FLEXIBILITY OBJECTIVES FOR REAL-TIME TELEMETRY PROCESSING SYSTEMS

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Summary. A generalized real-time telemetry processing system model is developed in four blocks: Demod/Synchronization, Data Channel, Processing/Control and Display. Flexibility objectives are stated for each block and illustrated with respect to the Navy's existing Real-time Telemetry Processing System (RTPS). Features and tradeoffs are discussed for each block along with references to the growing and significant body of such systems already existing and currently under development.

Introduction. The last few years have seen major changes in the problems facing the test and evaluation community and particularly the test data processing systems on which they depend for the bulk of quantitative results. The typical number of instrumented parameters has tripled: Instrumentation on the assembly line has become the rule rather than the exception for major test programs–effectively locking-in the telemetry variables before the test vehicle arrives and reducing the options of test center instrumentation engineering. Sophistication of the avionics, flight control and weapons systems has increased to the point where it is typical for airborne systems to have higher resolution, accuracy and capacity than their ground-based counterpart which was in use for test verification only a few years ago. The pressures of flight, manpower, vehicle and test duration costs have long since dictated real-time telemetry processing–computed results available to the project engineer/test pilot team during the event. The data rates presently available via telemetry far exceed the project engineer's ability to assimilate the results–in many cases even when aided by a large scale telemetry processing system and elaborate human-engineered mechanisms for sorting out results. Current project mixes at the Naval Air Test Center include 12 to 15 major projects on the Real-time Telemetry Processing System (RTPS) ranging from flying qualities, performance, carrier suitability, avionics testing, propulsion and structures work on F-14, S-3A and other Navy aircraft to 3 different surface-effects ships and spin coverage for Test Pilot School's T-2C. With several hundred projects in process at NATC an extremely broad spectrum of project types and data formats could later require real-time telemetry processing. The current and 4-to-5 year problems, then, center around flexibility to handle the cases rather than state-of-the-art bandwidth, rate or demodulation techniques. This paper develops a generalized real-time telemetry processing system and considers the flexibility objectives applicable to each block. Assumptions include: (1) multimillion dollar test vehicles or components thereof, typically prototypes though testing may or may not be developmental and could just as well be demonstration or specification compliance, (2) that the decision to go with real-time and/or online post-test handling has been made and (3) that reliability and dollars are of sufficient concern to preclude major fractions of the hardware being developed uniquely for the target system, and (4) that the useful life-span of the system will extend at least until 1980. The Navy's Real-time Telemetry Processing System (RTPS) is used heavily for discussion and illustration of how flexibility objectives may be realized.

Generalized Real-time Telemetry Processing System. In order to consider flexibility aspects, the generalized block diagram, Figure 1, is used.

Demod/Synchronization. This block contains all of the classic ground station elements necessary to decode and obtain synchronization with required formats. In the Navy's RTPS this block consists of PCM bit synchronizer, stored program PCM decom, FM discriminators, analog and parallel PCM tape recorder/reproducers, stored program simulation/calibration and distribution matrix and patching hardware. See references (14)and (19) for more detail concerning that particular implementation.

Data Channel. The functions of this block include limit checking, linearization, data compression, scaling to Engineering Units (EU), digital formatting and conversion and floating point conversion.

Prior to about 1968 these were generally considered to be central processing functions and in most test data processing facilities were done off-line or post-flight. While some efforts [13,22] and notably the Sikorsky Flight Data Processing System by System Engineering Labs have retained this orientation, the predominance of "large-scale" real-time telemetry systems [14,8] recently implemented and at least two others currently under development–the Air Force B-1 facility at Edwards and the Boeing-Vertol facility in Philadelphia–have separated these as preprocessing rather than central-processing functions. The coming-of-age of fast, inexpensive minicomputers and the promise of readily available microprocessors [10] for algorithm implementation and updating has secured the separate Data Channel approach for the foreseeable future.

In the Navy RTPS this block contains a 16-bit general purpose digital computer, A-to-D converter, random-addressing stored-program multiplexor, D-to-A converters, 1600 bpi tape units for EU recording/playback, and a special-purpose Programmed Algorithm Unit for handling the Data Channel functions.

Processing and Control. This block consists of a large general-purpose digital computer and peripherals, the majority of system software, instrumentation files containing calibrations and format descriptions, applications software, distribution/patch control, and a terminal or other means for telemetry engineer operational control. In the Navy RTPS this block also includes a microwave telecommunications link for range data and an alphanumeric CRT and keyboard for operational control. Remote central processing such as that being done [20] by McDonnell-Douglas for the F-15 does not fall within the scope of the generalized system presented here except in cases where the transmission bandwidth equals the original data rate coming from the test vehicle. Network resources may, however, be an extremely valuable asset to future real-time telemetry processing systems.

Display. The output subsystem is by far the simplest to visualize but the most difficult to design for rapid response, flexibility and user demand for features without making it so complex as to be unuseable, in the human engineering sense, for all but highly specialized dedicated 'operators.' Systems typically employ [7,16,14] a computer-driven graphics CRT, hardcopy and strip-charts for time history presentations. A voice transceiver is provided for closing the loop to the test pilot. Many systems including the Navy RTPS provide line printer, time-code and numeric displays in this block.

Having developed the concept of a generalized realtime telemetry processing system, Figure 2, each block will be considered in detail with respect to applicable flexibility objectives. All of these will vary in relative importance according to user needs and type of testing (aircraft, missile, weapon system, transportation system).

Flexibility Objectives-Demod/Synchronization

Codes and Formats-FM. For handling 'high frequency' data, vibration measurements, many 'internal' avionics signals, hull buffeting, acoustics and the like, IRIG standard(9) FM, either CBW or PBW is expected to remain the medium of choice. While several current programs (notably S-3A at 800 Kilobits/sec.) and several future programs (proposed instrumentation for Advanced Navy Fighter) have gone to higher rate PCM to avoid a project mix of analog and digital data, many programs through 1980 will retain FM and a viable target system must be capable of handling it. One factor which will maintain pressure to retain FM capability is the need for filtering. In order to handle all data digitally (i.e., PCM) presently operational realtime systems within the scope of this paper must resort to software digital filter routines or cope with the realities of programmable digital filters such as cost, word length compatibility, difficulty of checkout, added software cost, and awkwardness for switching in/out. The Test Center presently uses software digital filtering for the isolated few PCM measurements that presently must be filtered in the ground-based system. This is not practical however for large numbers of parameters due to CPU bandwidth limitations. Another factor creating pressure to retain FM is the reliability, ease of installation and checkout, adequate noise performance and broad availability of FM instrumentation. The Navy RTPS employs standard discriminators (DCS GFD-13's) configured for plug-in PBW, CBW and translated CBW handling. For maximum flexibility, two programmable “universal demods” (UDMODS) are included in each demod/synchronization front-end. These allow non-standard center-frequency/filter/deviation combinations to be handled with ease. In addition, these units are configured so that the Telemetry Engineer can easily arm the system software via a switch panel allowing a UDMOD to be substituted in milliseconds for an out-of-lock discriminator. These are also indispensable for the occasional “wrong” tape speed or as substitutes for FM reproduce electronics. Auto-cal (IRIG standard) as well as software calibration corrections are available (but not heavily used) for in-flight calibration.

Codes, Formats and Loading-PCM/PAM/PDM. To cover the range of new developments and potentials here would be to cover much of Communication Engineering as it exists today and is clearly beyond the scope of this paper. Due largely to the wide popularity and universal applicability of PCM, the use of PAM/PDM has and is expected to continue to decline. Auxiliary interface provisions exist in RTPS at Patuxent for use of a PAM/PDM decom should the need arise.

The majority of present and expected future programs are PCM with many PCM and FM combinations. The IRIG standard serial codes [(9)] are adequate at present. Through 1980, bit synchronizer updates to handle such codes as Miller and rates up to 1.5 mbps are considered desirable. As mentioned in the introduction, it is difficult to visualize Test Data Processing Systems end-users in the 1970’s making effective use of data content above the 1.0 to 1.5 mbps range. Another factor which will tend to hold these rates down is tape recording and tape usage rates.

The primary flexibility objectives for PCM in the target system are quick, repeatable programming, stand-alone capacity and wide ranges of synchronization methods, word lengths, discretes handling and filler/parity/unwanted-data-discard capability. Implementations which depend on the cycle time of a general purpose digital computer for decommutation are limited from the flexibility standpoint. These implementations are generally limited to lower word rates than their stand-alone stored-program counterparts and are inherently dependent on the repeatability of software execution rates in a computer not designed with that goal in mind. The Navy RTPS utilizes a Monitor 1126A stored-program decom providing rate capability to 1.6 mbps, variable word length formats from 1 to 16 bits, 2 asynchronous subcoms to a depth of 128 and the commonly used main and subframe synchronization methods. This unit is equipped with core memory which receives a software load module from the CPU at log-on time. The load module is prepared by a “Telemetry Compiler” processing pass on format descriptions stored in the RTPS database. The net effect is a very fast repeatable means of configuring or reconfiguring for a new project, between unrelated jobs on the system and between various instrumentation status levels within the same project. An additional advantage of the stored-program approach is standalone capability. In the event of CPU failure, the Data Channel and decom may be used for scaled linearized EU strip chart output. In the event of Data Channel computer failure, the decom is equipped with ‘raw’ DAC’s and can still output strip chart data. Essentially these flexibility advantages are those described in 1969 by Galpin and Mabe [(2)] and others. RTPS format flexibility includes 16-track parallel tape input, serial input from tape or TM and stored program simulation capability. The simulator memory receives a load module identical to that of the decom for readiness testing purposes. Readiness testing in RTPS provides such flexibilities as simulation value modification by keyboard/CRT entry and throughput to CPU with software tolerance tests for both calibrations and floating-point converted PCM simulation levels. Many of the readiness test objectives described by Lemke [(11)] are achieved by this heavy emphasis on stored program approach. Flexibility has been added at NATC by dual utilization of the bit synchronizer. During 16-track PCM playbacks software commands the programmable bit synch to the correct ‘bit rate’ allowing level-shift time-code from the tape to be routed via a specially designed card in the bit synch to the normal IRIG-B translator. This is operable for both search and playback speeds, and with the standard Datatron 3030 programmable tape-search facility the NATC project engineer can do auto tape searches via time-slice selection from the display station for both parallel and serial front-end tapes. Since the bit synch is not otherwise used in parallel tape input mode, the cost of a level-shift translator has been saved. Other modifications accommodate such formats as the so-called “bursted” or variable-frame-length formats which have had noise or patterns added to complete a fixed frame length. In this mode, throughput will occur for data in the same frame in which synchronization is acquired.

Flexibility Objectives–Data Channel. As in the Demod/Synchronization block the ideal or ‘target’ system Data Channel flexibility objectives include quick, repeatable programming, stand-alone capacity, and wide ranges of format/ project capability. In the RTPS Data Channel, Figure 2, two design concepts contribute most heavily to meeting these objectives. The first is the stored-program (read-only-during-processing) aspect and the second is the shared memory feature.

The problem of mixing FM and PCM data in real-time is solved in RTPS by building separate buffers for both PCM and FM, sized on the basis of rates and double-buffering both for EU (gapped) tape generation. The stored-program advantages come to bear in the random-addressing multiplexor controller. A commutation sequence is stored in a core memory private to the multiplexor controller for each project at log-on time via a load module from the central processor. The TM Compiler software which prepared the PCM load module also prepares the FM sampling sequence and resolves rate mix and buffer lengths to allow continuous merging of the two asynchronous data sets. PCM, if present, is used as boss for buffer switching. The PAU, Figure 2, is a small, special-purpose digital computer with 8K-32 bit private core. It too receives a load module at log-on time from the CPU.

The entire system is based on a shared-memory approach. In the case of the Data Channel, both the PAU and the Sigma 3 share memory with the Sigma 9 CPU making for extremely fast and therefore flexible data transfers. This design allows considerable mode flexibility. The Data Channel can operate in ‘integrated’ or full system mode, passing data to the CPU at rates in excess of 50K words/second. It can operate in EU tape playback mode where gapped 1600 bpi 9-track tapes are ‘ungapped’ and played back through the CPU as if the test were taking place but with better repeatability of data values than would be the case with analog tapes. Unusual flexibility exists here in that EU tapes can be played back at non-factor-of-two data transfer rates higher or lower than original data rates for optimizing throughput and processing speed. Another mode which meets a flexibility objective is stand-alone. The Data Channel Sigma 3 can be loaded with a configuration tape containing multiplexor controller and PAU load modules. Engineering Unit (EU) DAC’s are switched via a peripheral switch from Sigma 9 I/O to Sigma 3 Data Channel I/O. In this mode, all PAU features (except for limit checking) are performed such that scaled, linearized strip chart data and EU tape are provided in real-time or post-flight without any CPU services. This provides the flexibility to configure around failures should they occur in the CPU and to completely avoid CPU time being used for customers who desire only strip charts and EU tape.

Programmed Algorithm Unit (PAU). In the Navy RTPS, the PAU [19] is a subsystem developed for the Test Center and unlike the remainder of the system was not ‘off-the-shelf.’ Departure from the safe, off-the-shelf route was chosen for reasons of speed, applications programming economy and overall system flexibility. The PAU performs calibration curve linearization by executing a 5th order polynomial computation algorithm for up to 512 measurements, converts all measurements not selected as discretes to floating-point Engineering Unit values and loads Sigma 9 core areas called ‘measurement string buffers’ with data samples. These samples are directly compatible with Sigma 9 software and ready for immediate realtime processing. The PAU also limit-checks up to 512 measurements against high and low limits, time-tags data and effectively merges PCM and FM samples. These features are available at a specified 50,000 samples per second and NATC has operated the unit at 107% of this level. The unit, designed and built by Xerox, the overall system contractor, is constructed from off-the-shelf logic modules and core memory unit. By using the PAU for the above functions, applications programs become more modular and flexible as well as creating a much lower demand on CPU processing bandwidth. Discretes and syllables of 16 bits or less may be transferred bit-for-bit without scaling if desired. It should be noted that this design allows virtually unlimited percentage mixes between FM and PCM. NATC has operated the system using less than

1% FM data on one end of the spectrum and less than 2% PCM data on the other. The trivial cases of all FM and all PCM are, of course, supported.

Cross Stream Feature. In the multi-stream (more than one Decom/Synchronization and Display block) system it is extremely desirable to be able to log-on with any of the front-end and Display block combinations. In RTPS this flexibility is provided. The primary use is to configure around problems and to retain setups where manual patching or other nonstandard features are involved.

Data compression is not utilized in RTPS other than that the measurement string buffers may be resampled at lower rates if redundant data is known to have been collected and that the PAU and PCM decom make excellent editing devices for not passing data that is unwanted. Additional flexibility is provided via software which allows the calibration coefficients to be modified on the basis of inflight calibration sequences for FM and to be tested for PCM.

Flexibility Objectives-Processing and Control. To cover the total range and potential of existing and new developments for this block is to exhaustively treat the field of digital computation and is clearly beyond the scope of this paper. Currently feasible features can be treated as they relate to real-time test data processing, however, with a view to evaluating future developments and to retaining integrated system objectives as opposed to computerization mania. Many references are available in the real-time computation area [(10,1]) in addition to voluminous vendor information concerning specific machines.

Features which have proven to be extremely useful for real-time processing include the flexibility offered by combination hardware (interrupt) and software task scheduling, multi-programming for foreground real-time jobs, the ability to do input/output without cycle-stealing, memory sharing capability, and low-overhead operating system software. These should be considered as mandatory on a selective basis for the target system depending on total integrated system context. This block will be considered further only in terms of features as seen by the Telemetry Engineer and the impact on the end-user or Project Engineer. The adequacy of core storage, execution speed and peripherals is an obvious overall requirement.

Telemetry Engineer Terminal. The importance of software design, reliability and depth cannot be overemphasized with respect to todays real-time telemetry processing systems. Software ultimately determines the useable flexibility of the system at any point in time. A primary flexibility objective is immediate Telemetry Engineer control of system operation and access to pertinent files and status information. An extremely effective mechanism in the Navy RTPS is an alphanumeric keyboard and CRT combination directly connected to the central processor and referred to as the Telemetry Engineer Station (TES). One very effective feature is the utilization of menus for selecting activity, displaying information and maintaining logical organization. The TES, Figure 3, is completely menu-oriented. This terminal provides direct control for enabling a total integrated data path or stream (“log-on”). A single terminal serves two streams in RTPS. One stream may be logged on or off while the other continues processing, instrumentation files may be interrogated, created or updated and front-end equipment can be configured or readiness tested, all through the TES terminal. All inputs are in English-language telemetry terminology and no programming experience is needed for operation. A major flexibility objective is to be able to quickly configure the system to handle a real-time test or playback. By utilizing disc storage and automated patching control, approximately 60 different projects can be available for immediate log-on. The system can be configured to halt processing on one project, call up all necessary files and be logged on for full integrated processing of a different or unrelated project in under 2 minutes. This provides good utilization potential and rapid response to operational trade-off decisions, for example when a scheduled flight is cancelled or when a new flight is begun on short notice.

The flexibility of any real-time telemetry system is greatly enhanced by a ‘Telemetry Compiler’ software package. In RTPS, this allows simple format description to the system in TM terminology–no programming involved–entry of calibration data, and generation of all machine language load modules for decommutation, sampling and Data Channel functions. In effect, this package is software which writes the tedious machine language load modules for all front-end devices, preprocessing and simulation for all projects, regardless of format–a program which ‘writes’ programs on behalf of the Telemetry Engineer. The prime flexibility objectives from the telemetry engineer’s viewpoint are accomplished via a menu oriented terminal connected directly to the central processor supported by universal Telemetry Compiler, instrumentation file, readiness test, equipment configuration and log-on software.

Concurrent Batch. Most processors utilized for realtime telemetry processing [19,21,7,22] can support batch processing as a background feature. This is a valuable flexibility fall-out of the inclusion of a large-scale general-purpose digital computer. In the NATC system two real-time or tape playback streams are supported concurrently with background batch utilizing a Xerox sigma 9 with 224K-32 bit core, 55 million bytes of disc storage and the CP-R operating system. This has proven quite flexible for processing EU tapes in the background while handling two real-time tests or integrated mode tape playbacks.

Space Position Interface. A key flexibility item in terms of weapons system and certain other tests is the ability to compute upon telemetered data and range-collected space-position data in the same system in real-time and to display combined results. This capability exists with the Navy RTPS utilizing a microwave link from a theodolite/radar range facility.

Measurement-string Buffer Concept. The key to flexibility in the RTPS-CPU for real-time processing is the measurement string buffer concept. Fixed, known real-memory locations (as opposed to virtual addresses) are loaded with the latest samples of data by the Data Channel Programmed Algorithm Unit. These buffer locations are then available for retrieval-scan use by the RTPS operating software which provides (a) automatic availability of EU data outputs to all output devices without writing individual project software (b) fetch for NATC applications programs in a "latest sample" mode and (c) fetch for applications in an "every sample but no redundant samples" mode. This storage and resampling scheme, then, is the key to data throughput flexibility in RTPS. In this particular system all applications software (relating to a unique project or type of project) written by the Test Center is done on the Sigma 9 CPU. The bulk of this software is extended Fortran IV with some in-line assembly code where extra speed is required. The flexibility provided by the in-line assembly code feature of Xerox extended Fortran IV has proven to be of value in conserving the manpower needed to do real-time applications programming.

Flexibility objectives–Display. The range of features and outputs for real-time display [5,7,15,16,14] is so broad that there are wide variations from system-to-system based largely on the subject matter (aircraft testing, transportation vehicle testing, weapons system testing) but also due to individual preferences of the customers involved. The objectives discussed here are referenced to aircraft/weapon-system testing in support of all divisions of the Naval Air Test Center, Test Pilot School and Surface Effect Ships Test and Evaluation Facility.

The Navy's RTPS output/display subsystem is called a Project Engineer Station (PES), Figures 4 through 7. A major decision must be made at the design stage for a system of this type as to who will operate the display subsystem. Presumably, more complex and intricate features can be applied if the operator is in a computer specialty field and prepared to mentally visualize the inner-workings of the system. There are several problems with this approach however. First, the assumption that detailed knowledge of internal hardware or software mechanisms is helpful is not valid in a system of this type. In fact, preoccupation in this area tends to distract the operator from the objectives of the test being conducted. It further contributes to the chronic problems which inhibit optimum application of digital computers: a tendency toward unjustified job security through jargon and rote memory mechanisms and a tendency toward introverted attention to the machine rather than to the overall purpose of the integrated system. Secondly, the barrier and time-delay of interpersonal communications between end-user and operator would preclude optimum man-machine interaction in real-time testing activity. This is probably the most basic premise underlying the productivity of any real-time telemetry processing system. Based on the above reasoning, the Naval Air Test Center determined in 1969 that Project Engineers who would be the end-users of results available through real-time telemetry processing should also be the operators of the Display Subsystem of RTPS. The validity of this decision is supported by current experience at NATC. The end-users (almost exclusively engineers) have learned to use the PES, Figure 7, with only 3 half-days of formal training augmented by 2 or more days of hands-on utilization. While simplicity appears to contradict flexibility objectives, the net effect has been greater flexibility to the end-user because learning to use the PES has not been an obstacle. Another advantage of this approach [(14)] is increased Project Engineer involvement with the realities of his quantitative test information. The conclusion is that high productivity cannot be realized in the real-time telemetry processing system without Display block operational simplicity. Flexibility objectives are met in this subsystem in the design stage by subordinating other factors and demands to the goal of simplicity.

Function Keyboard. The primary selection device placed before the user is the 64 key function keyboard, Figure 6, and discussion here will center on that device. A typewriter-like ‘standard’ keyboard is also used, primarily for response that is prompted by prompting messages at the bottom of the CRT. Commands for Start/Stop of Flight, strip-chart output, EU tape generation, out-of-limits processing, and maneuvers (specifically characterized test events) are all handled by direct single-button “function key” selection. Each selection is followed up by a prompting message on the screen indicating any further action or input required of the user. Any typed input is displayed on an “echo” line below the prompting line. If the user is satisfied with his tentative input he completes the entry by pressing an end-of-message key. Extensive logical validity checks are applied to the message and the operator is advised if textual or typing mistakes have been made.

The top 48 of the 64 function keys are dedicated to specific systems functions such as the Start/Stop operations noted above and have the same meaning for all projects. Several keys are spares for future system features. The remaining (bottom) 16 are universally available for (NATC-written) software definition and retain their particular use only for a single maneuver or flight. This provides virtually unlimited flexibility for the Project Engineer to have unique applications software written and tied to his test program without interfering with the work of other projects and other disciplines. This feature facilitates support of diverse projects (such as weapon systems and flight testing) on the same system. An extremely useful systems enhancement implemented by NATC is the Calibration Plot Function, Figure 6. This function provides a full-screen plot of any calibration curve stored in the RTPS data base. Figure 7 shows an example of the result. The plot is Engineering Units of the subject measurement/transducer versus Telemetry Units (either PCM counts or FM % bandedge). All pertinent file information and a tabular list of the calibration points is provided. A third column shows the table of residuals from the polynomial fit being applied in the Data Channel algorithm unit. This provides feedback to the instrumentation personnel and a rapid means for resolving any questions of calibration which arise. Note that an indicator alongside the residuals shows which points are not fitted within tolerance by the first or fifth order fit applied by the system.

Systems-level function keys are provided for routing digital output “Nixie” displays, selected measurements in the screen header and strip chart parameters. Further “define” keys are provided for maneuver, plot group within maneuver and individual plot grid setup. Wide varieties of plotting formats are provided as standard features. None require “new” software and all are available for use by the Project Engineer as he sees fit in forming his test plans. By using the save/restore key each user saves his entire setup (plot group, maneuver and all output routing) in a disc file at the central processor. The same key is used to restore the file by name, making well-planned, lengthy display/output arrangements immediately available at flight time. Another flexibility objective is satisfied by the ability to modify and make changes at or during the flight. Routine operation involves use of the Select Maneuver key to select predefined maneuvers during the flight or tape playback prior to Start Maneuver. Once the maneuver is started Select Group is used to pick out one of up to 16 display setups to use at the moment. All 16 plot groups are being collected and stored on a recall file regardless of which is being viewed. The Plot Recall key is used after Stop Maneuver to display any or all of those plots in the full-screen format for detailed inspection. Any useful result appearing on the CRT is committed to paper by use of the Hardcopy key. Various other convenience features are provided by the remaining system-level keys such as limit-check alteration, plot scale changes, smoothing (“fair”), text editing and note entry on the screen. In-flight calibration keys are also provided. Finally, keys are color-coded by functional group.

Other features included with the Display block in the Navy RTPS are video tracking coverage (both realtime and playback)for close-in flights, automatic user controlled tape search of analog, parallel PCM, serial PCM or EU (computer) tapes all from the PES for quick-turnaround, on-line, post-flight processing.

Conclusions. FM handling will be retained for the next several years due to needs for filtering, reliability, ease of installation and availability strengthened by the lack of drawbacks which have seen PAM/PDM decline in recent years. Primary flexibility objectives for the Data Channel block are speed, rapid repeatable project/format switching and stand-alone capacity. The ability to merge widely varying percentages of FM and PCM from project to project is highly advantageous in meeting customer demand. These objectives can be met by using a heavily stored-program approach and special-purpose algorithm units to do the high-rate repetitive scaling limit-checking and linearization functions. This will be more so in the future as microprocessors and microprogrammed minicomputers advance into common use. A menu-oriented terminal off the CPU supported by a Telemetry Compiler, instrumentation file and related software can provide extremely good control and response flexibility for the Telemetry Engineer. Processing and

Control block objectives can be met effectively using a large-scale digital computer with combination hardware and software task scheduling, multiprogramming for foreground real-time jobs and concurrent processing during input/output. The measurement-string buffer concept has proven very flexible for realtime data throughput. Display block flexibility objectives should evolve from a heavy simplicity design requirement including the end-user as the Display Subsystem operator. The simplicity objective in relation to computer-driven graphics CRT and typical real-time/rapid post-test processing can be achieved using a dedicated function keyboard to control operation while retaining the flexibility to handle widely diverse project types. The key to success with computer applications such as real-time telemetry processing is to make software/hardware details transparent to the logically unconcerned end-user and to apply careful human engineering attention to all operational sequences.

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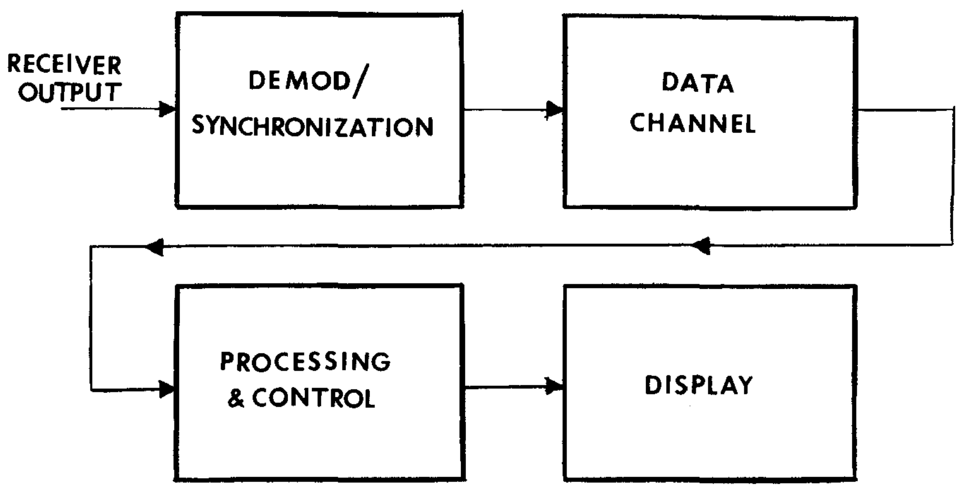

FIG. 1 GENERALIZED REAL-TIME TELEMETRY PROCESSING SYSTEM

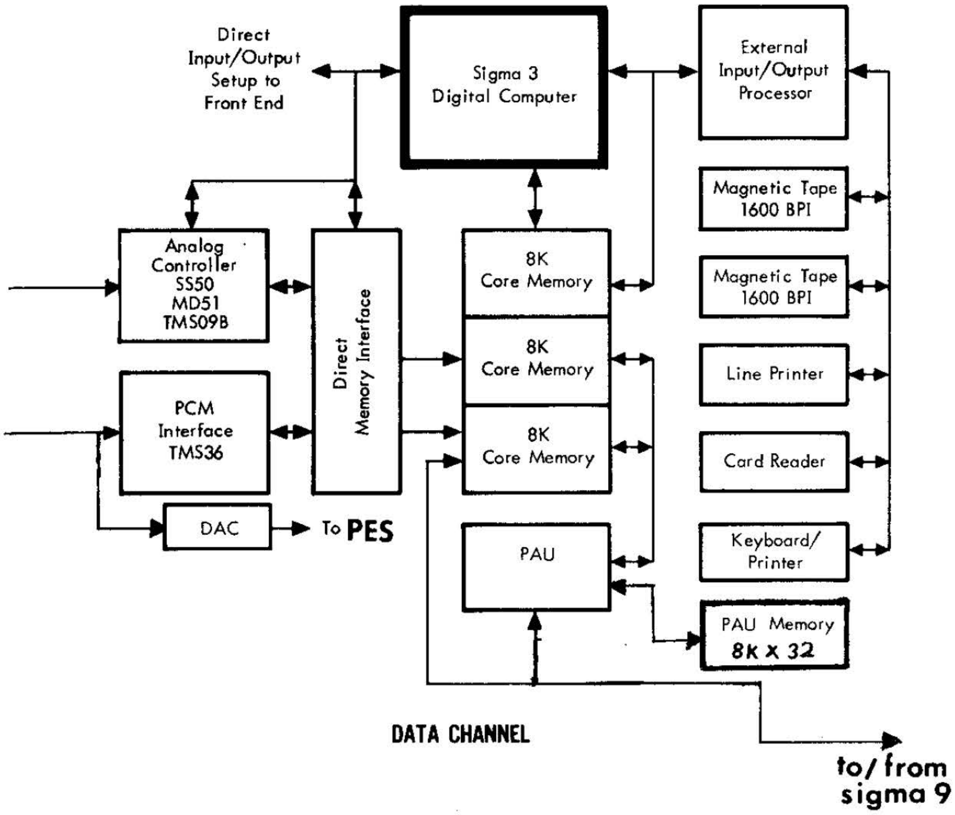

FIG. 2 DATA CHANNEL - RTPS (one stream shown)

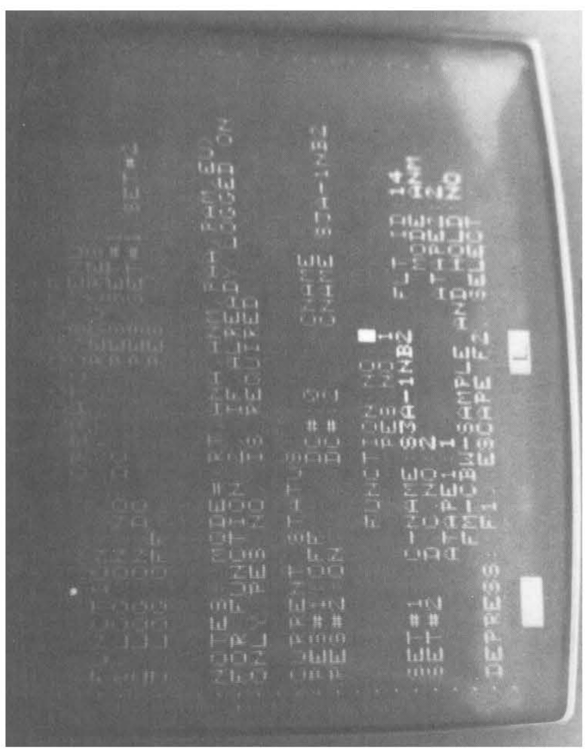

Figure 3 - Telemetry Engineer Station CRT Example Menu

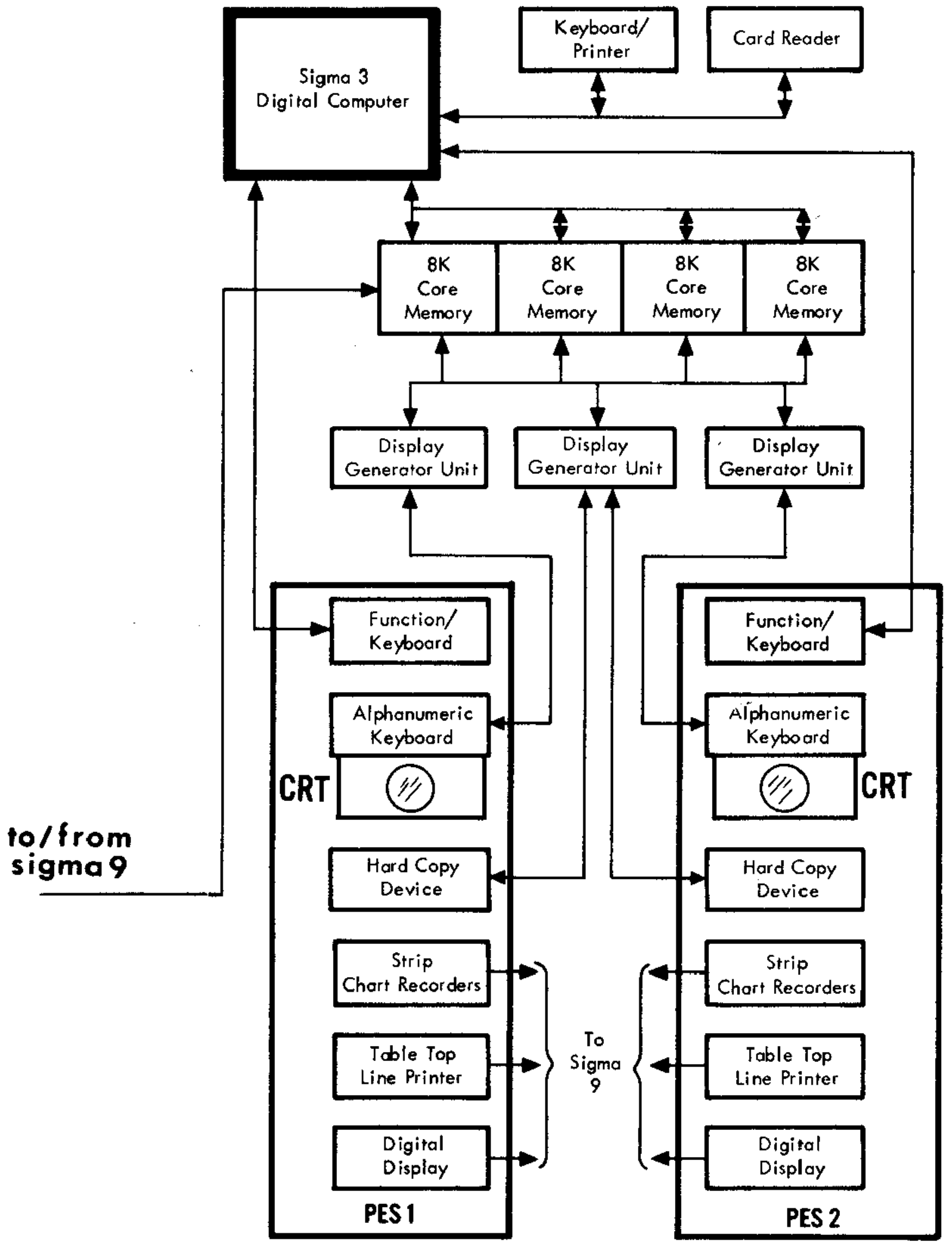

FIG.4 DISPLAY SUBSYSTEM - RTPS

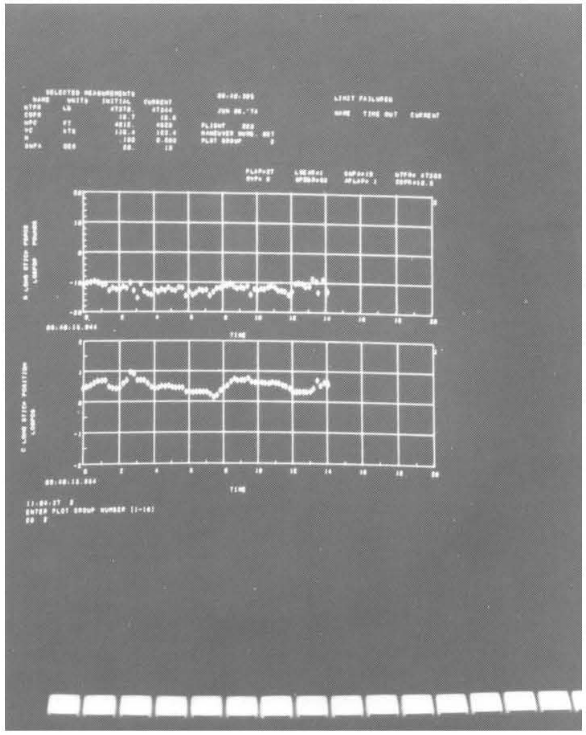

Figure - Project Engineer Station CRT Example Plot Format

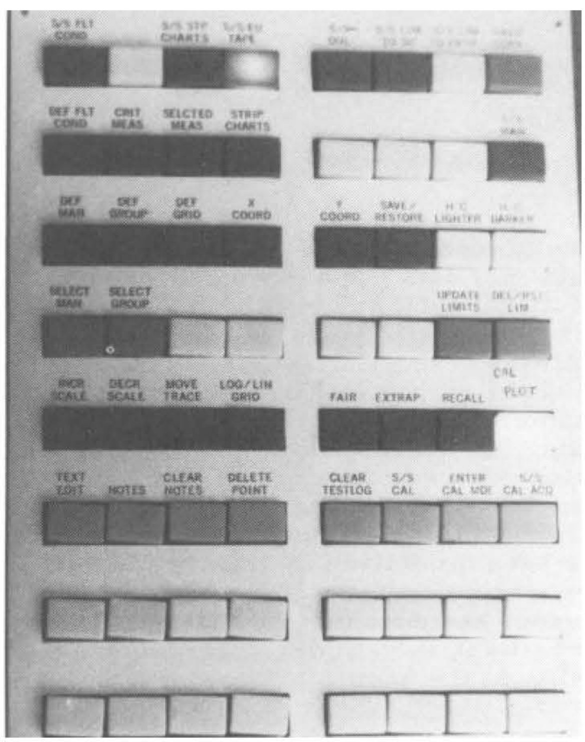

Figure 7 - RTPS Display Calibration Plot Example

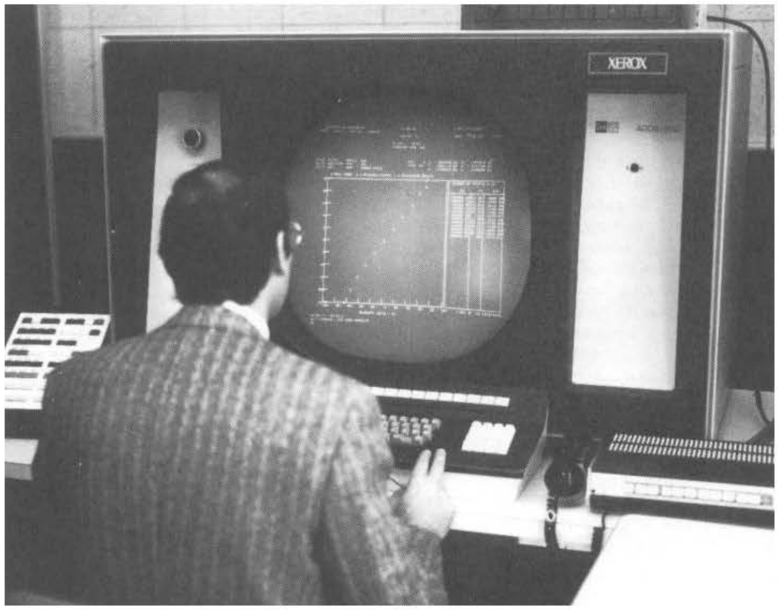

Figure 7 - RTPS Display Calibration Plot Example