TELEMETRY DATA PROCESSING AT WHITE SANDS MISSILE RANGE

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ABSTRACT

Prior to 1985 the National Range had, for a number of years, serious and recurring mission support problems with the IBM 360 Telemetry Data Processing System due to equipment reliability and obsolescence of the system which was installed in 1968. These problems became particularly acute when higher data rate requirements and the need for reliable telemetry data processing dictated that prompt and unusual action was necessary if WSMR was to continue to provide telemetry data processing support. Realizing that the above cited problems of reliability and obsolescence would continue in detriment to the mission of WSMR, Department of Defense (DOD) and the nation, coupled with the loss of thousands of dollars in reimbursables due to WSMR’s inability to support missile test requirements, the Systems Engineering Branch was tasked by the Director of National Range to lead a study, and propose and implement solutions to meet current and future requirements in telemetry data processing support.

With the explosion in PCM data rates, it had become obvious that WSMR could not continue to upgrade existing systems and meet the demands of the future. More data parameters at higher data rates were being processed in PCM, FM, and PAM. Telemetry formats were becoming more complicated, such as embedded asynchronous subcomms and dynamic format changes. More real-time decisions had to be made for mission safety, verification of location, and mission success. WSMR needed a more versatile system that would synchronize, process and display higher data rates with more accuracy than it had at this time.

This paper describes a historical perspective of steps WSMR has taken to satisfy present and future test vehicle telemetry data processing requirements.

I. Prior to 1985 the National Range had, for a number of years, serious and recurring mission support problems with the IBM 360 Telemetry Data Processing System due to equipment reliability and obsolescence of the system which was installed in 1968. These problems became particularly acute when higher data rate requirements and the need for reliable telemetry data processing dictated that prompt and unusual action was necessary if WSMR was to continue to provide telemetry data processing support. Realizing that the above cited problems of reliability and obsolescence would continue in detriment to the mission of WSMR, Department of Defense (DOD) and the nation, coupled with the loss of thousands of dollars in reimbursables due to WSMR's inability to support missile test requirements, the Systems Engineering Branch was tasked by the Director of National Range to lead a study, and propose and implement solutions to meet current and future requirements in telemetry data processing support.

It has been said that before we can plan the future we must understand the present and learn from the past. The history of telemetry data processing at WSMR begins with the installation of the IBM 360 based system in the Telemetry Data Center (TDC) that went into operation in 1968. This system was able to process data at a rate of 50K samples per second. These samples could come from six PAM streams, four FM streams, two PCM streams, or a combination of these inputs as long as the total rate of data was 50K or less.

Telemetry (TM) data of this era was fairly simple consisting of standard measurements of pressure, vibration, attitude, voltages, and events. Data rates used by projects were well below the 50K limitation of the IBM 360 TM system.

Telemetry technology began to change in the early 70's as electronics began to shrink in size and grow in capability. Telemetry test packages began using onboard microprocessors which allowed them to respond to changes in mission profiles in real-time. The need to monitor these changes led to an increase in measured parameters with a corresponding increase in data rates. One of the first projects to severely tax the IBM 360 TM system was an Army missile system. It used a 100K sample PAM for its TM. TDC support was limited to recording the data in real-time, then making reduced speed playbacks to slow down the rate to a speed the IBM 360 TM system could handle. The rule of thumb became for every hour of real-time, two and one half hours of playback time were required. With this system being just one of many projects to support, there literally was not enough time in a day for TDC to support the range. It became necessary to run a second shift crew, whose sole purpose was to catch up on playbacks.

The escalation of measurements and data rates also had the effect of changing the basic type of TM used by project for data transmission. Just as FM had been replaced by PAM in the sixties, so now was PAM being replaced by PCM in the seventies. With the advent of onboard computers, PCM being a method of digital transmission was a natural for passing on the computer data being generated by the package being tested.

The actual data itself also began to change. The standard parameters such as pressure, voltage, attitude, remained, but they were joined by computer status, guidance parameters, packed events, and flag words. These new parameters had a marked effect on the IBM 360 TM system. The higher data rate cut into the basic 50K system rate, the special processing required to recognize the new data types effectively lowered the IBM 360 TM system data rate to 25K and less.

Something had to give, and in 1976, another missile system support requirement forced the issue. The range had to prepare for a three missiles on three targets mission. The IBM 360 TM system with only two PCM stream capability, was already one short for supporting the mission. It was decided to buy three stand alone PCM systems for real-time support, and use the IBM 360 TM system for post-flight processing. Consequently, in 1978, WSMR purchased three EMR 700 stand alone PCM systems. These three systems were used to supplement real-time support. Any special processing requirements were done by the IBM 360 TM system, leaving raw data handling to the stand alone systems. This concept worked for real-time, but did nothing to relieve the post-flight processing backlog.

In 1981 an additional EMR 700 PCM system and two Telemetry Controller Systems (TMCS) were purchased for the support of an Army missile system. Using the TMCS in conjunction with the IBM 360 TM system, WSMR was able to support the majority of real-time telemetry mission requirements satisfactorily in the early 1980's.

A notable exception to this was an Air Force project validation program. Starting in 1980, this program ran for the next two years. Since the program was a fly-off between two different vendors for the contract, timely post-flight data processing was critical. Due to the data rates, and special processing involved, the IBM 360 TM system was not able to meet post-flight requirements. The offshoot of this came in 1982 when the contract was awarded. The first thing they asked the government for and got, was an independent TM post-flight processing system. This was located at Holloman Air Force Base for the Full Scale Development (FSD) program.

This program once again forced WSMR to react to changing technology by increasing the PCM bit rate capability up to around two Megabits. This rate was completely out of the range of the IBM 360 TM system. The TMCS could handle the rate, but not the special processing required. The project accepted WSMR's plan to modify the TMCS and provided funds for the EMR 715 Compressor/Preprocessor.

WSMR Systems Engineering Branch personnel prepared a plan to augment the Telemetry Controller System (TMCS) which had been developed and funded specifically to support the Army missile system requirements and augment it to support the Air Force FSD telemetry data processing requirements. The plan also included the use of available telemetry subsystems which had been separately acquired over the years to support real-time project requirements which could not be supported by the IBM 360 TM system. These subsystems included Pulse Code Modulation (PCM) Bit synchronizers, PCM Decommutators, Pulse Amplitude Modulation (PAM), Word Selectors and the EMR 715 Data Compressor/Preprocessor. Since the various subsystems had been purchased separately there were severe incompatibilities which had to be resolved.

Systems Engineering Branch personnel developed and implemented hardware interfaces, firmware and software to resolve equipment incompatibilities and integrate the various subsystems into a very functional telemetry data processing system now known as the ATMCS. This notable achievement did not cause any range downtime while it was being implemented, nor jeopardized or degraded the real-time operations support. With the ATMCS WSMR was not only able to support Air Force FSD real-time requirements, but also other highly complex test scenarios.

By 1985, Systems engineers designed a direct interface between the EMR 715 and the Real-Time Operations Control Systems (ROCS) which are the systems that provide all of WSMR real-time support. This provided the ATMCS with the capability of generating digital tapes of PCM data on the ROCS instead of the IBM 360 TM system. By 1986, Systems Engineering Branch personnel had modified existing PAM and FM equipment to work with the ATMCS. With full format capability on the ATMCS/ROCS, there was no longer a need for the IBM 360 TM system to remain on-line. The IBM 360 TM system was disconnected and turned-in on 30 September 1986. This accomplishment was approved as a Value Engineering project with a savings of $1,097,297.00 to the government in FY 1987.

The ATMCS itself has been upgraded to keep up with more complex project requirements. One Air Force program required the addition of new decoms able to process asynchronous PCM formats. A recent Strategic Defense Initiative (SDI) program required additional decoms to handle the 10 Megabit rate, and special recording equipment to record the incoming bit stream.

II. With the explosion in PCM data rates, it had become obvious that WSMR could not continue to upgrade existing systems and meet the demands of the future. More data parameters at higher data rates were being processed in PCM, FM and PAM. Telemetry formats were becoming more complicated, such as embedded asynchronous subcomms and dynamic format changes. More real-time decisions had to be made for mission safety, verification of location, and mission success. WSMR needed a more versatile system that would synchronize, process and display higher data rates with more accuracy than it had at this time.

As early as 1981 Systems Engineering personnel prepared a position paper on the modernization of the TDC. Studies of the shortcomings of the TDC brought out the following points:

- Poor system availability, reliability, and maintainability.

- Restrictive system architecture limiting the amount and rate of data which can be processed in real-time.

- Lengthy setup and turnaround time.

- Cost of operation.

The solution to these problems became the basis of a new Telemetry Data Handling System (TDHS) design goals. The major goals were:

- Modular system architecture to allow updating of individual modules as needed, instead of total system replacement.

- Parallel systems, either of which could handle the basic mission being supported at that time (i.e., target drone, missile), or both working together to support complex missions (i.e., missile vs target drone).

- Ease of setup through use of computer setup and standard data path routing.

- Multi-mission capability of either the two systems supporting separate real-time missions, or one system doing real-time support while the other did playbacks, future development, setup for the next mission, or backup for the ongoing mission.

III. A comprehensive investigation for data processing was conducted to define the optimum data processing system. This study involved personnel from the Instrumentation Directorate along with personnel from the Data Sciences Division. Every effort was made to define a system that had the flexibility and data processing power required, and yet maintained a simple man-machine interface that the average telemetry systems operator could operate. By an integration of the facts derived from all of these inputs, the following general system characteristics began to develop.

- The system should be a mission test tool, with the mission controller in control of the data analysis process through real-time system activity.

- It should have a very high availability factor.

- It should use distributed processing techniques to obtain the processing power required.

- Man-machine interface should be via CRT display terminals with a straightforward telemetry systems language for the Telemetry Operator.

- It should reduce man power required for mission support.

- Time tagging of real-time data.

- Real-time data analysis should emphasize display of analytical results rather than raw data in an effort to reduce post-mission processing.

- Multi-mission configuration information should be stored on system disk files with rapid set up for a particular mission. This should include a library of flight test analysis routines.

- Versatile and flexible with a minimum capability to process all IRIG Standard Formats.

- It should have the capability to process multiple missions simultaneously.

- Modular for future expansion.

- Multiple data displays with modern microprocessor-controller color graphics with large screens.

- A set of diagnostics software to aid in troubleshooting the system problems and minimizing the downtime.

- Capable of processing complex data formats, and higher data rates to support WSMR testing for the next decade.

- Real-time data logging.

IV. As the desirable telemetry data processing characteristics were examined in detail, it became apparent that there were several requirements for the TDHS that were unique. These requirements included PCM bit rates up to 20 Mbps, PAM rates up to 250,000 SPS, higher frequency FM data rates, embedded asynchronous PCM formats with several hundred words-per-minor-frame, high processing rates to handle higher compression rates and faster real-time data processing, and straightforward man-machine interfaces capable of supporting multiple missions simultaneously.

The TDHS system as envisioned would consist of seven major subsystems. These subsystems are:

- Input Signal Distribution and Control Subsystem

- Telemetry Front-End Equipment

- Calibration and Simulation

- Preprocessing Subsystems

- Timing and Tape Transport Control Subsystem

- High-Speed Host Computer

- Data Outputs, including Graphic Displays, Video Generation and Strip Charts

- Executive software that would bring all of these subsystems together as one operating system written in FORTRAN.

The data rate requirements dictated the use of a high-speed data preprocessor in the system. The preprocessor would multiplex digital data streams, convert data to Engineering Units, perform data compression and distribute the processed data. This allows the host to perform more real-time functions in analyzing and displaying data.

V. It is important to note that the basic concept of the TDHS requires dual systems. The purpose of this is not merely a redundant capability, but a basic change to the way telemetry data is processed at WSMR. We have moved from a requirement of supporting one missile system, to supporting multiple object testing scenarios with multiple high data rate streams. Today’s high performance test vehicles require multiple TM tracking sites to improve flight coverage of critical TM functions through all flight maneuvers. In the past the TDC would use the majority of its resources supporting just one missile system, such as the IBM 360 TM system support of either the missile or an instrumented target drone. When the systems were tested against each other, it was impossible for the IBM 360 TM system to provide required support. Without the use of the TMCS in conjunction with the IBM 360 TM system, WSMR could have never supported this mission, at that particular time.

As missions become increasingly more complex the number of data streams and tracking sites have also increased. Growth is due to two factors, first, more packages to process (i.e., Shooter aircraft, Missile, Target), and more stations on one package to ensure total coverage (i.e., multiple trackers on low flying vehicles to cover the entire course over the range). These are the types of growth envisioned when the parallel systems of the TDHS were specified to work together.

The greatest fear in the use of anything new is whether or not it will work. The concept of parallel, modular processing systems has been proven with great success at WSMR in the concept, design, and operation of the ROCS processors, and the Evans & Sutherland Interactive Systems. With the TDHS we have an advantage due to our experience with the ATMCS. When the requirements for the Air Force FSD program became known in 1982, the capabilities of the TMCS were closely studied. It was found that all the elements of the ATMCS with the exception of a preprocessor were in the TMCS. With the addition of the EMR 715 the resulting ATMCS was used not only to support the Air Force, but to serve as a test bed and proof of concept for the TDHS design. The personnel who performed the design, development, and testing of both hardware and software, wrote the great majority of the functional specifications of the TDHS. These personnel are charged with the operation of the TDHS.

The original IBM 360 TM system when delivered was incapable of providing required mission support. All applications software was developed in-house at WSMR. The lessons learned from this system were incorporated into the design of the TDHS. Lessons learned in the development of the ATMCS are also incorporated within the TDHS. Lessons learned operationally have allowed the TDC to provide not only requested support to project, but to go beyond initial requests and generate data products not originally requested. This has lead to a direct increase in reimbursables as follows:

FY 1989	$1,288,711.37
FY 1987	924,745.60
FY 1986	676,650.50
FY 1985	560,593.00
FY 1984	325,870.00

With the greatly expanded capability of the TDHS, there is no reason that this trend will not continue.

The TDHS was designed to support the programs of today and tomorrow. The implementation of the TDHS is a technological accomplishment which will materially advance the research and development achievements of WSMR, DOD and the nation and will enable WSMR to stay in the forefront of missile testing technology. This achievement is considered to be of exceptional potential value and of general application since it superiorly improves WSMR’s capability to respond to the Army, Air Force, Navy and NASA telemetry test requirements, affecting a general area of technology and major DOD and NASA programs. These intangible benefits will translate into an increase in earnings since the increased capability of telemetry data processing equipment will have a multiplier effect on the overall Range reimbursable earnings.

The Telemetry Data Handling System (TDHS) will become the backbone of telemetry data processing at WSMR for the 1990’s and beyond.