THE EVOLUTION OF AFSCN TELEMETRY SIMULATION SYSTEMS

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Abstract:

The Air Force satellite control capability was started in the late 1950s to support command and control of orbiting spacecraft. A need to train and certify ground support personnel as well as to validate equipment configurations soon became evident. Ground personnel would have to know how to generate satellite contact plans, establish connectivity between the satellite and telemetry display terminals, analyze satellite telemetry data, and transmit commands to execute the contact plans. They would have to learn specific ground systems capabilities, satellite design information, and approved command and control procedures.

This presentation will review the evolution of telemetry simulation systems as they apply to systems test, personnel training and evaluation. Included will be a discussion of the ground and satellite systems, and how system upgrades and changing operations concepts have fostered the development of telemetry simulators. In describing the next generation of AFSCN simulation systems, this paper will highlight the important part they play in validating system configuration and in personnel training.

THE EARLY YEARS

The rush to get the United States into space in the late 1950s dictated an accelerated approach to manufacturing and operating space systems. This need was met by ground system teams who designed satellite telemetry systems that were relatively simple compared with today’s standards. These teams performed ground tracking and telemetry processing and therefore did not need a great deal of operator training.

Initial telemetry readouts were verbally relayed over telephone lines to Sunnyvale control engineers. Increased space missions, each with increased telemetry data points, required the Air Force to augment the telemetry processing equipment with computers. These systems also provided for electronic data transfer between the remote tracking stations and the Sunnyvale control center. Modulation techniques such as Pulse Amplitude Modulation/Frequency Modulation (PAM/FM) and analog were used. These allowed for transmitting only a few telemetry points.

Manual patch panels were used to configure ground system equipment. Patching and other errors caused the loss of spacecraft telemetry. The loss of data reinforced the need to improve the training methods of ground personnel to check out the system configuration before actual contacts were made.

The first spacecraft simulation consisted of playing previously recorded telemetry tapes through as much ground equipment as possible. The ability of ground personnel to capture a few seconds of spacecraft telemetry data brought about dramatic changes. Spacecraft and ground systems were upgraded to process increased telemetry data rates. The impact of electromagnetic noise was minimized by switching to digital telemetry systems. As advances continued, more satellite missions were entering the planning stages. With the lack of standardized telemetry systems, each satellite design team began planning individual telemetry systems.

The Air Force reacted to these challenges by standardizing satellite and ground telemetry systems. Inter-Range Instrumentation Group (IRIG) standards were applied to frequencies and telemetry formats. From 1966 to 1970 the Space Ground Link Subsystem (SGLS) was installed at each tracking station to provide for multiple telemetry data streams between the satellite and the ground. It continues to be the primary telemetry system in use today. The Advanced Data System (ADS) was installed to increase telemetry and command data processing capabilities at the remote tracking stations (RTSs). It also increased realtime data transfer capabilities between the RTSs and Sunnyvale.

The Air Force had the foresight to include a digital simulator with the ADS installation. This simulator was excellent for system configuration testing and validation. In order to simulate the vast variety of telemetry schemes, the simulator was reprogrammed each time the ADS computer was initialized for a specific satellite contact. This simulator could provide only static telemetry data thus limiting its use as a realistic satellite training tool. Space vehicle training continued to be conducted on the job, through technical discussions with experts, and by playing pre-recorded telemetry tapes.

Nonetheless, the ADS and SGLS systems located at the remote tracking stations proved successful over the years. As new satellite missions entered the network, only minor modifications were needed to these systems to establish support capability. However, the problem of training personnel to support these new missions continued to be a factor in system operations.

Rehearsal and training exercises were conducted by playing telemetry tapes, recorded during factory testing, through the ground system. Factory testing occurred for one specific subsystem at a time. Other subsystem data remained static. Factory data did not correspond with planned rehearsal, contacts, timelines, and other activities. Ground support personnel continued to have their first look at realistic spacecraft telemetry data during the first satellite contact following launch. This resulted in incomplete training and depended on the operator's ingenuity rather than his skill to resolve problems.

In the late 1970s, NASA requested support from the Air Force for planned Space Shuttle missions. NASA expressed a critical safety concern about the way the AFSCN conducted spacecraft training. In order to validate ground equipment configurations, NASA deployed their Portable Simulation System (PSS) to the Indian Ocean Tracking Station. As PSS data fed through the system, it became apparent that an increased complexity in ground support configurations was required to meet all data processing needs. Satellite management decisions had to be made on a much tighter timeline. NASA and the Air Force agreed that a new satellite simulator would be required to train personnel supporting NASA missions.

TODAY'S SYSTEMS

For today's simulation capability, the Air Force uses a Telemetry Simulation System (TSS). At first, this simulator was limited to supporting Inertial Upper Stage (IUS) missions. The contract was later modified to include simulation capabilities for United Kingdom Skynet, DOD Global Positioning System (GPS) , and other space missions. As each mission was added, a complete software package had to be developed. The IUS simulations required the TSS operator to manually type in satellite commands sent by the Mission Control Team. The GPS simulations allowed the TSS to respond automatically to satellite commands received directly from the Mission Control Complex computers. Complete software packages had to be developed for each added mission support capability. Today's TSS can support only a few satellite missions.

However, the TSS does provide for modeling of satellite subsystems and produces a telemetry wavetrain output that nearly replicates that of the satellite. TSS databases allow for tailoring from one specific mission profile to another. TSS telemetry data interfaces with the Mission Control Complexes in exactly the same way as live satellite telemetry data.

In 1980 the Air Force began implementing the Data System Modernization (DSM) program to upgrade our command and control segment (CCS). Previously, telemetry data processing was shared between the remote tracking stations and control centers. With this upgrade the telemetry data handling capability was enhanced by installing mainframe processors in each Mission Control Complex. This upgrade is currently being augmented by the Automated Remote Tracking Station (ARTS) program. ARTS replaces the SGLS equipment at the tracking stations and allows the removal of the ADS equipment.

The upgrade included plans for a simulator to support both system testing and personnel training. Budget constraints limited these plans and this capability was scaled back. A simplified hardware simulator was built to support system testing, and a software simulator was built to support personnel training.

The training simulator provides data to the front end of the mainframe processing software and does not allow for external interfaces. However, it does allow satellite operations personnel to develop math models of satellite subsystems. Priority has been given to fixing operational software problems over simulation problems. The lead time to develop a scenario is extensive. Today, the CCS simulation capability is used to train new personnel how to use the mainframe system. Its use for specific satellite command and control training is extremely limited.

Increased satellite contacts combined with an increased loss of workforce expertise are critical factors in a need for an improved simulation capability. Today's CSTC certification training is conducted within the operational complexes. With the conversion of the CSTC from an operations to a testing environment, future certification training may have to be conducted in an external training facility. This could have some limited impact on the training's effectiveness.

In the early 1980s a classified satellite program office began to develop a space vehicle simulator to meet their personnel training requirements. However, due to budget problems, this effort was shelved. Recently the Air Force Communications Satellite Program Office reactivated development of this simulator and have called it the Generic Telemetry Simulator (GTS). Currently the GTS is being used to train ground support personnel. For GTS, procurement of spare parts has been difficult, and the software has been developed to support only one specific program.

Today, the Consolidated Space Test Center (CSTC) at Sunnyvale is supporting many Space Defense Initiative (SDI) and other space test missions. Typically, the short lead time for this type of mission support does not allow for long term simulation development and major software changes between missions. In order to meet this need, a generic simulator is required that allows satellite operations personnel to quickly tailor simulator databases.

FUTURE SYSTEMS AND PLANS

Today's ground hardware and software systems have experienced rapid technology advancements in data processing capabilities. SDI project offices and others are favoring off-the-shelf systems to process their telemetry data. The current CCS will need to be augmented with technology advancements to meet future needs. High speed data busses such as TOKEN RINGS, Fiber Distributed Data Interface (FDDI), and Ethernet systems are already in use for offline processing, and will be included in future system architectures. A distributed telemetry processing network allows for new systems and equipment upgrades to be installed without impacting continuing operations on existing systems. This approach provides for a flexible architecture that can meet the processing requirements for individual users.

One such distributed network approach is under study by CSTC personnel. It is known as the Information Processing and Analysis System (IPAS) and provides for telemetry data to input to a data server system. Here the data is recorded and passed to an FDDI ring. Processing equipment attached to the ring includes Macintosh and IBM PCS and UNIX-based SUN workstations. The goals of the IPAS software are to:

1. Provide a common operating system that can support other computer systems throughout the network
2. Use network communication protocols that conform to government and industry standards
3. Provide a software environment that is not limited to specific hardware platforms
4. Provide a standard software platform for the development of operations support software, that easily accommodates the needs of new users
5. Support realtime monitoring and anomaly detection
6. Support data analysis and trending
7. Provide a means for controlling the system configuration, both hardware and software.

The IPAS software architecture is designed in a layered approach. The bottom layer is formed by the operating system, compilers, and network and display management software. Next is the development layer. Formed with off-the-shelf expert system software, the development layer includes realtime processing, graphical interface, orbit determination, relational databases, statistical analysis, and math applications. The development layer makes it easy for the end user to develop highly specific tools, which can be integrated into a workbench concept. The workbench contains a set of tools available to all users.

The existing software simulation capability operating within the CCS mainframe cannot support such a system because it does not generate a telemetry wavetrain. Potential development of the TSS and GTS simulators to support new missions is not practical due to equipment age and the software development requirements.

FUTURE PLANS

In light of this history, the Air Force is looking towards a simulation capability that will fulfill future needs. Performing simulation functions for multiple and diverse satellite missions is technologically difficult. No single simulator can currently meet all needs. Limited budgets require the systems to be portable and reusable to avoid having to develop new systems for each mission. The Air Force is now considering several simulation development approaches. Requirements include generalized databases to tailor models, user selectable algorithms, and system hooks for custom software.

Future plans include separate satellite vehicle and network simulators for training purposes. Long range goals are to develop a “system of systems” that will include engineering, mission planning, training, hardware and software validation simulators.

Summary:

Throughout the history of the AFSCN, system testing and personnel training have relied on playing telemetry tapes

and the use of old technology simulators. Because of past stable workforces, equipment configurations, and long term satellite programs, these methods have been satisfactory. The future's rapidly changing environment will include new systems, operations concepts, shorter lead times to prepare for satellite launches, and future workforce personnel. System validation and personnel training can no longer be accomplished with current systems. Future simulators will be needed to validate the software processing of telemetry measurands as well as conduct readiness training.

Our future simulators should meet the needs of both AFSCN control centers (Onizuka Air Force Base, California, and Falcon Air Force Base, Colorado) and other potential satellite tracking networks.

Great challenges and opportunities are now at hand to test and checkout system configurations and train ground support personnel effectively and efficiently, through the use of high fidelity telemetry simulators. The expertise developed over thirty years of AFSCN satellite operations will be applied to meeting these challenges.