TELEMETRY INTEGRATED PROCESSING SYSTEM OPERATIONAL OVERVIEW

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ABSTRACT

The Telemetry Integrated Processing System (TIPS) at the U.S. Air Force Western Space and Missile Center (WSMC), Vandenberg AFB, California, is a large scale, computer based, telemetry decommutation and data processing system. This system is utilized to process telemetry data from numerous missile and aircraft programs supported at the WSMC. In the late 1970's and early 1980's, while TIPS was under development, some information on this unique system was presented at the ITC. This paper will present an overview of the operational system as it exists today. Hardware and software components will be discussed. A presentation of the standard, no development cost, features available to Range users will be made. A summary of the current missile/aircraft telemetry systems that must be supported will be included along with some of the special processing developed for these systems. The primary emphasis will be an overview of the system capabilities and the types of telemetry processing encountered in the operational WSMC environment.

INTRODUCTION

The Telemetry Integrated Processing System (TIPS) processes telemetry data resulting from support of ballistic or space missile launches, aircraft fly-bys and/or orbiting satellites. Data may be in real-time or input from wideband analog tapes (playback). TIPS is capable of supporting activities associated with prelaunch, launch and post launch operations and, in addition, supports batch and timesharing environments. TIPS provides a hardware and software system upon which these functions can be performed for all Range users.

Figure 1 illustrates the flow of telemetry data at the Western Test Range. The primary signal acquisition points are the Vandenberg Telemetry Receiving System (VTRS) located on the peak of Oak Mountain on South Vandenberg AFB and the Pillar Point Telemetry Receiving System (PPTRS) at Half Moon Bay, south of San Francisco. Data are routed to Building 7000 located in the central portion of Vandenberg AFB. Analog recording, signal detection and distribution to the TIPS is provided by the Telemetry Analog Equipment Room (TAER). Also located in Building 7000 is the Telemetry Decommutation Validation System (TDVS) which is a versatile PCM simulation system.

SYSTEM HARDWARE

Figure 2 is a block diagram of the TIPS. TIPS utilizes programmable Telemetry Front-Ends (TFEs) to perform telemetry signal processing, Telemetry Preprocessor (TPP) computers for most real-time data processing functions, central Mass Storage Controller (MSC) computers for history recording of data, Configuration and Interface Control (CIC) computers for real-time system control support and Quick-Look Display Area (QLDA) computers for user display and control. These real-time computers and their supporting system software are interconnected such that any required subset can be scheduled in support of any Range user. Those computers not scheduled for one user are available for concurrent support to other users and activities. All TIPS real-time computers are Gould/SEL series 32 computers. There are 21 of these 32 -bit word scientific processors in TIPS. TIPS is digital throughout from the point of serial to parallel conversion in the case of PCM and from analog to digital conversion for PAM/PDM/FM data.

A Control Data Corporation CYBER 173, the Near Real-Time Batch Processor (NBP), provides the large computational capabilities needed to support multiple data reduction and analysis activities, batch operations and timeshare operations.

Telemetry Front-End

There are eight PCM and three analog TFE’s in the TIPS. The analog units are switched between the processing strings as needed. The TFE equipment provides for bit, word, frame, and sub-frame synchronization, decommutation, data compression, and data time tagging. PCM data streams from 64 bits/second to 5 million bits/second can be accommodated. Each analog front-end unit contains 22 analog-to-digital converters and five PAM/PDM synchronizers.

The PCM equipment consists of “off-the-shelf” Aydin-Monitor 335 Bit Synchronizers, 1126B Stored Program Decommutators, and 595 Data Compressors.

A key feature of the TFE is the insertion of data time tags as soon as possible following digitization or decommutation. The time tag may have a resolution as fine as 10 microseconds when an IRIG G time code is utilized. The time tag stays with the data sample through all system processing thereby eliminating ambiguities between measurements undergoing different levels of processing.

The output of the TFE consists of a Compressed Data and Interface (CDI) and a Raw Data Interface (RDI). The CDI data is routed to the TPP. The RDI data is routed to the Quick-Look Display Areas as well as to the TPP.

Telemetry Processors

The TPPs are Gould/SEL 32/55 and 32/75 computers each with a 40 megabyte local disk. The TPP receives telemetry data from the TFE through three CDI ports and one RDI port. One CDI is normally used for data processing and the other two for selected measurement history file recordings. The RDI is utilized for 100 percent raw data history recording and for short burst full frame processing. The TPP shares memory with the MSC and the CDI/RDI inputs directly to this shared memory so that a minimum of data movement is required.

As the name suggests, the TPP performs preprocessing in support of system functions such as real-time displays, history recording and outputs to the WSMC Range Safety processors.

System Control Processing

a. Mass Storage Controllers

There is one MSC for each pair of TPPs. The MSC computers are Gould/SEL 32/75 processors. Each MSC has a 40 megabyte local disk and three 300 megabyte disks. The MSC interfaces with the TPP via shared memory and with the CIC through a High Speed Data (HSD) inter-bus link.

The MSC works in conjunction with the paired TPPs to provide for history file recording. The MSC also provides for the interface of the real-time processors with the Near Real-Time Batch Processor, CYBER 173.

b. Configuration and Interface Controllers

Each system (A, B, and C) includes one CIC. The CIC computers are Gould/ SEL 32/75 processors with two local 40megabyte disks. The CICs also provide system access to a pool of peripheral card readers, card punch, line printers, and 9-track digital tape units. The CIC interfaces with the Quick-Look Display Area via a General Purpose Device Controller (GPDC) inter-bus link.

The CIC functions include central system control of the mission data processing and flow. The CIC also provides console support.

c. Status, Display and Control Console

The Status, Display and Control Console (SDCC) is the primary point of human interface for system configuration and control. The SDCC contains the CIC control terminals. There are numerous lighted displays to monitor the status, and switch-panels to control the routing of data. There are also two plasma display devices which may be switched to any Quick-Look Display to monitor mission data.

Quick Look Display Areas

The Quick-Look Display Areas (QLDAs) are the primary user interface to the system. Each of the six QLDAs contains a Gould/SEL computer with a 40 megabyte local disk. Display devices in each QLDA are IEC plasma displays (3) and Gould 5200HS electrostatic printer/plotters (5). Each QLDA can receive data from two input sources (links). Plasma and printer displayed data is generally processed data received from the TPP. Plotter data is received on the RDI bus directly from the TFE.

The primary function of the QLDA is to provide the users with control and display of their mission data.

SOFTWARE COMPONENTS

A functional diagram of the TIPS software components and their interfaces are depicted in Figure 3.

Tips Telemetry Compiler

The operation of TIPS is adaptable to each user via the vehicle and link-oriented Run-Time Files (RTFs) which are generated on the NBP using the TIPS Telemetry Compiler (TTC). The RTF for a given operation is a specific set of process control tables which define unique mission applications of the general-purpose TIPS hardware and software. Once assembled, the run-time files are distributed to all applicable elements of the real-time system during operation initialization. These files provide the set-up parameters associated with preparing a system to process user data. These files also become the basis for future missions allowing rapid response to new requirements.

The TTC processes a unique set of keywords called the Telemetry Source Language (TSL) which describe the processing of a telemetry link from from TFE setup, to measurement processing, history recording, display formats, and system resource assignments.

Distributed Operating System

Control over the real-time system is provided through the Distributed Operating System (DOS). DOS is an extension of Gould/SEL's Real-Time Monitor (RTM) operating system and provides for centralized monitoring and control of the Gould/SEL series 32 computers, the telemetry front-ends, the system display and recording equipment, system control consoles, and all other peripheral equipment.

Control over the real-time system is exercised by human controllers interacting through the CIC computer via DOS. These controllers, using the TIPS consoles, can direct the entire system operation and, through DOS, monitor all aspects of that operation. They can also monitor and modify run-time file parameters to ensure the best possible support for all the various users who may be utilizing TIPS at any one moment.

Real-time Applications

While DOS permits control of the operation of the TIPS real-time system, and the RTF defines the specific processing which is done by applications functions within that system, the actual mission oriented processing is accomplished by Real-Time Applications (RTA) software which operates in the TPP, CIC, and QLDA computers to:

-Process telemetry data.
-Record the data in central history files.
-Display the data.

Flight Analysis Applications

Considerable preflight and post flight data processing is accomplished on the NBP (CYBER 173) which is functionally separated from the TIPS real-time system. This separation permits the CYBER to perform tasks, which include execution of the telemetry compiler, post flight data reduction and special data analysis as required to support each Range user. Special interfaces permit the NBP to communicate with the TIPS real-time system to receive data directly from central history recording.

STANDARD SYSTEM FEATURES

The TIPS was basically designed to support DoD IRIG telemetry formats. The telemetry front-end hardware and system processing features were selected with the criteria for supporting the test programs conducted at Vandenberg AFB (mid-to-late 1970's). Some of the primary features available as standard items are listed here. It must be noted that effective, efficient support depends on the judicious selection of data compression criteria and processing and display options. The design of TIPS provides “hooks” so that special processing and display requirements can be easily developed and integrated into the standard system.

TFE Features

PCM data stream from 64bps to 5Mbps.
Two synchronous sub-commutators.
One embedded stream strip-out with fill pattern detection.
Minuteman word synchronization with special computer word look-ahead features.
Word sizes from 1 to 16 bits.
Limited computational algorithms.

FM continuous data sampled from 100sps to 125Kbps (250ksps aggregate).
PAM/PDM sync/decomm, 5 signals with sub-commutators.

Data Compression, 7 algorithms.

TPP Features

Hardware measurement concatenation up to 32 bits.
Software measurements generation up to 64 bits from non-contiguous samples.
Software decoding of indexed parameters.
Limit checking on all measurements (up to 32 bits).
  Compares current measurement value to pre-defined upper and lower limits. Two sets of limits available, Standard and Critical, modifiable by user in real-time.
Event detection - 128 sequences of 32 events containing up to 16 conditions.
  Compares vehicle activity to pre-defined criteria.
  Generates messages and executes commands as a result of pass/fail criteria.
Sequence Command Blocks - up to 256 sets of prestored system commands
Full frame data acquisition and formatting
History file control -
  Composite - all system control, event and limit messages.
  Compressed - two files of selected decommutated or generated measurements. Provides time tagging to a 10 microsecond resolution.
  Raw - 100 percent data for post test. Provides time tagging to 1 millisecond resolution.

Special processors -
- Range Safety outputs for Telemetry Inertial Guidance (TMIG) and Telemetry CRT displays (TMCRT).
- Embedded asynchronous data synchronization and decommutation.
- Derived measurement processing.

QLDA Features

The six Quick-Look Display Areas provide the user with a flexible set of data displays. The user controls the processing of data in the QLDA through command input at the plasma display devices. All display formats are pre-defined in the run-time file and may be modified, to some extent, in real-time. Data is displayed in a variety of modes: octal, decimal, hexadecimal, percent, and engineering units. Processed data is displayed on the real-time printer and plasma displays while raw data is displayed on stripchart time-history plots.

To accommodate unique processing and display requirements, special processor software modules may be developed and easily integrated with the standard QLDA features.

Plasma Displays

There are three display devices in each QLDA. The plasma displays 32 64-character lines on an 8.5" by 8. 5" screen.

- Up to 256 display pages.
- Fixed pages -
  - Critical limit failures.
  - Event messages.
  - Equipment and processing status.
- Variable pages -
  - User defined.
  - Up to 29 measurements per page.

Printer Displays

One or more of the 5 printer/plotter devices in each QLDA may be designated to receive print reports. The devices are capable of up to 5000 lines per minute. The writing width is 10.5" with 132 character positions.

Up to 127 report formats may be defined. Report formats include those for limit failures, full-frame prints and measurement status reports. Fixed format outputs are provided for event messages, system commands and status, plasma hard copy and special reports.

Plotter Displays

One or more of the 5 printer/plotter devices in each QLDA may be designated to provide stripchart time-history plots. The plot format is completely definable in the run-time file. The plot device provides a 10.5" display area with 200 by 250 plot points per square inch. This translates into 2112 plot points (nibs) per scan line with 250 scan lines per inch. The plot paper speed can be selected from 0.25 inches-per-second to 10 ips in 0.25 increments. The entire plot image including channel boundaries, grid lines, time marks, and data is drawn on the electrostatic device creating a complete and permanent image.

- Up to 127 plot formats.
  - Up to 16 measurements per format.
  - Channel widths from 1 to 2112 nibs.
  - Overlapping channels allowed.
- Programmable features include trace widths, background grids, trace identifiers, timing marks and annotation positions.

CURRENT TELEMETRY SUPPORT EXAMPLES

TIPS is involved in a wide variety of telemetry support. The primary programs currently being supported are outlined below with some comments on the unique features that must be considered and the special process modules that have been developed. Figure 4 summarizes the primary telemetry support characteristics.

Minuteman II/III

The SAC operational testing of Minuteman II and III has been supported at the WSMC for more than 20 years. Three distinct types of support are provided: boost vehicle, payloads and Airborne Launch Control System (ALCS).

The booster 345.6Kbps PCM telemetry contains numerous unique processing considerations. Synchronization must consider a three bit trailing word sync pattern. This pattern has three unique values: frame marker, analog word and computer word. Computer words do not occupy specific word time slots but can preempt analog words at any time. The computer words must be detected by “looking ahead” at the word sync pattern. Special processors for booster data include Range Safety TMIG and prelaunch computer word event detection for special reports.

Minuteman payload telemetry has a variety of configurations with straight PCM and hybrid PCM/FM systems. Bit rates run from 29.7Kbps to 43Kbps. Payload support remains within the standard TIPS capabilities.

The ALCS outputs a communications type message which is handled by TIPS as a PCM wavetrain. Two bit rates are utilized, 64bps and 1300bps. Special process software decommutation and report generators have been developed for ALCS.

Titan 3

The Titan 3 booster uses PCM telemetry at 384Kbps. TIPS support includes up to 28 plot formats in real-time and a detailed event sequence.

When an inertial guided payload boost stage is included in the launch configuration, the 62.4Kbps PCM signal is processed to provide Range Safety with TMIG data.

Peacekeeper

The Peacekeeper booster telemetry is a 1.6Mbps PCM wavetrain. Three strapping formats are utilized with programmed switches occurring during flight. Embedded within the basic frame are three multiplexed buses. The primary data contained in these buses is from the guidance computer. Software decommutation schemes are utilized to format the mux bus data for processing and display. Special processing modules have been developed to process unique measurement reports and to software decommutate embedded data for stripchart displays. TMIG data is also processed for Range Safety. The booster support requires multiple run-time files due to the extensive number and types of data processed and the large number of plot displays (approximately 150) required.

Peacekeeper payloads utilize PCM telemetry ranging from 100Kbps to 345.6Kbps. Interleaved real-time and delayed data is transmitted.

ASAT

The 128Kbps boost vehicle telemetry used by ASAT appears to be a straightforward PCM wavetrain. However, the embedded guidance data uses a “semi-synchronous” scheme which requires examination of additional information to determine which half of the data is in synchrony with the sub-frame count. Two analog and five guidance strapping formats must be accounted for. Special process software is utilized to provide engineering unit conversions requiring approximately 20 different conversion algorithms as well as Range Safety TMIG and TMCRT data.

ASAT also utilizes a multiplexed FM link which switches to a 128Kbps PCM signal for short periods of time. The PCM signal is processed for plotting and history files.

The ASAT payload uses a unique 10Kbps PCM wavetrain. The bit rate is constant but the frame length varies in relation to a vehicle function. In addition, the index for sub-commutator measurement identification is not an ordinary counting ID and can appear following the sub-commutator word time slot rather than prior to it. Five strapping formats are also used. Special processing modules are utilized for processing and display.

Space Transportation System (STS)

Current plans are to support the STS orbitor during the ascent phase for Range Safety TMIG and TMCRT. The STS PCM telemetry is primarily 192Kbps. A switch to 96Kbps is made for satellite retransmissions. The downlink PCM wavetrain contains two asynchronous data streams for guidance computer data in addition to the basic operational interface data. The downlink stream may be switched to 128 different strapping formats. Only a small number of these are expected to be supported in TIPS. Special process software has been developed to provide sync and decomm of the embedded computer data and to provide TMIG and TMCRT data to Range Safety.

Minuteman I

The Minuteman I booster is utilized for a wide variety of ballistic payload test programs. The booster telemetry is currently a multiplexed PAM/FM system. At least one of the FM channels is modulated with a low rate PCM wavetrain. TIPS has been assigned the PCM processing while the PAM/FM is primarily supported in the TAER. Conversion from the PAM/FM to an IRIG PCM system is currently underway.

Minuteman I payloads run in the range from PAM/FM systems to PCM wavetrains up to 864Kbps. While most payloads are straightforward configurations, many unique situations are encountered. The most common non-standard features found are multiple interleaving of real-time and delayed signals, and multiple asynchronous embedded data streams.

SUMMARY and CONCLUSIONS

The TIPS provides the primary telemetry data processing support at the WSMC. It is anticipated that the system will continue to provide the USAF and other using agencies with comprehensive support for many years to come. The designed-in capability to develop software special processors ensures that future telemetry data processing requirements can be satisfied. A program of system hardware and software maintenance and modification provides for a continuing improvement in the reliability of support and a higher level of standard system capabilities.

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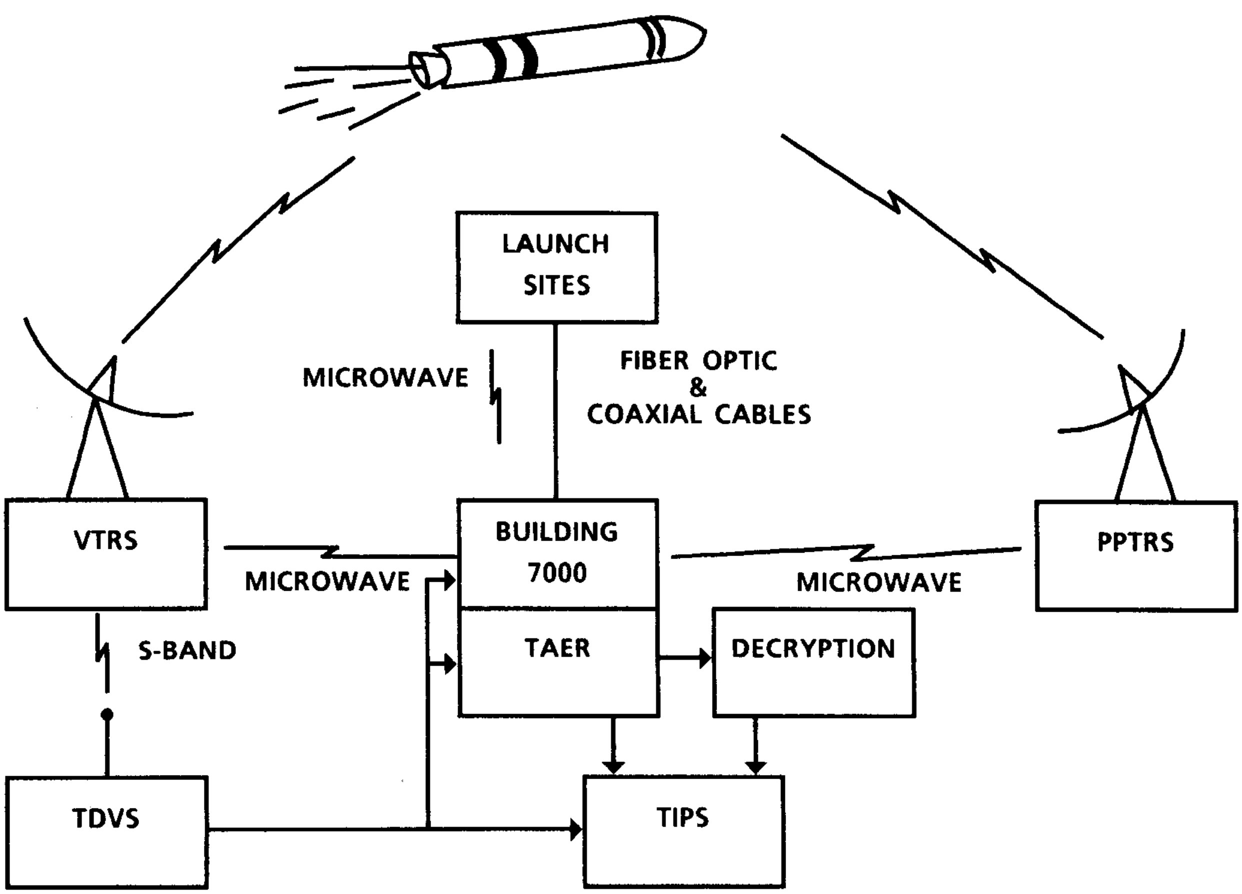

Figure 1. WTR Telemetry Flow.

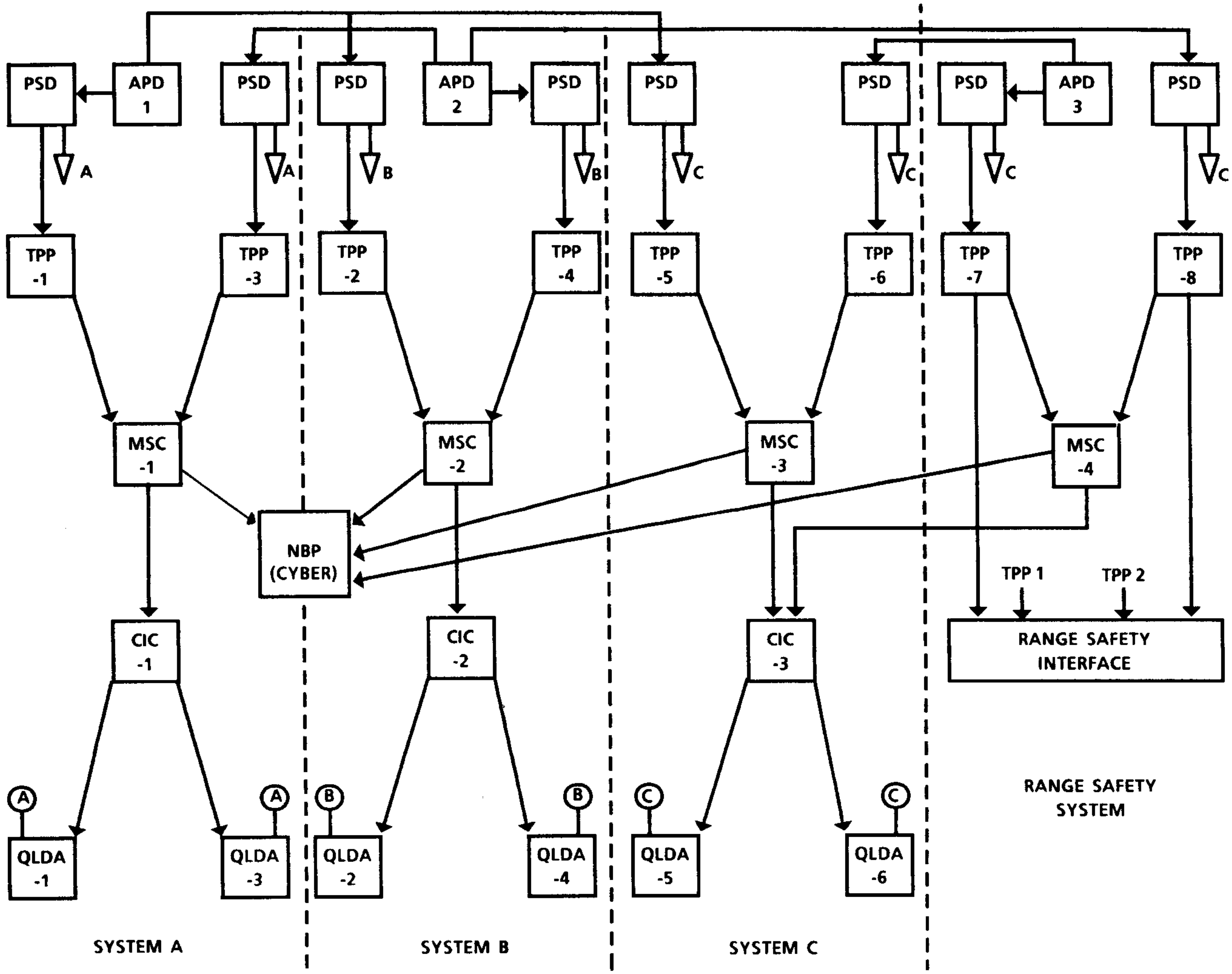

Figure 2. TIPS Diagram.

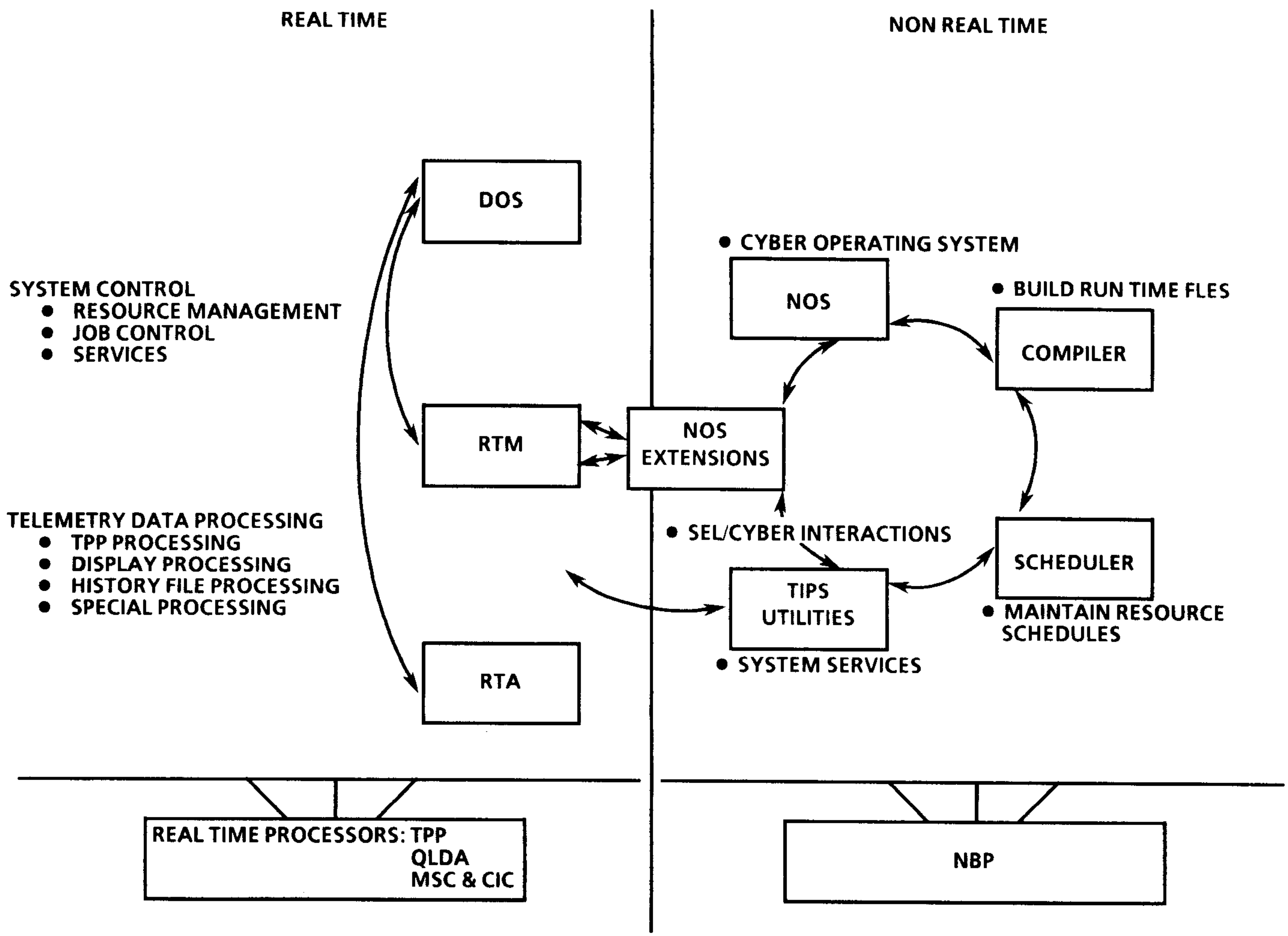

Figure 3. TIPS Software.

MINUTEMAN II/III			
BOOSTER	PCM	1 LINK	345.6K
PAYLOAD	PCM/FM	1-3 LINKS	29.7K/43K
ALCS	PCM	2 LINKS	64/1300
TITAN 3			
BOOSTER	PCM	1 LINK	384K
AGENA	PCM	1 LINK	62.4 K
PEACEKEEPER			
BOOSTER	PCM	1 LINK	1.6M
PAYLOAD	PCM	1-3 LINKS	100K/345.6K
ASAT			
BOOSTER	PCM/FM	2 LINKS	128K
PAYLOAD	PCM	1 LINK	10K
TARGET	PCM	2 LINKS	128K/256K
STS - ORBITER	PCM	1 LINK	96K/192K
ATLAS - BOOSTER	PAM/FM	1 LINK	400-124K/90 X 1 0
MMI - BOOSTER	PAM/FM	1 LINK	2300-124K/60 X 10
PAYLOAD	PAM/PCM/FM	1-3 LINKS	30 X 10/864K

Figure 4. TIPS Primary Telemetry Support.