SAMTEC INTEGRATED TELEMETRY SYSTEM ANALYSIS

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Summary. The goals of TCAS were to recommend a Telemetry Integrated Processing System (TIPS) that will improve SAMTEC mission support, increase flexibility and modularity of the system, and provide a system that is more easily operated by the range operations personnel with an associated reduction in overall operating cost. SAMTEC has completed the conceptual phase of the classical system life cycle. The validation phase is now well underway and the development phase is expected to start early in the calendar year 1975. The Integrated Telemetry System was derived utilizing the fundamentals of good engineering practices, common sense, and very extensive analysis. The resultant system should satisfy the goals of improved support, flexibility and modularity, and should provide at least a 20 to 40 percent reduction in the current telemetry processing expenditures.

Statement of the Problem. In performing its function as a test range, the Space and Missile Test Center employs a number of computer based systems to perform the telemetry processing function. This support includes the data processing for missile ground tests, missile launches (both ballistic and orbital), and the post flight analysis of missile performance. In addition the systems provide off line data reduction for programs like the Space Test Program and the Minuteman Launcher Equipment Room Evaluation series. SAMTEC provides support to foreign nations such as Canada, Great Britain, Germany and the Netherlands as well as other branches of the military and NASA.

The problem is that SAMTEC cannot meet its support requirements without obtaining more system capability. The requirements now being received are beyond the capability of the current systems.

The Environment: SAMTEC currently is experiencing an environment of increasing requirements and increasing data processing for analysis of the telemetry data. The requirements vary widely with increasing emphasis upon more sophisticated techniques and faster response. Furthermore, there is an ever increasing need for more efficient and less costly modes of operation.

Typically the approach at SAMTEC has been to incrementally acquire hardware and software to support each new requirement. The computer inventory to support telemetry processing has more than tripled in the past six years and continues to grow annually.

SAMTEC spent in FY74 a record sum of money for operations and support personnel in telemetry processing and even more is projected for FY75. Additional money has been expended for system modifications and for lease and maintenance costs.

New requirements continue to be received that dictate further expansion. This mode of development creates many interfaces and multiple maintenance contracts. Reliability goes down often resulting in many reruns to produce good data, maintainability becomes more complex with experiences of increased difficulty to adequately obtain and provision spare parts.

In summary, SAMTEC's problem is that many new telemetry requirements exceed capability which results in high reoccurring modification costs and operating costs while lengthening lead times required for proper support.

Statement of Objectives: SAMTEC in order to continue in its role as a national test range must establish and attain the following goals:

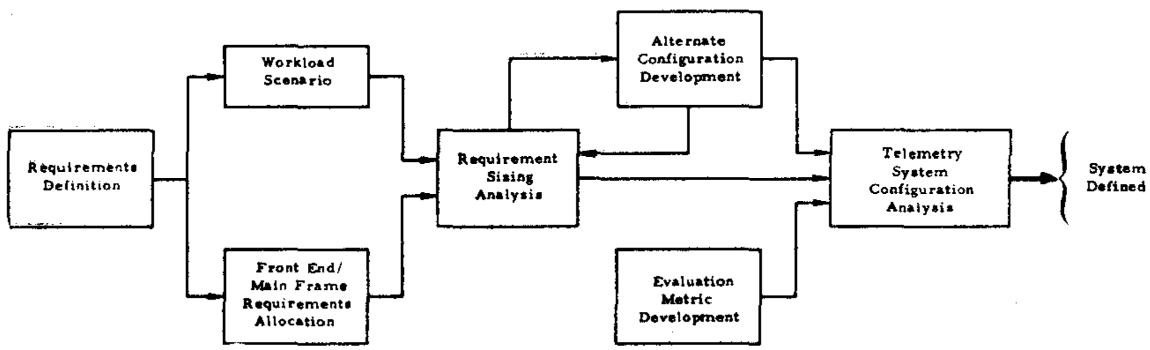
1) The program office (or any user) test support requirements must be satisfied. This must be accomplished within a reasonable time and cost constraints.
2) Annual operation costs must be reduced.
3) It must be recognized that requirements will continue to vary wl 'dely and therefore systems must have flexibility and planned growth capability to minimize development costs and risks.

Preliminary analysis during the Long Range Computer Study (LRCS) performed by Logicon for SAMTEC in FY72 indicated that consolidation of the telemetry functions on a centralized multi-processing computer complex was feasible and would result in significant improvements in mission support and operational flexibility.

A Telemetry Consolidation Analysis Study (TCAS) was initiated by the Space and Missile Test Center (SAMTEC) to define a new telemetry system that would result in improved operating efficiencies and satisfy user requirements through the next five years. The consolidation study was performed by Logicon and had the following goals:

- Improvement of SAMTEC telemetry support
- Increase telemetry system flexibility, modularity, and growth
- Consolidated telemetry system operational requirements
- A telemetry system with improved operating efficiencies and associated reduction in operating costs

The technical approach utilized during the TCAS is illustrated below: In brief, the technical approach included a requirements definition phase to determine system requirements, design contraints and loading parameters.



TCAS Technical Approach

A workload scenario was derived as a basis for the sizing task to determine parameters such as number and type of launches per worst-case month, number and category of front-end links, and telemetry stream characteristics such as bit rates, frame rates, and syllable sizes. The purpose of the requirement allocation task was to: define the telemetry functions at the lowest processing level possible; allocate the previously defined requirements to these functions; and then categorize the functions as front-end, main-frame (e.g., large scale computer system), or solution dependent (e.g., either main frame or front end).

These basic functions were then sized in applicable units which included throughput rates for the special-purpose front-end devices (e.g., synchronizers and decommutatiors), and processing loads, memory size, execution speeds, etc. for the digital computer devices.

The configuration development task was to define technically feasible telemetry configurations that satisfy the system requirements previously derived and sized.

At the same time evaluation metrics were developed for application to these system configurations. The metrics were designed to support quantitative configuration selection.

The purpose of the configuration analysis task was to determine the most suitable configuration to meet SAMTEC’s telemetry requirements. This was accomplished by comparitive analysis and by application of the evaluation metrics to each of the postulated configurations. Once the configuration was selected, specific detailed requirements were determined for support of possible SAMTEC procurement activities.

Telemetry Consolidation Analysis. The results of the consolidation analysis are described in the following subsections which include: requirements definition and allocation, workload scenario, requirements sizing, configuration development, evaluation metrics, and configuration analysis.

Requirements Definition and Allocation: The telemetry system requirements were obtained from numerous interviews with SAMTEC personnel and with major range users such as SAMSO and their associated industrial contractors. In addition the present SAMTEC telemetry systems were analyzed in detail to provide insight into the current requirements. Approximately 70 major requirements were formulated and included categories of system design, automated setup and validation, remote terminals, display, range safety, and post flight data reduction. These requirements were then mapped to the telemetry functions shown in Table I and allocated to either the front end or main frame portion of the telemetry system. In some cases the allocation was to either portion of the system depending on a given configuration. These fundamental functions then formed the basis for the sizing analysis.

Workload Scenario: In addition to the telemetry functions defined during the requirements definition phase, it was necessary to determine a workload scenario to fully prepare for the sizing analysis. The workload scenario consists of the number and distribution of the launches during a worst-case month, the system loading characteristics, and the expected monthly hours of utilization on the system. From SAMTEC historical launch records over a 2 year period a worst case month of ten launches was derived. From a statistical analysis of the launch data the following categories were determined: six launches will be Ballistic-Operational Test (B-OT); two will be Ballistic-Research and Development (B-RD); and two will be Space (S). The distribution over the one-month period is shown in the following sketch:

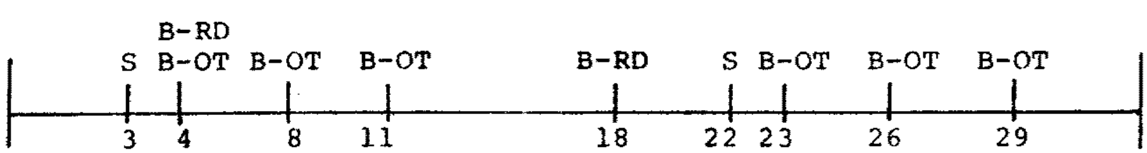


Table 1. Function Requirement Allocation

Function	Allocation
PCM Decommutation	Front End
PCM Identification	Front End
PCM Routing	Front End
PAM/PDM Decommutation	Front End
PAM Identification	Front End
PAM Routing	Front End
FM Processing	Front End
FM Identification	Front End
FM Routing	Front End
Timing	Front End
Incremental Processing	Front End
Discrete Processing	Front End
Tape Formatting	Main Frame or Front End
Event Detection	Main Frame or Front End
Engineering Unit Conversion	Main Frame or Front End
Data Compression (Redundancy)	Front End
Limit Check	Main Frame or Front End
Telemetry Validation	Main Frame or Front End
Real-Time Range Safety	Main Frame or Front End
Real-Time Control	Main Frame or Front End
Data Base Management	Main Frame
Display	Main Frame or Front End
Analytical Processing	Main Frame
Operating Systems	Main Frame and GP Computers
Setup	Main Frame and GP Computers
General Data Processing	Main Frame
Diagnostics	Front End and Main Frame

The telemetry system front-end loading characteristics were derived by projecting existing workloads and are shown in Table 2.

The worst-case real-time loading is postulated as the 10 PCM links operating simultaneously at the specified rates for 900 sec. The 900 sec was determined as the average missile flight with respect to real-time telemetry data being received at SAMTEC (e.g., from VAFB or Point Pillar). For the ten-launch worst-case month, approximately 700 hours of real-time and 1800 hours of batch processing were derived based on a statistical analysis of historical utilization data and addition of the new processing requirements.

Table 2. Telemetry System Front End Loading

Loading Characteristics	Source
10 links of PCM • 2 links at a 2-mbs rate • 8 links at a 0.4-mbs rate	Worst case ABRES R&D launch planned in the near future
13 links of PAM/PDM • 2 links at a 25K-sps rate • 11 links at a 0.9K-sps rate	Worst case derived from existing combinations of prelaunch and launch activities
5 links of continuous data (e.g., FM) Each link consists of IRIG PBW channels 11 to 21 or CBW channels 3B to 21B, or equivalent	Worst case derived from existing combinations of prelaunch and launch activities
PCM 200 frames/sec at 2 mbs 40 frames/sec at 0.4 mbs 1200 unique 8-bit data syllables/frame	Worst case approximated from the Minuteman frame rate and word length at the 346-kbs rate
PAM/PDM 800 frames/sec at 25K sps 30 frames/sec at 0.9K sps 30 unique 10-bit data syllables/frame	Worst case based on existing SAMTEC programs
Continuous data (FM) 11 unique quantities per link 500 frames/sec at 50K wps 100 10-bit data syllables/frame	Worst case based on the capacity of the top 11 IRIG channels
900 sec average dedicated real-time support/launch/link	Representative launch times

Requirements Sizing: The functional requirements previously defined were sized based on the postulated workload scenario. The sizing technique used were primarily two approaches. For the front end realtime oriented devices a data throughput approach was developed. For the more complex functions that required computer processing the sizing analysis included evaluation of the required amount, characteristics, and speed of execution of the processing, in addition to the data throughput.

For the throughput analysis each of the front end functions was evaluated for input and output volumes and data sizes. For example for a serial 2 megabit per sec telemetry stream input rate into the PCM decommutation function the output was an average rate of 250K syllables per second, each 8 bits in length (parallel). With the addition of the identification and routing functions the syllable rate remained constant but the syllable size increased to approximately 28 bits in length. It should be noted that while described separately the sizing function was an iterative process with the configuration development task. This is required since functions such as routing, have variable data length dependent on a particular configuration. The telemetry links both PCM and analog were sized based on the workload scenario. The individual links were sized on a worst case basis, but the composite throughput for input to the main frame computers was based on a combination of worst case and nominal.

The functions requiring computer processing were sized using several techniques. The most desirable sizing approach was to utilize an existing model that closely represented the particular function. To obtain this type of sizing information, software program questionnaires were constructed for SAMTEC telemetry system programmers to answer based on existing telemetry software. To size functions for which no model exists, pseudo programming techniques were used. To size by pseudo programming logic flowcharts of the required processing are constructed. The number and type of instructions are then estimated from these flowcharts. Therefore from either the existing model data or by pseudo programming the number and type of instructions, and memory sizing was determined for each of the complex functions. From the LRCS study techniques were developed for transferring sizing parameters from one computer to a representative computer model (baseline computer). This allowed sizing data from a variety of computers to be utilized and compared. The sizing data from the existing telemetry systems was thus transferred to representation in terms of the baseline computer. The pseudo programming data was directly sized based on the speeds of this baseline computer. Utilizing the baseline computer sizing data and associated execution speeds in combination with the data throughput, the required processing speeds were determined. At this point in the analysis the functions were sized so as to permit various combinations to be evaluated during the configuration development analysis iterations.

Configuration Development: Based on the requirements and design constraints determined earlier and the functional sizing results, four telemetry system configurations were developed. Each of these systems was functionally designed to be technically feasible and to satisfy both SAMTECs existing and long term telemetry requirements. Figure I shows a brief overview of these configurations and their salient features are summarized in Table 3. The configurations were designed to a level sufficient to allow meaningful comparative evaluation but were not necessarily optimumized.

Evaluation Metrics: Evaluation metrics were developed and applied to the four configurations to arrive at the recommended configuration. These metrics are:

1. **Long-Term Follow-on Confidence:** This metric evaluates the potential of the configuration to allow upward growth with technology improvements.

2. **Growth Potential:** The growth potential metric evaluates the ease and response time of modular expansion with increased loading.

3. Developement and Operating Costs: The cost metric evaluates the initial development costs and the monthly operating costs.

4. **Hardware and Software Complexity:** The complexity metric evaluates the development risks associated with the hardware and software as well as factors such as acceptance testing time and costs, maintainability, etc.

Each of the metrics was mathematically derived for application to the four system configurations. For example the metric for long term follow-on confidence (M_F) is:

$$M_F = \frac{\sum_{i=1}^{n} M_u^i \times \left(1 - M_l^i\right)}{n}$$

where

n = number of types of computers within the system

M_u^i = probabilities for each type of system computer for upward-compatible

M_l^i = probabilities for lateral follow-on

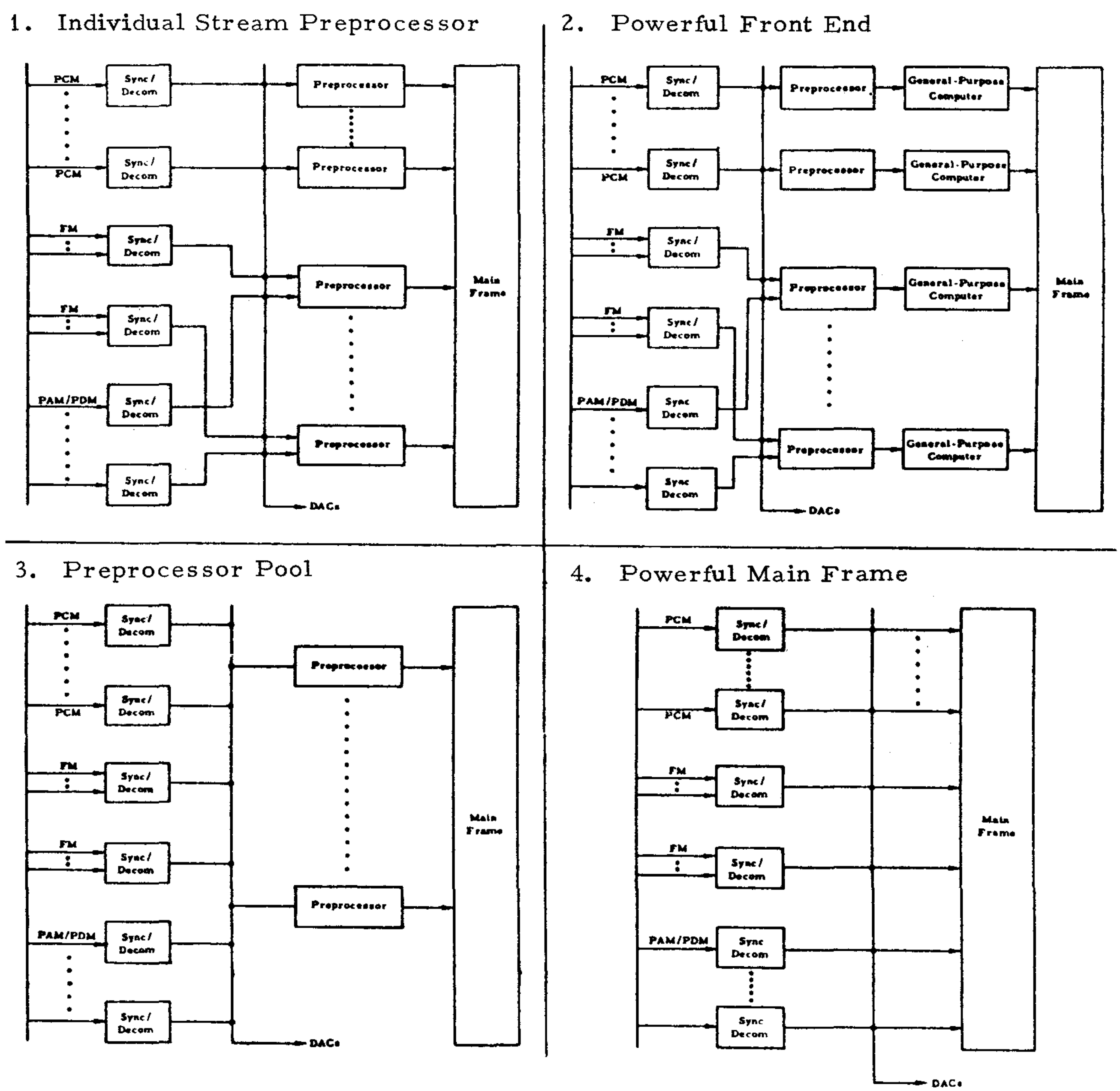


Figure 1. Configuration Overview

Table 3. Salient Features of the Four Configurations

Configuration Description	Advantages	Disadvantages
1) Individual Stream Preprocessor • Preprocessor per link • Main frame real-time and batch • Similar to SAMTEC existing approach	• Little front-end software • Moderate amount of simple front-end hardware • Extra growth capability within most links • Independent links	• Main frame software must handle real-time and batch
2) Powerful Front End • Preprocessor per link • General-purpose computer for real-time processing • Main frame - batch processing	• Critical real-time functions accomplished in front end • Main-frame software simplified • Independent links • Extra growth capability within most links • Potential batch load support by general-purpose computer	• Two different computers require programming support (e.g., main frame and general purpose) • Additional front-end hardware
3) Preprocessor Pool • Shared loading by the preprocessor • Main frame real-time and batch loading	• Little front-end software • Share loading by the preprocessor implies minimum front-end hardware required	• Growth capability within links requires additional preprocessors • Main-frame software must handle real-time and batch • Complex front-end hardware to allow shared preprocessors
4) Powerful Main Frame • Minimum front-end functions • Main frame heavy real-time and batch loading	• Least amount of front-end hardware and software • Simple setup and control • Only one computer requires programming support	• Main frame must process high volume of real-time data in addition to the batch loading • Main-frame hardware and software most complex

Applying these metrics to each of the four configuration is shown in Table 4. The metrics were combined using the composite function:

$$F_{(M)} = 0.23\ M_F + 0.16\ M_G + 0.26\ M_C + 0.18\ M_H + 0.17\ M_S$$

Table 4.

Configuration	Follow-On Confidence (M_F)	Growth Potential (M_G)	System Cost (M_C)	Hardware Complexity (M_H)	Software Complexity (M_S)
Individual Stream	1	0.52	0.99	0.75	0.80
Powerful Front End	1	0.83	0.95	0.50	1
Preprocessor Pool	1	0.52	1	0.30	0.67
Powerful Main Frame	0.75	0.28	0.84	1	0.50

This resulted in selection of the powerful front end configuration. The evaluation results for each of the configurations were:

Individual Stream - 0. 84
Powerful Front End - 0. 87
Preprocessor Pool - 0. 74
Powerful Main Frame - 0. 70

Telemetry Consolidation Results The powerful front end configuration was selected as the best for SAMTECs particular requirements. Figure 2 illustrates the selected configuration primary concepts. Based on this configuration and associated analysis a detailed specifications were developed for eventual procurement by SAMTEC.

The salient characteristics of the recommended powerful front-end configuration include automated setup and validation, identical PCM, PAM/PDM, and FM links alternatively feeding into dual-port preprocessors, a general-purpose minicomputer in the front end for critical real-time processing and limited stand-alone capability, dual main-frame computers for batch, timeshare, and data basemanagement processing as well as spooling front end real-time display, recording data to the applicable peripherals, and a real-time control and status mission operator function.

The automated setup concept is to provide approximately 90 to 95 percent automation of the setup process with the remainder accomplished manually via interactive terminals with printout instructions, etc. For a given test the required setup configuration data (hardware

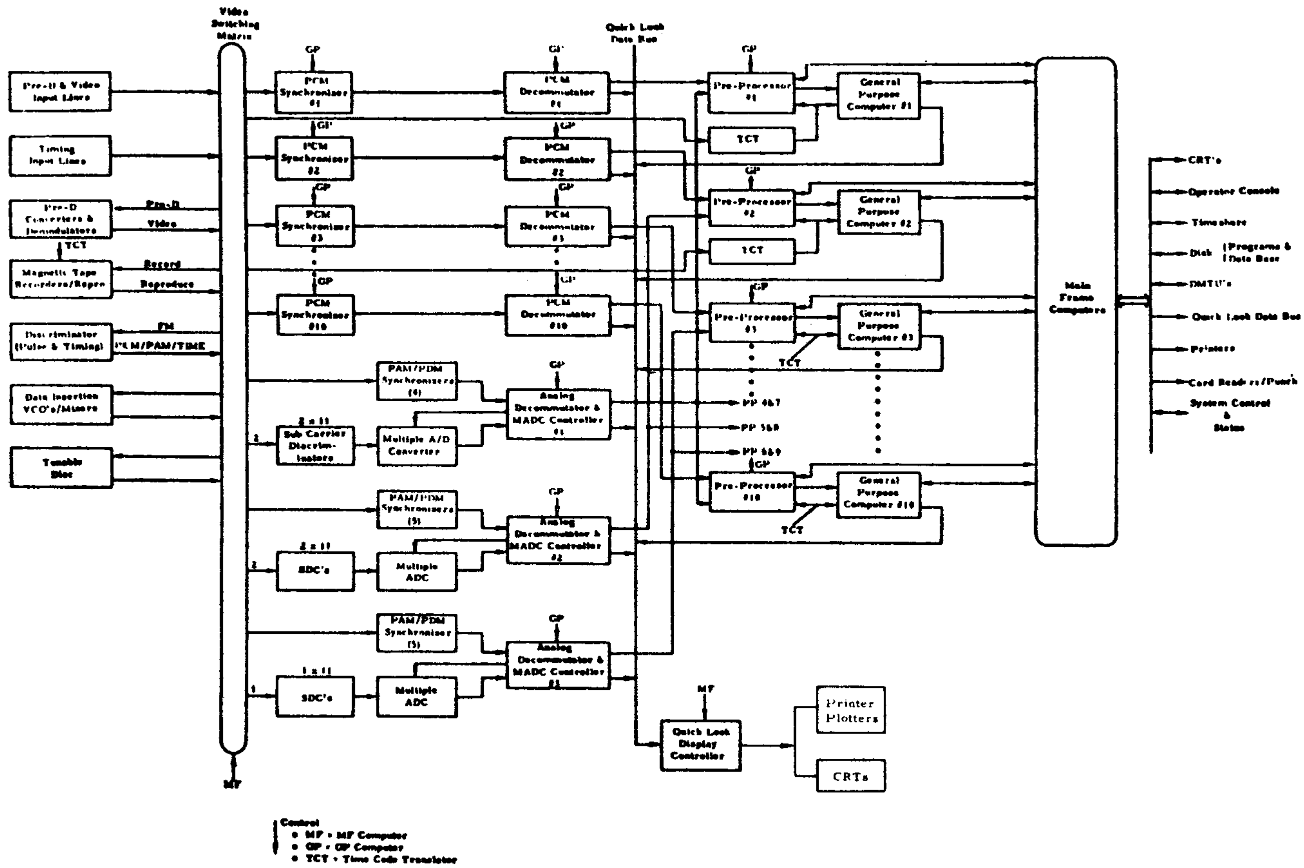


Figure 2. Powerful Front End - Consolidated Telemetry System

and software) will be contained within the Telemetry Data Base, located in the main-frame computers. The main-frame will utilize this data to select the appropriate and available equipment, send control data to the video switching matrix and quick-look display controller, and send programs and control information to the front-end general-purpose computer. The general-purpose computer will, in turn, properly set up the link subsystems which include the synchronizers, decommutators, andpreprocessors. The validation process will be initiated by the main-frame computer to provide TDVS-simulated mission inputs to the previously set up link(s).

Each of the preprocessors can accept either a PCM or an analog link. This allows for a minimum number of preprocessors and generalpurpose computers since it is not likely (nor required) that the PCM and analog links will operate simultaneously. Each of the PCM links is to be identical and capable of handling the worst-case loading as in each of the analog links. The preprocessor has a direct data link with the main frame for tOO percent recording of the telemetry stream. This 100-percent recording function is intended to minimize the need for time consuming playback modes originating from the analog tape recording.

The general-purpose computer does all of the critical processing for real-time functions such as range safety, event detection, engineering unit conversion, display, limit checking and status control. It is also required that the general-purpose computer have stand-alone capability (independent of main-frame computer) for data processing such as tape dubs, tape formatting, software development, and during real-time to provide range safety data in case of a main-frame computer failure.

The dual main-frame computers are primarily intended for batch and timeshare modes with limited real-time, data spooling from the preprocessor and general-purpose computers to display and recording peripherals. The spooling function was introduced to allow efficient display and recording peripheral utilization without complex switching matrices for the front ends. It is planned that either the main-frame or general-purpose computers will process the real-time control and status functions.

In addition to the normal data processing center computer operating function, there is a telemetry mission operating function. The intent of this real-time status and control function is, to ensure that the front-end system(s) are properly operating and to perform system control. The status data that should be displayed to the real-time telemetry controller include: synchronization status (bit/frame), realtime diagnostics, general-purpose or main-frame computer overflow, 100 percent data recording channel, general-purpose/main-frame data channel, and voice data on inputs/equipment, etc. The real-time control capabilities should include stream input selection, stream to main-frame selection, decommutation of format rate changes, recording and print changes.

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