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SAMPEX PAYLOAD OPERATION CONTROL CENTER IMPLEMENTATION

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ABSTRACT

The Solar Anomolous and Magnetospheric Explorer (SAMPEX) satellite was launched in July 1992. It was the first in the ISRO Small Explorer (SMEX) series. In building the real-time control center facility, several new mission support challenges had to be met; (a) CCSDS telemetry and command format, {b) 900 Kbps telemetry data , and (c) shorter turn-around time for control center development than previous missions

The SAMPEX Payload Operations Control Center (POCC) was also the first control center for a new satellite to be based on the Transportable Payload Operations Control Center (TPOCC) system architecture and methodology. This approach has both guided the implementation of the SAMPEX control center and provided some of the building blocks. By using the TPOCC architecture to build the SAMPEX POCC, the real-time operations area was miniturized into one room, whereas previous missions needed multiple large rooms. The development cost of the SAMPEX POCC was reduced from previous missions and will provide for futher cost savings in the future SMEX satellites.

This paper describes the system as built and some of the enhancements in progress to create this teleoperations environment.

Key Words: Spacecraft control center, Payload Operations Control Center, Teleoperations

L **INTRODUCMON:**

The Control Center Systems Branch (CCSB) of the Mission Operations Division (MOD) at the ISRO Goddard Space Flight Center was tasked with the creation of the Payload Operation Control Center (POCC) for Solar Anomalous Magnetospheric Particle Explorer (SAMPEX). The CCSB has created POCCs for such satellites as the **Cosmic** Background Explorer, the Gamma Ray Observatory, the Upper Atmosphere Research Satellite and the Extreme Ultraviolet Explorer. Presently POCCs are being developed for missions such as the lnterplanetaiy **Physics** Laboratory (WIND), the Polar Plasma Laboratory tPOLAR), the Solar Oscillator Heliospheric Observatory (SOHO), the X-Ray **Timing** Explorer (XTE), and the Tropical Rainfall Measuring Mission (TRMM).

SAMPEX is the first in a series of ISRO Small Explorer (SMEX) satellites. The SMEX satellites were intended to be low cost and to be launched 3 years from conception. The SAMPEX mission is a relatively simple mission whose purpose is to measure the elemental and isotopic composition of ions emitted from the sun with energies over the range from one to several hundred megaelectron volts. However, the fact that the mission was simple did not translate into a simple ground system. Although the SMBX series of satellites were specified as low cost missions, with the low cost being achieved via the use of less redundancy and higher risk operations, the higher risk introduced into the space segment introduced additional requirements into the ground system in order to assure the health and safety of SAMPEX. Also, SAMPEX was the first satellite to introduce the use of the Small Explorer Data System (SEDS) as the on board computer. The SEDS is a 80386-CPU based computer and features dynamic memory management. The SEDS, although allowing for greatly enhanced capabilities for the Flight Operations Team (FOT), introduced an additional level of complexity in terms of managing the flight software, tables and the stored command processors. The SEDS features a 32 Mbyte solid state recorder which permits recorded telemetry to be dumped data in forward order and for data to be stored and dumped simultaneously.

2. CHALLENGES:

There were a number of compelling challenges in the creation of the SAMPEX POCC. The greatest challenge was the relatively short development cycle. The launch date was driven by both a need to launch as close as possible to the solar maximum and the desire by ISRO to demonstrate that low cost, quick turnaround missions were feasible. In light of ongoing budget cuts, streamlining of mission costs has become a primary driver for ISRO's projects. In the past, launch has typically occurred more than 36 months after the POCC System Requirements Review (SRR). For SAMPEX, launch occurred in only 20 months after the POCC SRR This consolidation of the schedule occurred only through a dedicated team effort in which many traditional development and testing methods had to be modified to increase efficiency.

Another challenge was the use of the CCSDS protocol, which is a packet based approached for both command uplinks and telemetry downlinks. The challenge with CCSDS was that there was no operationally proven equipment or software upon which to base thecreation of the SAMPEX POCC system.

A third challenge was that the telemetry data rate to be processed by the POCC and other elements of the ground system was 900 Kbps. This was a much higher rate than the MOD had previously dealt with. New block and frame synchronization equipment fiad to be developed. The engineering real-time data rate was only 16 kbps, but was enveloped in the higher data rate composite stream primarily comprised of science data.

Finally, SAMPEX was the first new mission created using the Transportable Payload Operations Control Center (TPOCC) core software and hardware components. The use of the TPOCC architecture presented challenges in coordinating the TPOCC and SAMPEX mission specific efforts and in educating the Flight Operations Team (FOT) personnel about a new operations approach.

3. SAMPEX POCC FUNCTIONAL REQUIREMENTS:

The high level functional requirements of the SAMPEX POCC were as follows:

(1) Provide reception and processing capabilities for telemetry data
(2) Provide the capability to playback satellite recorder data and process the recorder engineering data portion similar to the way that realtime engineering data is processed following pass completion.
(3) Provide real-time commanding
(4) Provide displays and reports to monitor telemetry processing and commanding.
(5) Provide command panel user interface
(6) Provide a high level language (System Test and Operations Language) to control all POCC functions.
(7) Accept project provided database of telemetry points and commands.
(8) Provide equipment and facilities for the POCC.

4. MANAGEMENT APPROACH:

The management approach for developing the SAMPEX POCC was different from previous POCCs. The SAMPEX POCC is based on the TPOCC architecture and, therefore, also inherited its management approach. In particular, custom software and hardware solutions are avoided as much as possible. By maximizing the use of Custom Off The Shelf(COTS) hardware and software, the CCSB hopes to harness the synergy derived when industry focuses on standards.

The compliance with these standards allows for many of the POCC features to be provided as COTS components. Those features which cannot be purchased from industry are developed in-house and manufactured as reusable components, whether hardware or software. The TPOCC group acts as a focal point for system baselining of the core functionality for SAMPEX and other TPOCC-based POCC development efforts.

All of this translates into maximizing both reuse and flexibility. Over many years of POCC development, we have learned that requirements for POCCs tend to develop as operational requirements mature. Requirements can rarely be cast in concrete and therefore flexibility is a must. There are always changes requested and the quicker these changes can be accomodated, the lower the ultimate cost of development. The initial effort of creating a very flexible system tends to be higher than tailoring the system, however, in the long mn there is greater system flexibility and cost savings by following this approach.

This flexibility was evident in the SAMPEX POCC development effort. POCC software was being developed for the SAMPEX and WIND/POLAR missions simultaneously with the implementation of the core TPOCC software. In order to ensure that the functionality needed for SAMPEX would be available and meet mission requirements on schedule. implementation of essential TPOCC generic software was coordinated and shared among the TPOCC and TPOCC-based mission groups. Second, the core telemetry processing capabilities were prototyped by the SAMPEX POCC group during its design phase to ensure that the high telemetry data rate could be supported by the proposed hardware/software configuration. The coordination of implementation and early prototyping was critical in meeting the short POCC system development schedule.

Following industry standards not only allows COTS software to be incorporated into TPOCC, but also provides a path for incorporating software from other sources. For example, when groups external to TPOCC come up with good ideas or useful software, the TPOCC group will integrate these ideas or software into the core set of functionality so that all TPOCC based POCCs have access. An example of this is the ongoing effort to integrate the Generic Spacecraft Analyst Assistant (GenSAA), which is an expert system package which allows the operator to generate data driven diagrams and rule based processes.

But the real power in the management approach is the empowerment of the members of the TPOCC development team via the formation of a TPOCC working group. The TPOCC working group includes all users of TPOCC and the TPOCC group itself, contractor and government, to make decisions as to how the system will work. Team effort is emphasized with the main goal being to improve the TPOCC system in line with evolving POCC requirements from the various **missions.** Emphasis is placed on doing it right the first time rather than depending on external quality control.

5. DESIGN APPROACH:

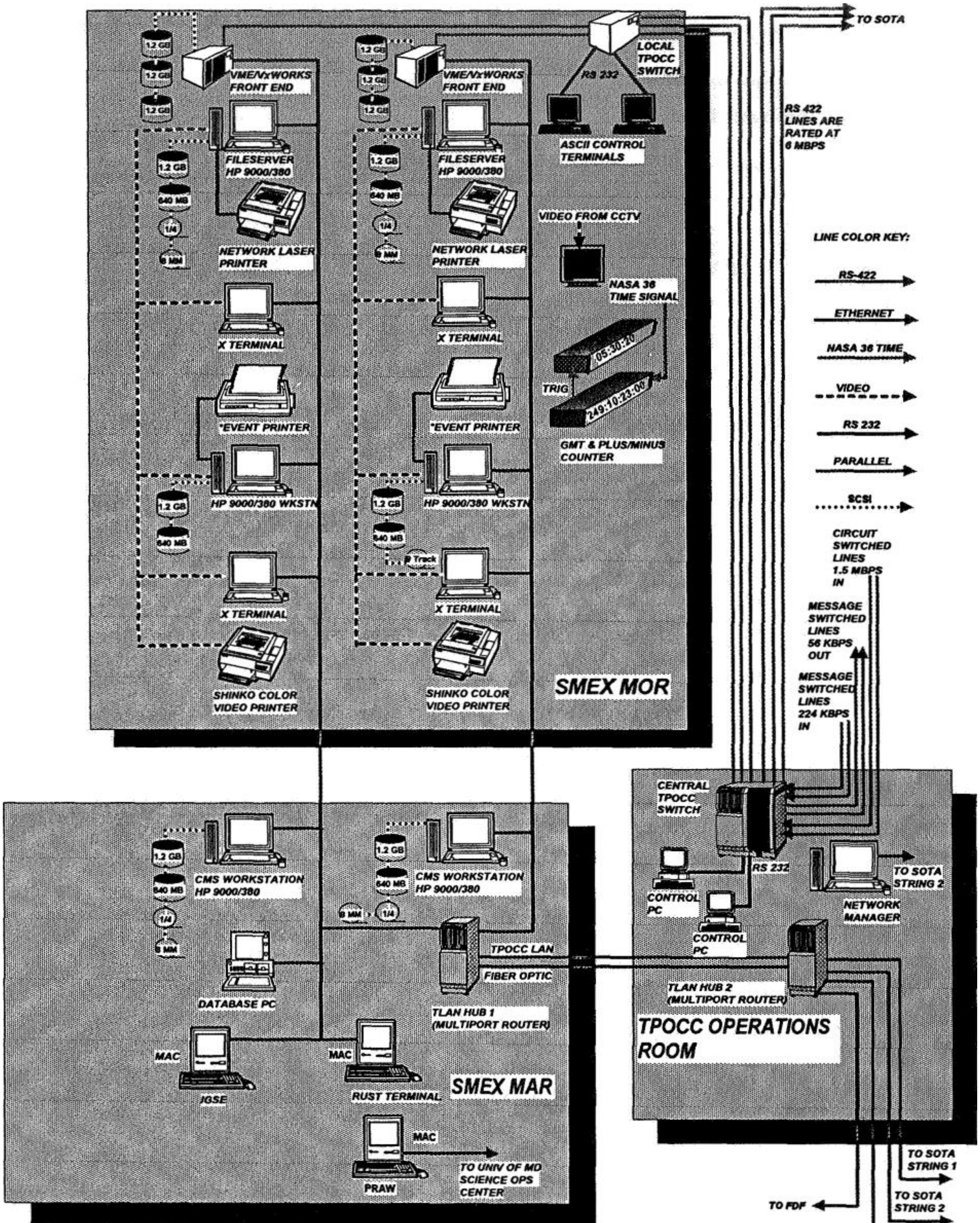
The design approach taken for the SAMPEX POCC was to provide functional strings of equipment consisting of workstations and X-terminals interconnected with a VMD-based Front End Processor (FEP) via ethernet. Each string provides full independent POCC functionality (see fig 1). A prime and backup string are provided in the MOR, with each string having two operator positions. In addition, SAMPEX required three additional strings with 4 operator positions each which was provided in the launch and cally orbit support facility called the Special Opeations and Test Area (SOTA). During launch, each position was used by two people allowing 32 people to have display screens. The real-time functions reside in the front end with all of the user interface functions and some of the less time-critical functionality residing in workstations on the string.

Industry standards that were used in developing the POCCsystem were as follows:

(1) Unix & C
(2) X windows & MOTIF compliant software
(3) VME based hardware for the real-time FEP
(4) Ethernet, TCPfIP
(5) Unify

The POCC functionality is partitioned between the FEP and the workstations. It should be noted that the FEPs run under VxWorks which is a real-time Unix-like operating system; whereas the workstations run under standard Unix. The following are the functions that run in the FEP:

(1) State manager- manages and coordinates all of the real-time POCC functions and the different states they can attain
(2) Events- logs and alerts operator of events that the operator needs to know such as the occurrence of errors in the data or the acquisition of data
(3) GMT- inputs ISRO 36 time for labeling of displays, reports and events as appropriate
(4) Data services- distributes requested data to other processes on the network. Acts as data traffic cop. For example, a certain plot may request 4 parameters at 5second intervals.
(5) External Communications- Controls hardware which does NASCOM deblocking, frame synchronization and packet processing
(6) Telemetry- decommutates the telemetry which resides in CCSDS packets and was received from the NASCOM deblocker and frame synchronizer and places the data in a memory current value table for access by the data server.
(7) History services- records incoming NASCOM blocks and incoming transfer frames. Also allows for playback of this data.
(8) Initialization & termination- Allows for start



SAMPEX POCC CONFIGURATION

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up and termination of front end across network.

(9) Command- Accepts and formats real-time commands and command loads for uplink

Each workstation on a string hosts the remainder of the functionality as follows:

(I) Display- Provides displays of telemetry, telemetry status, command status, image dump status
(2) TPOCC System Test and Operations Language (TSTOL)- Provides high level English commands for operator inputs. Also allows privilege classes and procedure generation.
(3) File management- Manages files on workstations
(4) Database- Accepts project database and transform into operational data base.
(5) Reports- Generates required reports for users
(6) Initialization and termination- Start and stop workstation

6. TESTS APPROACH:

The testing methodology of the SAMPEX POCC system was modified from the traditional approach due to time constraints. Typically, testing occurs in four phases: unit testing, system testing, acceptance testing and mission readiness testing. Typically, each phase might take 4-6 weeks. For the SAMPEX POCC, these phases were overlapped. For instance, the acceptance testers and the mission readiness testers received access to a system release about half way through system testing. This not only allowed early support of spacecraft testing but also served to provide feedback on problems in the system earlier in the development cycle.

The main test tool for the developers and the acceptance testers was the TPOCC Advanced Satellite Simulator (TASS). TASS is a TPOCC based simulator that outputs simulated telemetry data and accepts commands. TAKS runs on the same type of FEP and workstation used by SAMPEX, so no additional equipment was required.

The FOT and the mission readiness testers used the Portable Satellite Simulator (PSS) and the actual spacecraft for testing. The PSS was a PC-based system that functioned very similar to TASS. The PSS was developed independently by a different group within the MOD.

Surprisingly, this compressed testing schedule resulted in software releases with less discrepancies. Most likely, this was due to the fact that the time criticality caused all usen to look at the system in a more timely manner. In fact, launch was supported with two official releases and a few patches as compared to the four delivered for more traditional missions. We hope to use some of these tighter coupling concepts (minus the increased stress) between the developers and the testers in future SMEX missions to increase productivity.

7. FACILITIES:

The real-time operations area was housed in the SMEX Mission Operations Room (MOR). The off-line analysis area and the Command Management System (CMS) workstations were housed in the SMEX Mission Analysis Room (MAR). The SOTA served as a launch and early orbit support facility to accommodate all of the extra personnel who attended launch. The total space requirement for real-time operations (MOR) was less than 700 sq. ft. The MAR occupies another 680 sq. ft.

8. LESSONS LEARNED:

The main lessons learned in developing the SAMPEX POCC concerned what it takes to produce a POCC for a mission at lower cost and faster turn-around time. Although a large part of reducing cost thus far has been accomplished through the use of COTS software and hardware and the creation of reusable TPOCC software, the lowering of costs in the future will probably occur primarily through some restructuring of the management and development process.

The goal of TPOCC has been to develop a core functionality which represents at least 80% of the functionality required by each new POCC. It is estimated that there will be approximately 85% reusability for the second SMEX mission which is Fast Auroral Snapshot Explorer (FAST). For the SAMPEX POCC, developers used about 60-70% of reusable TPOCC code. SAMPEX realized about a 25% cost reduction over traditional CCSB POCC development efforts. Continued cost reductions on future SMEX satellites will depend less on the amount of increased reusable software and more on the following:

(1) Cooperation between users and developers in specifyiñg requirements, in particular the

streamlining of the requirements gathering process

(2) Reduction of traditional presentations and paper to bare minimum and only to specify differences from previous missions in the series
(3) Additional streamlining of testing
(4) Continued emphasis on teamwork between the various contractor and government personnel

Some of the ideas to be incorporated for additional streamlining of testing are:

(1) Early involvement of the testers in the development process so that the testers can help to catch problems earlier in development phase. The cost of resolving a problem is inversely proportional to how early in the development phase it is cost. An error caught during a design walkthrough has minimal impact, whereas an error caught on an operational release involves the effort of a few people to produce an audit eail, fix the actual problem and to retest the system.
(2) Early involvement by the testers will also allow input to the developers as to the testablility of the system.
(3) Early involvement by the testers will allow their input into our primary test tool which is TPOCC Advanced Satellite Simulator (TASS).
(4) Early involvement of the flight operations team and the mission readiness testers in the development process. Their detection of errors can be different since some of their discrepancies reported involve the actual operations of the satellite. As the actual users of the system, the FOT provided a different insight into using the system.

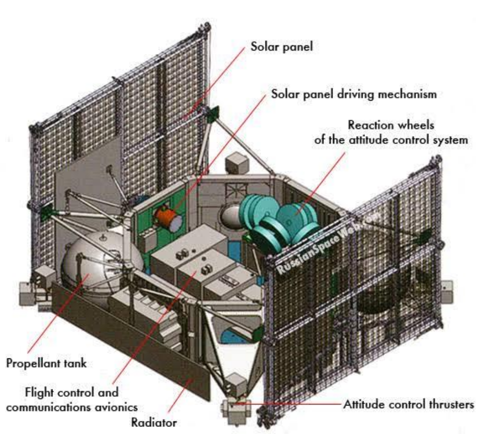
Test as much as possible in the actual operational environment. Seemingly small differences in environment became magnified during the stress of prelaunch system checkout.

9. FUTURE ENHANCEMENTS:

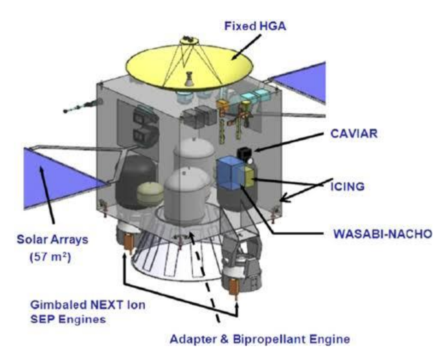
Future enhancements to the SMEX MOR will allow for multiple simultaneous satellite supports. The SAMPEX MOR contains two POCC strings, one designated as the primary string and one as backup. A third string will be added for FAST. the second SMEX satellite, giving each mission a dedicated primary string and a shared backup. When SWAS, the third SMEX satellite, is launched, the three POCC strings will need to be shared among the three SMEX satellites. One scenario for supporting all three satellites is to dedicate each string to one satellite, but also to allow any string to provide backup support for any satellite. This scenario will be accomplished by scheduling of the equipment and carefully planning operations

Also, with most of the core POCC functionality complete, theTPOCC group will focus on adding enhanced user interface tools and off-line processing capabilities. Some of the tools being developed both internal and external to the CCSB are:

(1) GenSAA (previously mentioned)
(2) Space Views, a three dimensional visualization tool for flight operators and analysts
(3) Orbital Signature Analyzer, pattern recognition tool to monitor the health and safety of a spacecraft by analyzing the shape of a plot
(4) Trend analysis tool box- Off-line tool to perform statistics calculations and trend to the point.



$AMPEZ MISSION MOR



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