by ground station equipment, some caused by the COTS software chosen, and some by the implementers understanding of the problems.

This effort represents the second in which a COTS industrial control package was used. The OMCS system implementation was much easier and successful because ATSC has refined the requirements for a COTS system from the previous project. The next project will be easier and less costly to implement because of the experience gained on GRTS.