THE FUTURE OF REAL TIME TELEMETRY SYSTEMS

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Introduction. This paper briefly outlines the development of real time data processing systems and discusses the techniques used in present systems to bring full power of computer facilities to the systems user. While discussing existing systems, future user requirements are examined and the application of recent technology to these needs is investigated. Software systems, hardware techniques and systems management are reviewed so that future systems design may be responsive to the human, as well as the technical elements of vehicle testing.

Background. Since the advent of the missile age, the complexity of aircraft and space vehicles and their associated costs have increased by several orders of magnitude. The task of testing these vehicles has also been magnified to the extent that computerized data processing is now required to handle the vast amounts of data produced by the sophisticated instrumentation systems. The need for more data, at higher rates and with greater accuracy, has led to the development of new digital data acquisition systems which, in turn, has spurred the evolution of present telemetry and data processing systems. The Apollo program, for example, telemetered approximately 1000 PCM parameters at a 51.2 Kbps rate. Typical aircraft flight test programs call for 300 to 500 measurements outputted at a rate of 600 Kbps. Equipment is now available to handle data streams above 10 Mbps, but present user requirements seem to indicate that a 1 Mbps rate will satisfy most needs over the next few years.

As the test vehicles become more exotic, so too have the acquisition systems. Sensors and signal conditioning units have been miniaturized, allowing still more measurements per unit volume. The cost per measurement has significantly decreased over the past five years, but the sheer number of sensors have driven the total instrumentation cost skyward. Single test vehicles, instrumented for multiple test disciplines, are now commonplace. Safety-of-flight, even on unmanned vehicles, becomes an overriding consideration, since the loss of a test vehicle may be catastrophic to the test program.

The on-board magnetic tape recording has gradually given way to telemetry of vehicle test data to ground based equipment. Some of the most obvious advantages of this approach are:

- The ability of ground based acquisition and processing systems to act on the test data while the vehicle is still under test;
- More efficient use of the ground based equipment may be expected, since it is available for other tests when the prime vehicle is not in use; maintenance is facilitated; cost per vehicle is reduced;
- Elimination of the recording systems in test vehicles save weight and space, and so on.

Of these items, the ability to process data during vehicle testing is most relevent to this discussion.

Early test efforts utilized FM analog techniques and the results, expressed in real time via strip chart recorders or oscillographs, were in pseudo-engineering units. Accuracy was severely limited by such factors as frequency response of the writing pen or galvanometer, damping coefficients, calibrations, drift, etc. Digitizing the FM data improved the accuracy but still left the number of transmitted data parameters as a direct function of the frequency bandwidth.

Then the manned spacecraft effort was initiated. The combination of the astronomical sums of money being spent on the vehicle equipment plus the safety-of-flight considerations for the men on-board, required that the ground control personnel have access to flight information without delay. Using the digital PCM techniques and advanced high speed processors coupled with new generation real time software and peripheral display devices, this effort was spectacularly successful.

The techniques proved in space were successfully adapted to other vehicle testing efforts. Improvements and refinements were made to allow multiple data streams from several independent sources to be simultaneously processed in real time. This creates greater machine efficiency and utilization.

Perhaps the greatest contribution of real time processing has been the ability of the test conductor to interact with the pilot/aircraft based on his knowledge of the on-going test results. This communication provides assurance for the entire test team and greatly enhances chances for successful fulfillment of test criteria. At the same time, safety-of-flight is improved.

A reduction in the total test time may be expected, as well as a pecentage of planned contingency flights. Real time processing allows comparison of test results with predicted values. In case of divergence, the test conductor may elect to include a more gradual progression of checkpoints, or if all values are normal, he may opt to skip certain functions.

Learning from the extensive aerospace experience and based on a firm foundation of technical computer expertise, Grumman Data Systems has created a new, user oriented, real time data processing facility. This hardware/software system, in operation for the past four years, continues to fulfill and expand upon its initial charter: to provide the user with answers, not just data, in real time. This task embodies several important concepts which point the way for future real time systems development. First, answers: presuppose that confidence in the entire system is assured from sensor through analysis display. Second, the ability of the ground personnel to assess this information must be facilitated through interactive display capabilities. Third, and probably most important, is the ability, through advanced software and hardware techniques, to avail the user of the full power and resources of the computer.

This discussion will outline the approach we have taken and some of the advances which have been made in the development of the Grumman Automated Telemetry System for real time vehicle testing. We will then attempt to extrapolate the future direction of these systems and forsee what is in store for the next generation of real time test facilities.

Software Operating Systems. The advent of larger and more powerful computer hardware creates the need for an advanced telemetry oriented, real time operating system. Such a system would combine telemetry hardware, computer resources and user requirements to produce meaningful results for the svstems user in real time. An example is the Grumman Tele-SCOPE 340™ operating system. The criteria used in designing and implementing such a system were flexibility, reliability and adaptability.

Such flexibility has been defined as the ability to adapt readily to the changing telemetry and system user needs and requirements. One approach which may be taken to achieve this goal is the separation of the system functions and responsibilities. In larger systems, this may be done by separating the preprocessing and analysis functions with the preprocessor handling all the front end functions such as data acquisition, decommutation, sync acquisition, engineering units conversion and data buffering. Other features which may be included are limit checking, data compression, strip chart display, etc. The analysis function, then, may be carried out using the full power of the main processor or central computer. The entire system, however, remains under the control of the real time operating system. It provides complete control of all elements of the system and enables the real time tasks to function smoothly, while simultaneously directing all other functions, such as batch, timesharing/ RiE and monitoring operations.

The control and direction of this real time operating system may be accomplished using a multi-level priority structure which may be dynamically adjusted according to system requirements. Since real time operations, under normal conditions, require only minor portions of the operating systems cycle time, the capability may exist to support batch, remote job entry and timesharing facilities simultaneously. The dynamically changing priority structure, allows for a continuously updated priority scale with the most critical jobs assigned the highest priority and the least critical functions the lowest. The highest priority is usually assigned to a real time task after it has been initiated and it has reached real time status. The operating system then schedules the non-real time periods of a real time task to be allocated to all lower priority tasks in concurrent execution.

In addition to providing the scheduling and task initiation for real time tasks, the operating system controls resource allocation. User program swapping, I/O staging, allocation of real time peripherals and mass storage may be efficiently handled through the real time operating system. Depending on the data file manipulation, the data may be accessed by multiple user programs. System flexibility is further enhanced by the use of option dependent programming. This is the ability to structure the computer routines using variables which are defined according to the user requirements. These definitions may include such items as data rates, types of interactive displays, size of user programs, etc. This feature eliminates costly reprogramming for each user application.

System reliability must be inherent to any real time system. One method of increasing system reliability has been to incorporate debug facilities within the operating system for user programs. The availability of this feature allows the user to locate logic problems prior to utilizing the program in a real time environment. Another feature which has been found desirable is the incorporation of real time status checks for all critical functions, both hardware and software, throughout the system. Using this facility, the system user may be assured that the answers presented are, in fact, results of good data input and proper system operation. In the event of program errors, recovery techniques should allow the user retention of as much of the acquired data as possible.

System adaptability is achieved through the capacity to change the course of a real time test without reloading or restarting. This may be accomplished by allowing the test director or console operator direct access to the operating system through interactive displays and appropriate software control points. This interactive capability allows the test conductor to notify the system of reconfiguration or changes in the types of data presentations. In most cases, all possible programs for use during a particular test are pre-defined and loaded into a system library for use during the real time operations. Also pre-defined are the telemetry data formats, interactive displays and user programs necessary to accomplish the designated tasks for the vehicle under test.

The immediate goal of the designer of real time computer systems is to free the user from concern about the data manipulation techniques, and allow him to concentrate on the on-going test results. Once this confidence has been achieved, the benefits of the real time system are limited only by the imagination of the user and the computer facilities available to him.

Hardware Systems. The previous discussion of real time operating systems assumed that the system hardware configuration was such that inherent hardware limits were never reached or exceeded. In reality, the choice of the hardware, including computer facilities and peripheral equipment, rarely comes close to this idealization. The cost/requirements tradeoff has been the subject of numerous papers, and shall not be discussed here. However, present systems, and the immediate application possibilities which are presented, may be profitably discussed. Multi-stream configurations, 1Mbps data rates, micro-programmable processors and highspeed remote intelligent terminals will all contribute to the near term plans of the real time systems designer. Applications apart from the purely aerospace activities are presently appearing in such diverse fields as environmental pollution monitoring systems, distribution network control systems, and monitoring and control of other computer subsystems. Recent advances in technology, particularly in the fields of Large Scale Integrated circuits, semi-conductor memories and low cost miniature components open vast new areas for the application of real time processing, test, analysis and control. Communication through fast multi-port memories to all functional elements of the system may eliminate the “traffic jams” which presently plague some large scale systems.

The shared memory technique, whereby the various system elements all share dedicated segments within a common memory, may take advantage of the technological achievements in recent years. Conventional core memories (cycle time in the order of 1-1.5 microsec.), MOS designs (600-750 nsec.), and the high performance monolithic circuits (100 - 250 nsec.) are becoming less expensive. Volatility is not significant since the memory is typically reprogrammed completely from the main processor prior to each use. Ideally, shared memory should be available with a range of from four to ten ports, with dedicated segments of from 1K to 16K words per port. This presents the maximum flexibility and versatility to the systems user while still maintaining a fairly simple and effective operating system for real time applications.

The hardware design configuration of new systems is beginning to reflect the rapidly changing technological base. Standardized microprocessors are now available off-the-shelf, with the user being given instructions for programming a unique instruction set for his specific application. In this manner, a building block approach may now be considered both realistic and economically feasible for new systems development. The advantages of this modular concept are fairly obvious. Lower cost results from the fact that most systems may be configured from a limited variety of standardized hardware elements. The non-recurring costs are associated with the development of specific applications software/firmware. The system may be tailored, in this manner, to the users' needs; he does not need to buy a capability which he does not require. "Off-the-shelf" hardware also permits more rapid fabrication of customs systems, since it eliminates the hardware development, with its associated long lead times. Standardized interfaces allow selection between several price/performance levels for each system element. In addition, non-standard functions, such as special processors, may be added with minimum impact to the overall system. Expansion is greatly facilitated and flexibility is virtually limitless. Upgrading may be accomplished easily, sometimes by just plugging in a module, or replacing an existing element with its higher performance counterpart.

The student of computer architecture will observe that the proposed system organization is essentially that of a "distributed processor" which is much in vogue in current literature. Examples of such systems are still relatively rare, but several current systems do make use of the concept, using multipart shared memories to link one or more processors with I/O channels.

Systems Management. While the real time operating system may be considered the heart of the computer facility, and the hardware elements may establish the boundaries for the system operations, the real key to making full use of the inherent capabilities of the entire complex, is system management. As technology advances, greater stress will be placed on this aspect of real time systems. New avenues of communication and understanding must be created among the analyst, test conductor, flight personnel, computer and real time programming specialists. Ground rules must be formulated and maintained until system reliance is assured. Once this changeover has occured, a new "real time oriented user" will emerge, ready to make full use of the power available to him by this new generation of real time computational facilities. The demands on the user are many. The planning responsibilities are awesome. Real time brings with it the direct responsibility to correctly determine which are the significant factors in the test, what displays are needed, and, if something goes wrong, what steps to take next. All this information must be thought out in advance so that appropriate routines may be prepared and loaded into the system, ready to cover all contingencies of the test. Interpretation of events and the establishment of limits for specific parameters take on new meaning when approached in the light of a dynamic real time test environment. No longer can the computer operator, programmer or user rely on the ability to go back and rerun the routine if data anomalies occur indicating program malfunction. Real time reliability and accuracy of the displayed information are essential to the overall use of the system. In conclusion, real time acquisition and processing systems are here to stay. New advances of computer technology are widening the scope of applications. Management must be ready with suitable plans for a unified approach to the problems associated with this type of facility. The combination then, of new hardware, flexible real time operating system software and a sensible system management plan will assure efficient and timely processing of real time information and provide the user with, not just data, but the necessary answers in real time.