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SPACELAB OUTPUT PROCESSING SYSTEM ARCHITECTURAL STUDY

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FINAL REPORT

8 DECEMBER 1977

PREPARED UNDER CONTRACT NAS5-23438, MOD. 37
FOR GODDARD SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GREENBELT, MARYLAND 20771

OPERATIONS RESEARCH, Inc.

SILVER SPRING, MARYLAND

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1.0 INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

GSFC is implementing a capability to support non-time-critical data from Spacelab payloads. It does not include the support of OFTs and data processing for specialized payloads such as life sciences or space processing. The data processing functions to be performed are essentially the same as provided by the Information Processing Division (IPD) for automated Earth orbiting spacecraft. These functions both remove perturbations introduced by the acquisition system and verify, format, and forward the data to the experimenter's facility. The reduction, analysis, and long-term archiving functions are not described in this document because they are not the responsibility of the data processing facility.

In general, the flow of non-time-critical Spacelab payload data is as follows (see Figure 1-1) the instrument digital data is time division multiplexed and transmitted on the wide band Ku-band link via TDRS and the "bent pipe" to the GSFC processing facility. The salient characteristics of this operation are the following:

- Bit rates up to 50 Mbps can be accommodated.
- Real-time and on-board tape recorded data can be telemetered on wide band link.
- No ground recording capability exists at TDRS or GSTDN ground stations. A Domsat channel is used to relay the data to GSFC.
- Payload data for POCC real time processing analysis are telemetered via the wideband link or are stripped out from the wide band link at JSC.
- The wide band link contains all the required ancillary data. All data required for processing will be contained in that bit stream.

In the Spacelab data processing facility, the telemetry stream is captured, i.e., quality checked, accounted for, and recorded in real time. Subsequently, not in real time, the data are processed and distributed to users via tape or data transmission channels. The data processing operations are similar to those performed in IPD on free flier data, i.e., the data are format synchronized, time tagged, quality checked, decommutated, etc.

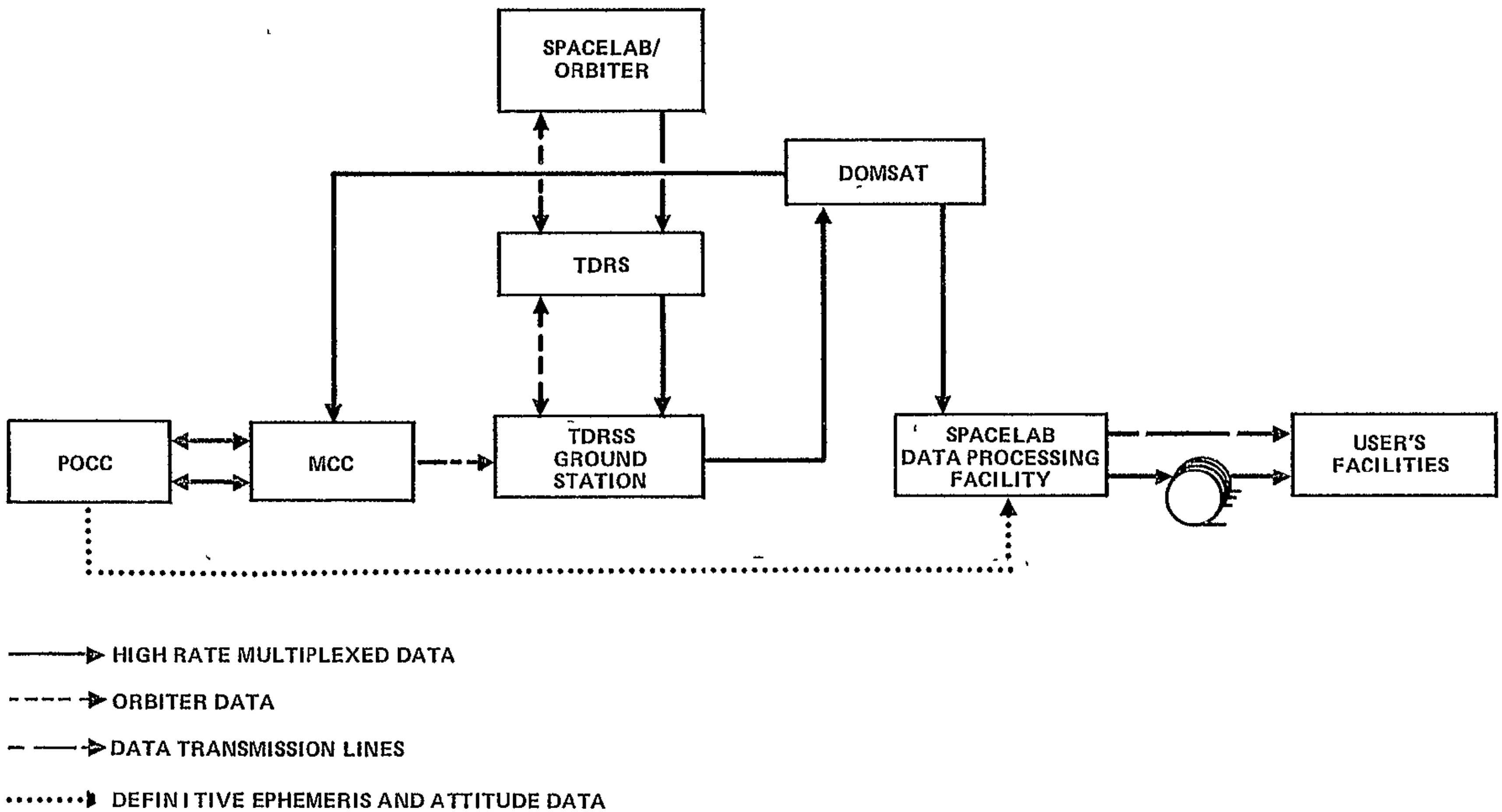


FIGURE 1-1. THE SDPF WITHIN THE OVERALL SPACELAB/ORBITER PROGRAM

Under the current concept, the Spacelab Data Processing Facility (SDPF) will consist of the following major functional elements

1. Spacelab Input Processing System (SIPS) previously known as the Data Capture System
2. Data Processing System
3. Mass Storage System
4. Output Processing System

Items 2 through 4 constitute the Spacelab Output Processing System (SOPS). The flow of data through these elements is depicted in Figure 1-2. The real-time wide band data are captured in real time for the duration of the mission. The data capture function includes recording of the raw bit stream on a suitable recording medium, such as a high density tape Subsequently, the recorded data are transferred to a working mass store, processed, and delivered to experimenters.

This study addresses itself solely to examining multiple SOPS architectures. The SIPS is not part of the SOPS architecture and will be referenced in this document only for the purpose of inputing data to the output processor

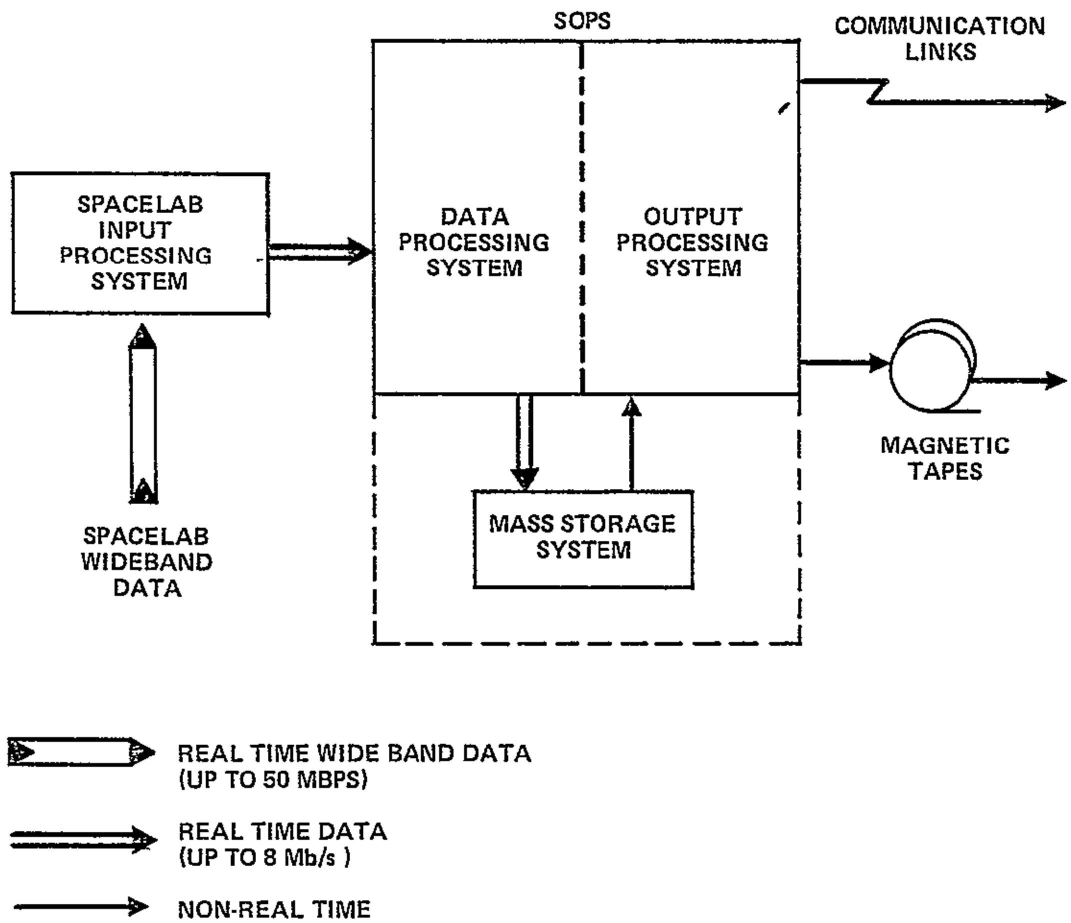


FIGURE 1-2 SOPS DATA FLOW

1.2 SUMMARY

This study presents different system architectures (Figures 6-3 and 6-34). These two architectures are derived from two different "data flows" (Figures 6-1 and 6-2) within the SOPS. The major differences between these system architectures are in the position of the decommutation function (the first architecture performs decommutation in the latter half of the system and the second architecture performs that function in the front end of the system). Another difference is that the first architecture uses High Density Tapes (HDTs) and the second uses standard 6250 bpi magnetic tapes.

So that the performance of these architectures could be examined, the system was divided into five stand-alone subsystems. (Work Assembler, Mass Storage System, Output Processor, Peripheral Pool, and Resource Monitor). Then the work load of each subsystem was estimated independent of the specific devices (CPUs, tape drives, etc.) to be used.

Next, the candidate devices were surveyed from a wide sampling of off-the-shelf devices. Then analytical expressions were developed to quantify the projected workload in conjunction with typical devices which would adequately handle the subsystem tasks.

All of the study efforts were then directed toward preparing performance and cost curves for each architecture subsystem (shown simplistically in Figure 1-3). Because the operating points of each subsystem cannot at this time be set exactly, it is necessary to interpolate between specific operating points. For example, (See Figure 1-3), it was found that in the Work Assembler (WA) at an operating point, R_1 (in Mb/s.), the WA would consume between "u_1" and "u_2" resources. This range of system utilization represented a range of costs between "a" and "b" dollars. If the study workload estimates are too low (even up to 100%), then the range of costs (at R_1 Mb/s.) could still be projected to be between "a" and "c" dollars. This sizing technique (known as computing a subsystem's utilization factor "u") was applied uniformly to all architecture subsystems.

It was found that the two architectures would function equally well. When each of their attributes were rated in terms of its intended function, the total scores of the two architectures were within (approximately) 5% of each other.

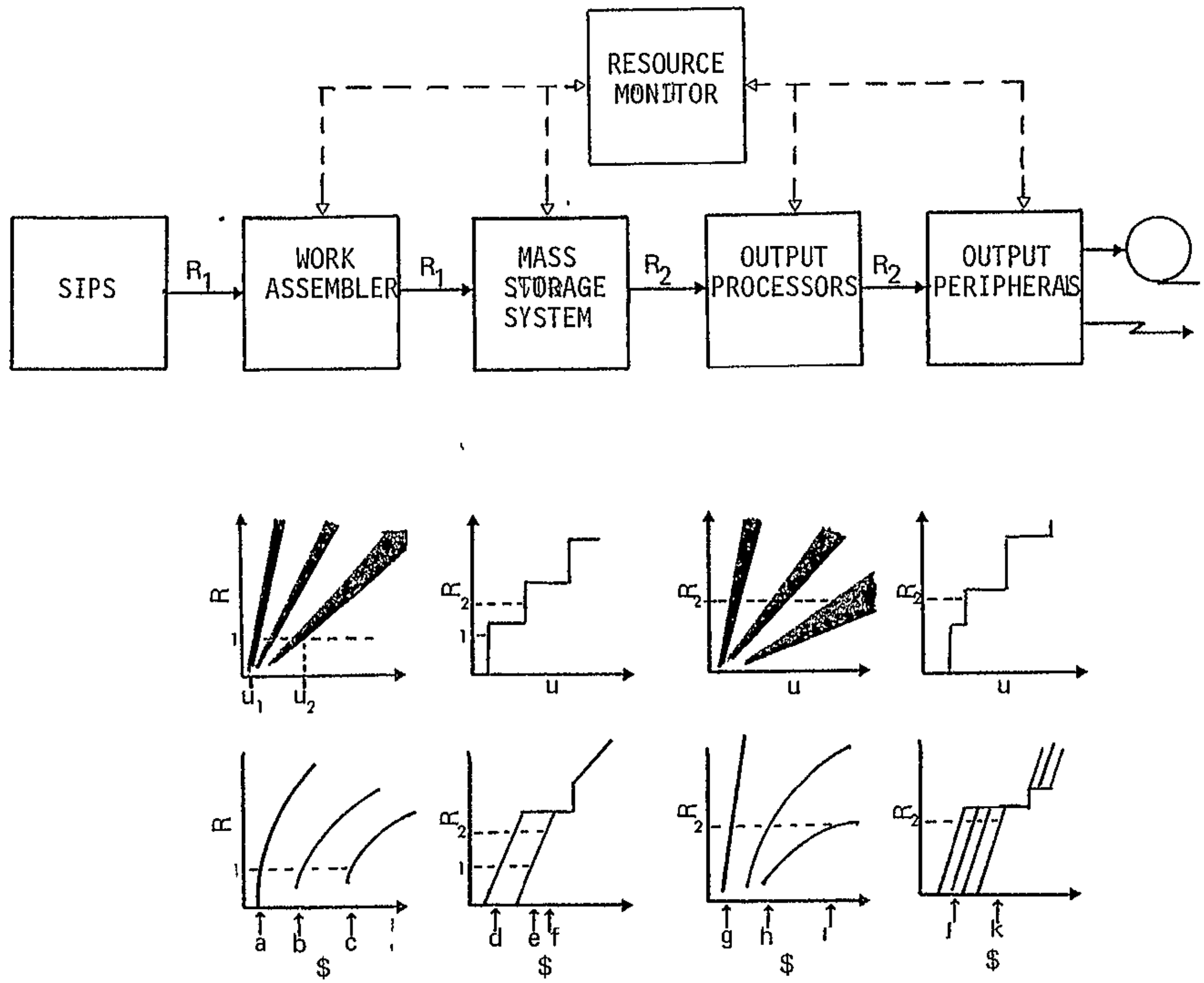


FIGURE 1-3. PERFORMANCE AND COST CURVES

In terms of costs, however, architecture number 2 was clearly more advantageous. Specifically design number 2 costs between 2.177 and 3.022 million dollars for hardware while architecture 1 costs between 2 337 and 3.400 million dollars.

2.0 SOPS SPECIFICATIONS

This section defines those specifications to be used in defining and analyzing various system architectures. These specifications are drawn from the Statement of Work, NASA/GSFC document Number X-560-77-56 entitled "Spacelab Payload Data Processing at GSFC," and an informal document entitled "Pulse Code Modulation Formats for Spacelab Experiments." Most of the specifications are functional in nature, but, where possible, quantitative information is used.

The statement of specifications is treated at two levels - those that are mandatory (as enumerated in Section 2.1), and those that are secondary or desirable (as stated in Section 2.2).

One overall specification is that any system architecture must be modular and expandable with the minimum of difficulty.

2.1 MANDATORY SPECIFICATIONS

2.1.1 Overall System Performance

This subsection relates to the data acquired by, contained within, and put out by the system. Initially, the specifications are stated as currently known and understood. From the quantitative information contained in that statement, additional data can be derived for use in later analysis. This data is in Section 5.

2.1.1.1 Input Data

Data are received into the SOPS from the SIPS. These data are both real-time and play-back data (from the HDT's originally used to record real-time telemetry).

The SIPS, as illustrated in Figure 2-1, will be procured separately from the SOPS High-rate Spacelab data will enter the SIPS at a maximum rate of 50 Mb/s. These data including GMT from the Spacelab are captured on high density tape recorders (HDTRs) in real time. At the same time that the incoming data are captured on the HDTRs, the data goes through a High Rate Data Demultiplexer (HRDM) where the original 18 Spacelab data channels plus the associated GMT are demultiplexed. The Frame Synchronizers (FSs 1 through 19) block incoming data and append the most recent GMT to the framed data. The outputs of the FSs are then sampled by the SIPS CPU (a minicomputer) for quality and other attributes. A running Quality Control summary is generated, and if the sampled QC falls below a predetermined level, a status message is created and sent to the Spacelab POCC at JSC.

Operationally, it is expected that low-and medium-rate experiment data will be passed onto the SOPS in real time. The high-rate experiment data will be slowed down in the SIPS and played back into the SOPS for subsequent processing (during the interval of time when the early Spacelabs cannot communicate with the ground - approximately 20 to 30% of an orbital time segment).

In the SIPS, the data is frame-synchronized and blocked as telemetry frames. The format[1] of the SIPS output data is shown in Figure 2-2.

The following parameters are applicable:

- Major frame rate is a binary function.
- If the size of a minor frame is m, and the size of a major frame is M, then
  $4m \lesssim M \lesssim 256\ m$
  $m \lesssim 4096$ bits
  or
  $m \lesssim 512$ bytes
- Minor frame efficiency e
  $70\% < e < 90\%$

1/Informal Documentation, "Pulse Code Modulation Formats for Spacelab Experiments".

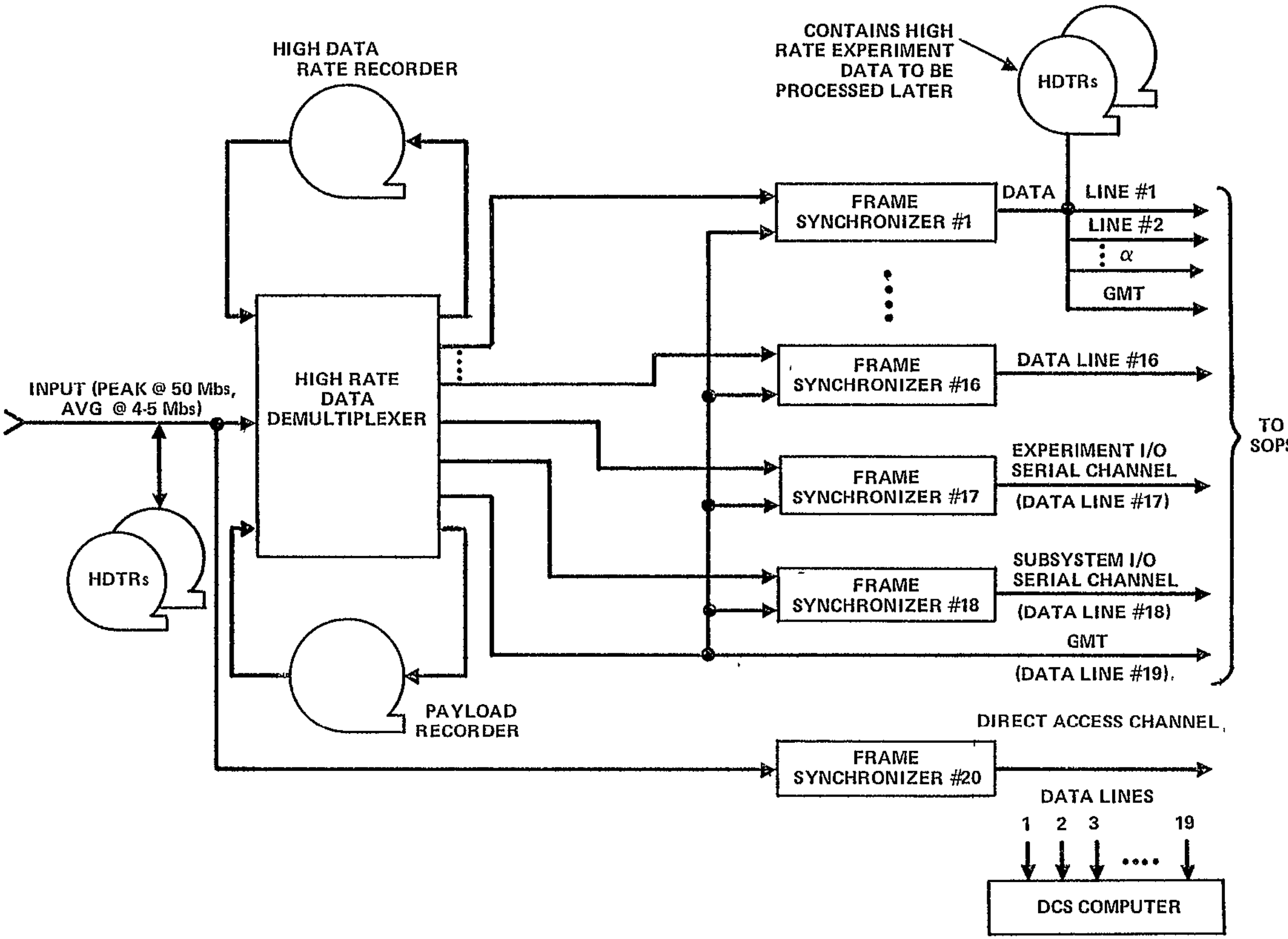


FIGURE 2-1. SIMPLIFIED SIPS BLOCK DIAGRAM

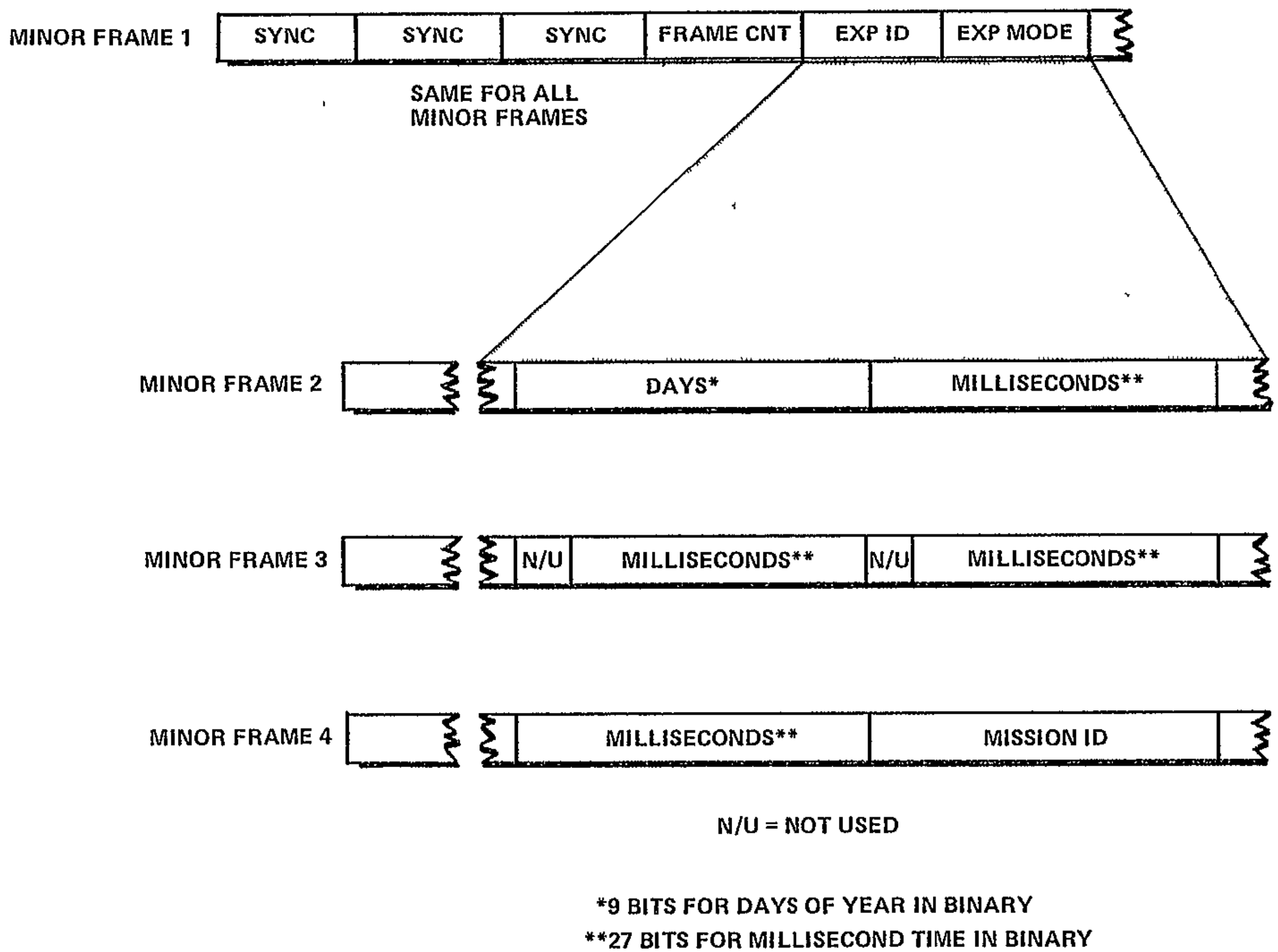


FIGURE 2-2. FRAME HEADER STRUCTURE FOR SPACELAB EXPERIMENT TELEMETRY

The data output from the SIPS is presented to the SOPS on 19 separate channels. Of these, 18 contain frame blocked experiment data and will appear in time as shown in Figures 2-2 and 2-3.

These frames will contain the following:

- Experiment data
- Experiment mode
- Mission ID
- Date and time
- Data quality check (TBD) information supplied by the DCS

These data are characterized as follows.

- Peak Data Rate - 48 Mb/s
- Average Data Rate - 4 to 8 Mb/s
- Data volume/seven day mission - 2 to 5 x 10^{12} bits
- An experiment mix profile as shown in Table 2-1

Of the remaining lines, two contain data from the Experiment I/O Serial Channel and the Subsystem I/O Serial Channel and will be received at the same time in a format similar to the first 16 data lines. These two data lines contain.

- Other experiment data (not to exceed 1 KHz)
- Attitude data (every 2 sec)
- Position data (every 2 sec)
- Other TBD ancillary data are characterized as follows:
    - Peak Data Rate - TBD
    - Average Data Rate (either 25.6 Kb/s or 51.2 Kb/s)
    - Data Volume/mission - TBD
    - Format - See Figure 2-4

The remaining line supplies GMT to the SOPS and appears in the same format with the following characteristics·

- Update Rate - 10 ms
- Data Rate - on demand
- Format - See Figure 2-2

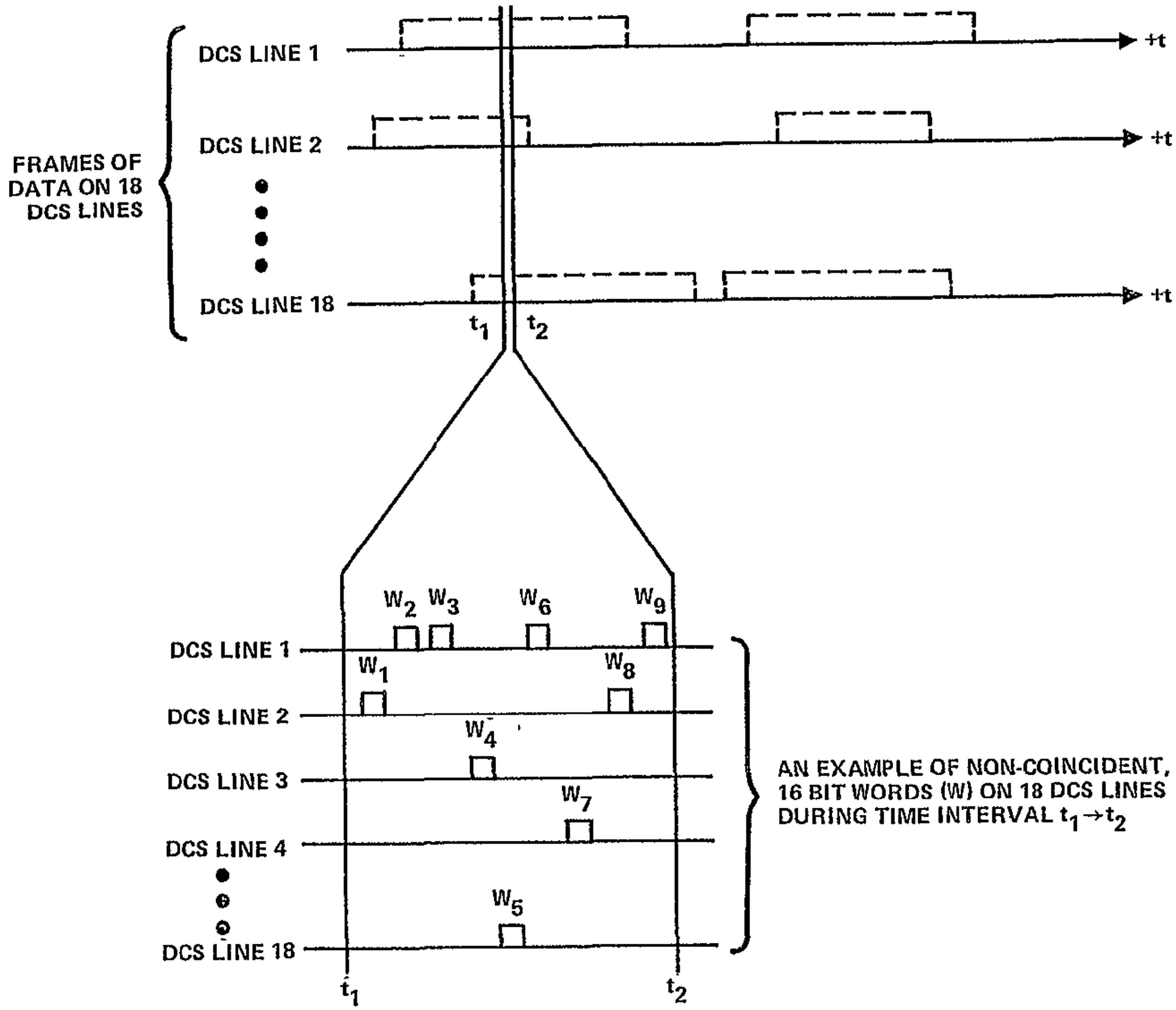
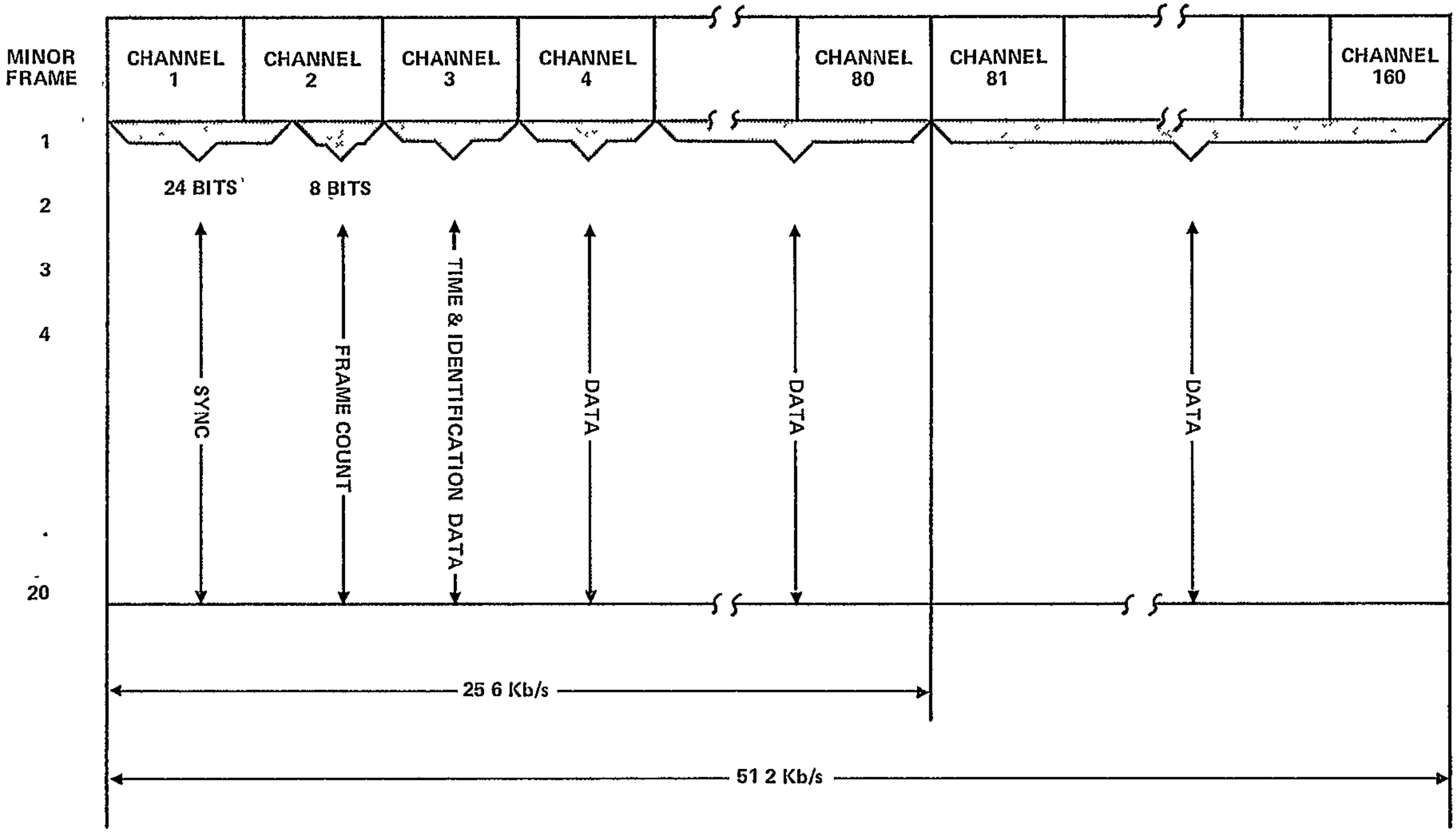


FIGURE 2-3. TIME RELATIONSHIP OF SOPS INPUT LINES

TABLE 2-1. A TYPICAL SL EXPERIMENT PROFILE

EXPERIMENT GROUP	BIT RATE RANGE	# EXPERIMENTS (TIME ON)	AVERAGE BIT RATE OF EXP. GROUP	% TIME ON	BIT RATE (MISSION AVG)
A	10 - 30 MBS	1 - 2 (part time)	20 MBS	2.5 - 5	1. MBS
B	1 - 10 MBS	1 - 4 (part time)	5 MBS	2.5 - 10	.5 MBS
C D	.1 - 1 MBS	4 - (full time) 8 - (half time)	500 KBS	50 - 100	2.0 MBS
E	10 - 100 KBS	10 - (full time)	40 KBS	100	.4 MBS
F	<10 KBS	20 - (full time)	5 KBS	100	.1 MBS



NOTE 16 BITS/CHANNEL, 16 BITS/DATA WORD

FIGURE 2-4. EXPERIMENT AND SUBSYSTEM I/O CHANGES MINOR/MAJOR FRAME FORMATS

To summarize, the SOPS must, during its data input phase, build minor frames, build major frames, and build buffer block data (associated with either blocks of minor frames or blocks of major frames sent to the mass storage system). The building of major frames (projected to be typically between 16 to 32 minor frames per major frame out of a possible 100 minor frames per major frame) should include fill data (for missing minor frames with appropriate fill flags set). When blocks of data are assembled (groups of minor frames or major frames), information such as the following should be generated:

- Block count
- Experiment ID(s)
- GMT time
- Experiment mode
- Number of minor frames per major frame
- Data quality flags
- Block statistics

2.1.1.2 Output Data

Output data is transmitted to experimenters as a set of "mission files" where each file contains all data relevant to a specific experiment.

The media for transmission will be:

- 1600 bpi Computer Compatible Tape
- 6250 bpi Computer Compatible Tape
- High density tape
- 56 Kb/s circuit and packet switched wire grade communication lines

The relevant data contained in the mission files will be:

- Experiment data
- Data quality information
- Attitude data
- Position Data
- Time validation information
- Ancillary telemetry data as required
- SOPS accounting data

The volume of output data is characterized as:

- 1600 bpi CCT - 50% to 10%
- 6250 bpi CCT - 20% to 25%
- HDT - 10% to 15%
- 56 Kb/s line - 20% to 50%

As an off-line function, data for each experiment must be available for 6 to 12 months after completion of the mission.

2.1.1.3 System Throughput

The system throughput is defined in terms of the maximum average input data rate, which is 8 Mb/s. The average throughput data rate will be between 0.5 and 1 times this rate (i e., between 4 Mb/s and 9 Mb/s). Note: mission duration is projected to be between one week and one month. The time allowed for output processing is projected to be between two weeks and two months.

An instantaneous peak input data rate of up to 50 Mb/s will be supplied by the SIPS. This rate may be slowed down to any required value as long as the average throughput rate is not reduced.

2.1.2 Data Processing

This group of mandatory specifications consitute the primary functions performed on incoming Spacelab data. The order in which they are presented in this section does not imply a mandatory data flow.

2.1.2.1 Input Data Accounting

The data accounting functions will be required to record both the input file statistical information and output file statistical information. Input file accounting tracks data such as:

- flags from the data capture system
- file start and stop times
- file size
- file location
- file name
- creation date

A "file" is defined as a homogeneous collection of experiment data from only one experiment.

2.1.2.2 Output Data Accounting

This function relates to the ability to retain information about the experimenter files and information regarding facility production status. This function also provides the capability for generating a series of accounting reports for the SOPS. Reports will be generated to determine the content of the telemetry, Ephemeris/Attitude and decommutation data files processed through the system.

The accounting processor will be used in conjunction with the query system, to locate and bring data on line for processing from past or present Spacelabs. The data base inquiry system (Query) will provide the capability of interrogating the data base directories for information concerning the different data files. The information returned should contain at least start and stop time of data, location of data (on line file name or off line tape and file no.), and general status pertinent to the inquiry. This accounting information is to be available for any Spacelab up to one year after mission.

As a minimum, the accounting application would:

- Keep records of all input data on a file basis
- Keep records of all output data on a file basis
- Inform the user of any missing data
- Provide production status data
- Keep records of previous spacelabs for at least one year

2.1.2.3 Quality Check

Quality checks on data within the SOPS would, as a minimum, assess both input and output quality. Input data quality assessment shall consist of but not be limited to:

- Identifying missing or incomplete data frames
- Identifying the position of missing or incomplete data frames
- Identifying error codes passed on to the system by the SIPS

Output data quality assessment shall consist of but not be limited to:

- Identifying missing or incomplete data frames
- Identifying the position of missing or incomplete data frames
- Identifying error codes passed on to the system by the SIPS
- Identify all subsequent errors unique to output data processing

2.1.2.4 Decommutation

The decommutation process produces ordered experiment data files. The input data is decommutated after it has been "edited". The decommutation process shall be performed according to a decommutation "map", which identifies all commutated data elements as received from the SIPS. The merging of ancillary data (as specified in another section) may be performed in parallel with this function.

In addition to decommutating the experiment data, the following shall also be performed.

- Sort by Experiment
    - The 16 experiment channels from the SIPS could be either dedicated to one experiment or contain telemetry frames from several experiments.
    - The sub-system and experiment I/O channels will be multiplexed with the very low-rate experiment telemetry, E/A, and experiment ancillary data.
- Sort Ephemeris and Attitude data
    - The E/A data is multiplexed in either the subsystem or experiment I/O channels.
    - The E/A data will be received every 2 seconds.
    - The E/A data will be expanded to produce parameters to meet the different experimenter needs
- Update the directory and accounting files

2.1.2.5 Merge Ancillary Data

The ancillary data for each experiment will be found commutated in the experiment I/O and subsystem I/O serial channels. Data from a particular experiment will be decommutated from each frame and collected until a predetermined number of frames have been processed. These experiment words will be formed into a single block for output to the appropriate experiment output device. Each frame will be of one second duration; a single time tag at the beginning of the block will be sufficient to correlate all the data to time throughout the record.

The record will consist of sequential frames of a particular experiment with given parameters occurring in the same word location of each frame in the record.

2.1.2.6 Data Storage

The data storage functions will be handled through the operating system's file management system. On-line data storage is required in the SOPS for:

- System and user software
- The accounting system
- Directories
- Intermediate storage of position/attitude files
- Intermediate storage for the different experiment ancillary data
- Various telemetry and decommutation maps
- Quick Look Experiment files
- Formatted data for the GSFC POCC

As a minimum, the system will

- Provide the user application programs with a set of procedures for creating files and accessing files by way of direct or sequential access methods
- Automatically allocate, log, and record files on the mass storage system

2.1.2.7 Data Edit

Prior to data editing, telemetry data enters the SOPS from the SIPS in the form of 16-bit data words present on each of the DCS output channels. These data are not entirely usable in the decommutation process for four reasons: partial minor frames (or major frames) may exist, time gaps may not be filled in, time tagging data may be in error, and the major frame structure may be defective. The purpose of data editing is to arrange these data into usable major frames, to attach verified time codes and quality flags, and to prepare these data for eventual separate experiment data files. The specific data editing functions to be performed are:

- Verify minor frame structure (build if required)
- Verify major frame structure (build if required)
- Insert fill data for missing frames and set appropriate flags
- Verify time tags (correct time if required)
- Remove overlapping telemetry data when required
- Order data chronologically when required
- Add data quality flags
- Verify the header record (build if required)

In general, data editing consists of building experiment data into major frames, validating time, removal of overlapping data, summarizing, generating fill data (when required), and other related editing functions. Detailed descriptions follow.

2.1.2.7.1 Time Validation Functions

GMT received by the SIPS and SOPS are in units of 10 ms. As illustrated in Figure 2-5 time t_0 + 10 ms is tagged to frame "a", even though a portion of frame "a" may be coincident with t_0 + 20 ms. The time-tagging of framed data is performed by the SIPS. It should be noted that if frame sizes are "small" (as illustrated at the bottom of 2-5), frame "d" and "e" are timed-tagged at t_0 + 10 ms. The time validation function will perform as a minimum higher-order corrections to correct for clock drift. This data will be provided to the SOPS. (These higher-order corrections could be illustrated as shown in Figure 2-6).

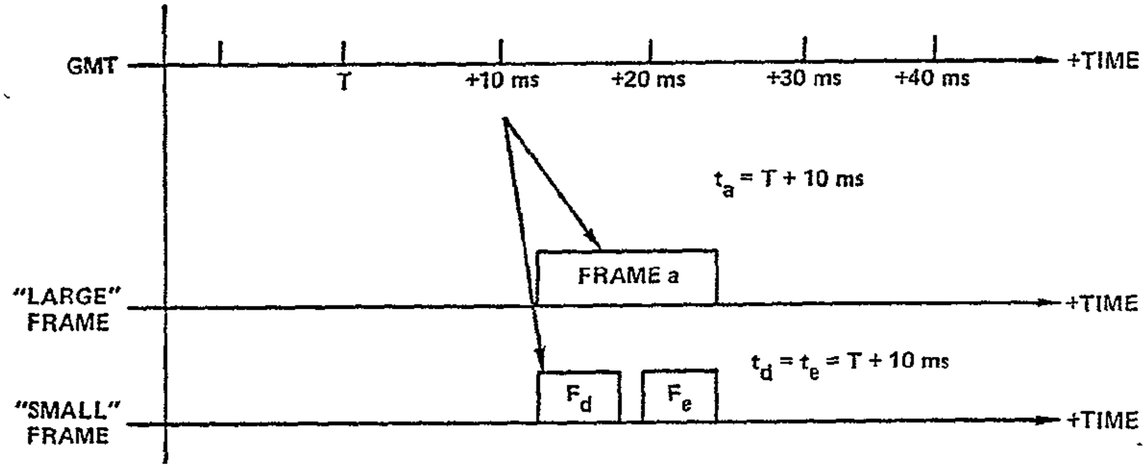


FIGURE 2-5. TIME TAGGING OF DATA

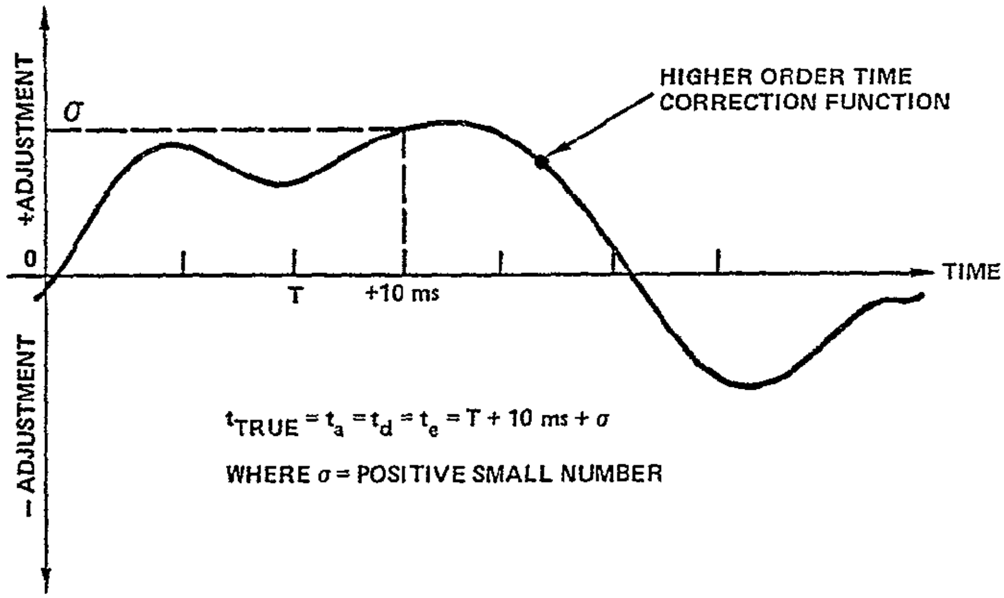


FIGURE 2-6. HIGHER ORDER TIME CORRECTION FUNCTION
(A HYPOTHETICAL EXAMPLE)

2.1.2.7.2 Removal of Overlapped Data

One major function of the SOPS shall be the removal of overlapped Spacelab data and the chronological ordering of data. Figure 2-7 illustrates this concept. During time interval $t_1 \rightarrow t_6$ Spacelab data is acquired. In real-time, this data is transmitted back to Earth, but for some reason the on-board tape recorder is activated during interval $t_2 \rightarrow t_5$. Data recorded during $t_2 \rightarrow t_5$ is transmitted later during $t_7 \rightarrow t_8$. The SOPS must be capable of purging received data interval $t_2 \rightarrow t_5$ and replacing it with $t_7 \rightarrow t_8$. Special attention should be placed in handling data intervals $t_2 \rightarrow t_3$ and $t_4 \rightarrow t_5$.

2.1.2.7.2 Generation of Fill

When a sequence of data is determined to be missing and subsequent data processing confirms this situation, the SOPS shall insert "filler data" into the data set. This filler data shall be placed in the chronological position corresponding to the missing experiment data. Furthermore, filler data shall be either all ones, or all zeros, or some other pattern that cannot be mistaken by the user as experiment data. In any fill operation, appropriate indicator flags in the data set shall be set to indicate filler data in lieu of actual experiment data.

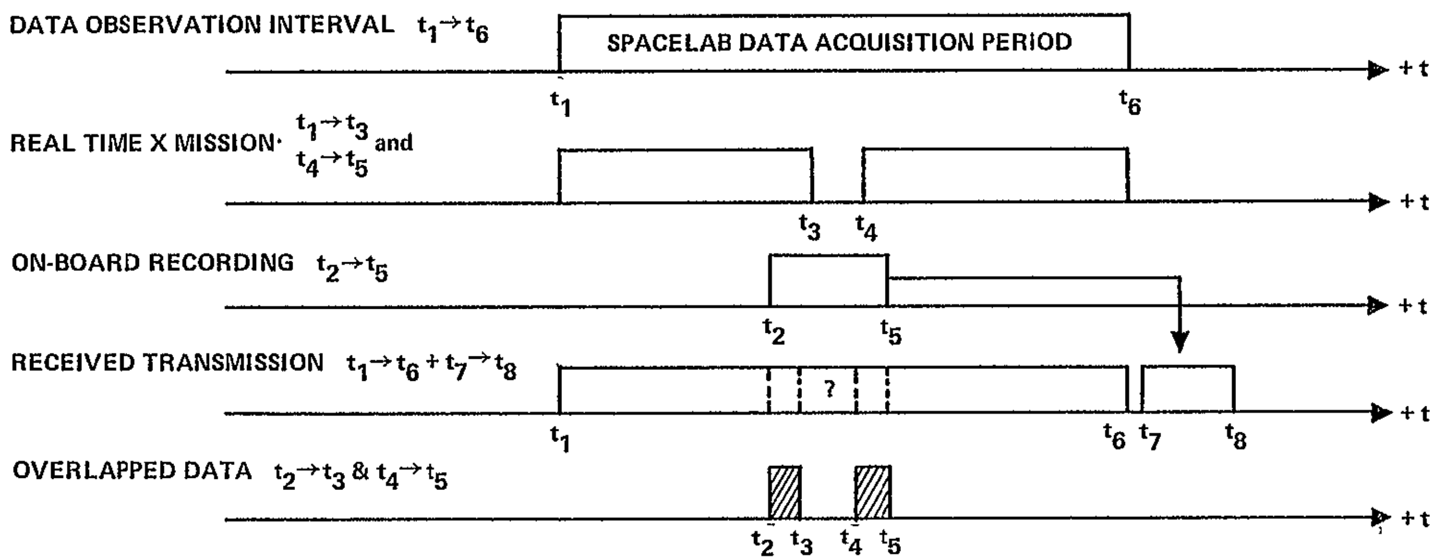


FIGURE 2-7. OVERLAP DATA

2.1.2.8 Ephemeris/Attitude

The Ephemeris/Attitude parameters* shall be double precision with an accuracy commensurate with 32 bits. The ephemeris application functions will as a minimum:

- Perform coordinate transformations from the given system to the experimenter's desired system, such as Geocentric Equatorial Inertial (GEI) or Solar Ecliptic Inertial (SEI).
- Replace predicted ephemeris data with definitive ephemeris data (and set appropriate flags to indicate definitive status) received from the Mission Control Center (MCC) of JSC.

Ephemeris/Attitude tapes will be produced for each NASA experimenter and for ESA with coverage on each tape of one or two days. The data records will consist of attitude (orientation), ephemeris (orbit position), and magnetic field vector parameters at two second intervals. These parameters will be derived from the Spacelab state vector, attitude vector, joint and gimbal angles, radiation flux, and magnetic field vector which are commutated in the experiment I/O and subsystem channels. The parameters will be expressed in appropriate coordinate systems as scaled fixed point words The scaling convention will be part of the header block at the first of each formatted output.

*Note. The sum of all derived ephemeris and attitude data shall be approximately 100 values every 2 seconds (4 bytes per value).

2.1.3 Mass Storage

The SOPS mass storage sizing requirements are primarily based on the peak and average data rates and on the time interval between data capture and data delivery to the experiments.

The implications of the above functional requirement are significant. The primary objective of the SOPS' Mass Storage System (MSS) is to provide a facility for the compact storage of large quantities of data and to make this data accessible to computer systems with minimal operator handling. The SOPS MSS will have the following capabilities.

- Modularity
  Modularity will be expandable from 5 to 40 x 10^{12} bits of data. Included in the capacity count is only that data which is generated by a host system. Any additional data generated for the purpose of file heading and code recovery, or due to recording technology are not included in this count.
- Capacity
  Storage capacity of each removable storage module should equal or exceed 1.2 x 10^9 bits.*
- Error Rates
  The unrecoverable error rates should not exceed 1 bit in 10^9 bits.
- Technology
  The technology used in the MSS should consist entirely of off-the-shelf devices with field-confirmed sets of reliability values.
- Recording Media
  The recording media should be reusable and should be available off-the-shelf.

*Note: This is based on 6250 bpi magnetic tape and 3330 disk compatibility.

2.1.4 Data Output

This function is divided into the following operations.

- Conversion of the decommutated data from the output processor format to the experimenter's computer format, e.g., IBM, CDC, Data General, etc.
- Writing the experiment and ancillary data in the desired tape or transmitting over a communications line
- Verification of the data output tapes before they are released to the experimenter

2.1.5 External Communications

Output data destined for experimenters will be transmitted in many instances over communication lines. Such data must meet the following criteria.

- Be capable of being transmitted over 56 Kb/s wire lines
- Conform to circuit - switched line protocol
- Conform to packet - switched line protocol

Since the transmission rate is limited to 56 Kb/s, this service will only be available to experiments in the E and F groups (Table 2-1). These selected experimenters will receive their telemetry, ancillary, and Ephemeris/Attitude data over transmission lines, they will not receive data tapes.

2.1.6 Miscellaneous

In addition to the functional requirements outlined earlier in this section, a number of other functional requirements are imposed on the SOPS. They can be grouped into the following classes.

- Operations
- Personnel
- System Efficiency
- Projected Lifetime

2.1.6.1 Operational Constraints

The output processor hardware/software shall be designed to operate with a minimum number of people. The following criterion must be considered during the designing:

- Ease of maintenance (hardware and software)
- Data throughput
- Job turnaround time
- Operator intervention
- Data base save and restore

The primary constraint upon the operation of the SOPS is assumed to be the restriction of productive data processing to up to three shifts per day. Other important constraints upon the productive capability of the system are:

- The non-processing time associated with tape/mass storage device handling
- The overall efficiency of the system
- The time required to search for given Spacelab data on archive source media

2 1.6.2 Personnel

A definitive staffing/personnel study has not been completed at this writing. An historical staffing profile for two similar systems is provided in Table 2-2.

TABLE 2-2. HISTORICAL STAFFING PROFILES

	MAINFRAMES/PROGRAM	
Devices:	Univac 1108	Sigma 9 (AE)
CPU (Operator's Console)	2	1
TAPE UNITS	33	10
PRINTER	2	2
CARD READER	2	1
CARD PUNCH	1	1
INTERACT. TERMINAL	12	NA
GRAPHICS TERMINAL	3	NA
Staffing/Shift:		
SUPERVISOR	1	1
COMPUTER OPERATOR	5	5
TAPE LIBRARIAN	2	NA
COMMUNICATIONS ENGINEER	NA	1

2.1.6.3 System Efficiency

Based upon past IPD experience and recognized industry practice, it is reasonable to expect that the SOPS will operate with a total system efficiency of approximately 85%. This estimate also accounts for hardware failures and repeated processing of products rejected in the quality control procedures.

2.1.6.4 Projected Lifetime

It is projected that the SOPS shall have a lifetime in excess of five (5) years. During this period the SOPS shall grow in a modular fashion without drastic changes to its architecture.

2.2 SECONDARY SPECIFICATIONS

The following section discusses functions that are the future requirements of the system. If they are feasible and cost-effective, these functions would be included, either wholly or partially, in the system.

2.2.1 Quick-Look

This function would give the experimenter the capability to access on-line experiment data in real-time, for data evaluation. The system must:

- Use a query program to interrogate the desired experiment data
- Retrieve the desired data from mass store via the file management system
- Use the decom application program to format the data
- Transmit over communications lines to the experimenter's computer or generate a quick-look tape.

2.2.2 External Communications Functional Requirements

This group of functional requirements supports two major subdivisions of functional requirements - query and POCC near real-time support functions.

2.2.2.1 Query Functions

The query application functions will as a minimum.

- Interrogate the data base to determine the presence of information or file status
- Answer all questions concerning the existence of data, both on/off line, for all files maintained under the file management system

2.2.2.2 POCC Near-Real-time Functions

In the future it is possible that a GSFC POCC may be established.

The POCC Near Real-time Functions will as a minimum

- Process data directly from input lines to POCC
- Retrieve data from mass store
- Format the data for the POCC
- Transfer the data to the POCC by way of communication lines

3.0 WEIGHTING FACTORS

In order to allow quantitative assessment of the various architectures in terms of their responsiveness to the stated specifications, each major specification is given a weighting. The weighting is expressed as an integer between 1 (lowest) and 10 (highest) and reflects the relative importance of that specification.

The mandatory specifications will fall in the range of 5 to 10, and the secondaries are in the range 1 to 4.

The remainder of this section consists of Table 3-1 referenced to the applicable paragraphs in Section 2, with the weightings assigned and the rationale for them explained.

TABLE 3-1
ASSIGNED WEIGHTS

SECTION 2 PAR. NO.	BRIEF STATEMENT OF SPECIFICATION	ASSIGNED WEIGHT (1-10)	RATIONALE FOR WEIGHT ASSIGNMENT
2.0	• Modularity • Expandability	8 8	System sizing at this time does not account for future missions, whose characteristics are unknown.
2.1.1.1	• Data characterization	9	Average rates must be handled.
	• Experiment mix profile	9	This mix is only typical.
2.1.1.2	• Tapes	10	This is the prime method of transmission to experimenter
	• Communications	7	This is a secondary method of transmission.
	• Data volumes	10	These volumes must be supported.
2.1.1.3	• Throughput	10	This rate must be supported.
2.1.2.1	• Update input accounting	10	This is mandatory for obvious reasons.
2.1.2.2	• Update output accounting	10	This is mandatory for obvious reasons.
2.1.2.3	• Quality check	10	This is mandatory for obvious reasons.
2.1.2.4	• Receive and sort TLM • Receive and sort ephemeris and attitude	10 10	These are givens.
	• E & A data		Data merge will be performed by the experimenter given E & A tapes as well as his own.

TABLE 3-1 (CONT'D)

SECTION 2 PAR. NO.	BRIEF STATEMENT OF SPECIFICATION	ASSIGNED WEIGHT (1-10)	RATIONALE FOR WEIGHT ASSIGNMENT
2.1.2.5	• Creating and accessing files	10	These are mandatory for making files and for providing information for accounting.
	• Allocate, log, and record	10	
2.1.2.6.1	• Time validation	5	This ensures data is tagged with correct time
2.1.2.6.2	• Remove overlapped data	10	Not removing might increase output volume significantly.
2.1.2.7	• Coordinate transformation	8	These could all be performed by the experimenter, given a separate orbit tape.
	• Ancillary data	8	
2.1.2.8	• Interpolate attitude	5	These could all be performed by the experimenter, given a separate attitude tape (combined with orbit).
	• Coordinate transformation	8	
	• Ancillary attitude computations	8	
2.1.2.9	• Merge ancillary	9	ancillary data must be merged
2.1.3	• Modularity	8	All of the requirements are stated as mandatory functions of the mass storage system, However, later feasibility analysis may show that the assigned weights for features can be traded off against operational considerations.
	• Capacity	10	
	• Error rates	10	
	• Technology	9	
	• Media	7	
	• Maintainability	9	

TABLE 3-1 (CONT'D)

SECTION 2 PAR. NO.	BRIEF STATEMENT * OF SPECIFICATION	ASSIGNED WEIGHT (1-10)	RATIONALE FOR WEIGHT ASSIGNMENT
2.1.3, cont'd	• Availability	8	
	• Interface	8	
	• Persistence	8	
	• Self-test	8	
	• Transfer rate	10	
	• Transferability	10	
2.1.4	• Convert to experiment format	10	These are all mandatory for obvious reasons.
	• Write to tape	10	
2.1.5	• Transmission rate	10	Although 2.1.1.2 assigns a weight of 8 within that substructure, each of these are mandatory.
	• Switched circuit	10	
	• Packet switched	10	
2.1.6	• Operations	9	These are required to maintain system operations.
	• Personnel	9	
	• Reliability and availability	9	
	• Maintenance support	9	
2.1.6.1	• Hardware	10	These are mandatory to retain reliable throughput.

TABLE 3-1 (CONT'D)

SECTION 2 PAR. NO.	BRIEF STATEMENT OF SPECIFICATION	ASSIGNED WEIGHT (1-10)	RATIONALE FOR WEIGHT ASSIGNMENT
2.1.6.2	• Software	10	These are mandatory to retain reliable throughput.
2.2.1	• Quick Look	3	Although this is a highly desirable feature, it cannot be shown at this time to enhance system operation sufficiently to account for potential time and cost burdens.
2.2.2	• Process data from GSFC POCC	3	There are secondary functions, which would enhance the overall missions, by coordinating real-time S/C data with SDPF functions to give a more responsive assessment of experiment performance.
	• Retrieve data	3	
	• Format data	3	
	• Transfer data to POCC	3	

4.0 OVERVIEW OF CHARACTERISTICS OF CURRENT TECHNOLOGY

4.1 HARDWARE

This section will present a summary of the hardware components that have a high probability of being used in any SOPS system design, and to present representative specifications that will be used in future sections of this report. The specific devices chosen were selected to approximate the state-of-the-art envisioned when the SOPS will be finally designed.

4.1.1 Mass Storage System

NASA document NASA-CR-147877, entitled "Online Mass Storage System Detailed Requirements Document", prepared by Aeronutronic Ford Corp., dated 2 July 1976, for the Lyndon B. Johnson Space Center, presents a functional requirements study that very closely parallels the requirements of the SOPS. In this study, exhaustive comparative studies were performed on Ampex Terabit, CDC 38500, IBM 3850, and CALCOMP ATL devices. It was found after verifying the stated results of the study, that these systems are candidates for the SOPS. Among these systems, the Terabit system appeared to be the most cost effective. Since publishing the referenced report, System Development Corporation (500 Machra Road, Sunnyvale, California) has taken over this product line. The costs for the Terabit system used in that report were somewhat lower than today's market price. Despite this, further study would show the Terabit system still to be a leading candidate. Table 4-1 tabulates the salient characteristics of each MSS studied. All of these systems have a sophisticated file management subsystem, and a portion of the functions in the SOPS could be off-loaded.

TABLE 4-1. CANDIDATE MSS STORAGE CAPACITIES

	AMPEX TERABIT	CDC 38500	CALCOMP 7110 (@ 6250 bpi)	IBM 3850	IBM DATA CELL
Media Unit Data Capacity (bits)	46.8×10^{9}	64×10^{6}	1.44×10^{9}	400×10^{6}	1.6×10^{6}
Max. System On-Line Capacity (Bits) w/One Controller	3.0×10^{12}	2.08×10^{12}	9×10^{12}	1.88×10^{12}	2.56×10^{10}

4.1.2 Computing Equipment

Three groups of computing equipment will be considered in this study: microprocessors (I), mini/midi-computers (II), and maxi-computers (III). They can be conveniently grouped as follows:

Group	Typical Machines	For Detailed Data Sheets, See Tables
I	Intel's 8080	4-2
	TI's 9900	4-2
	Motorola's 6800	4-2
II	Data General's ECLIPSE C/300	4-3
	DEC's PDP-11/70	4-3
	General Automation's 16/440	4-3
	HP's HP3000 Series II	4-3
	Interdata's 8/32	4-4
	Prime's 400	4-4
	SEL's 32/55	4-4
	Varian's V75	4-4
III	DECS PDP-10	4-5
	Honeywell's 64/60	4-5
	IBM's 360/370	4-5
	Univac's 1100/40	4-6
	CYBER's 170	4-6

The computers within each group represent a multiplicity of internal architectures and system interconnections. For the purposes of this study, however, each class of computing device will be characterized by one set of attributes. These attributes are tabulated in Table 4-7. Later in this study, the system architectures will be examined to determine which of these computer classes is most appropriate for each architecture.

TABLE 4-2

MICROPROCESSORS

MANUFACTURER & MODEL	INTEL 8080	TI 9900	MOTOROLA 6800
DATA FORMATS			
Word length, bits	8	16	8
Fixed-point operand length, bits	8	16	8
Instruction length, bits	8,16,24	16	8,16,24
MAIN STORAGE			
Storage type	RAM / ROM / PROM	RAM / ROM	RAM / ROM / PROM
Cycle time, microseconds/word	195 / - / -	- / -	1 0 / - / -
Access time, microseconds/word	5 / 5 / 5	- / -	55 / 55 / 55
Minimum capacity, words	256 / 2K / -	1K / 0	0 / 24K / 0
Maximum capacity, words	1K / 4K / -	1M / 64K	512K / 512K / 512K
Parity checking	No	Optional	No
Error correction	No	Optional	No
Storage protection	No	Optional	No
CENTRAL PROCESSOR			
No of accumulators	1	8	1
No. of index registers	1	16	1
No of directly addressable words	64K	64K	64K
No of addresssing modes	3	6	3
Control storage			
Add time, microseconds	2	2 7	2
Hardware multiply/divide	No	No	No
Hardware floating point	No	No	No
Hardware byte manipulation	No	No	No
Battery backup	Yes	Yes	Yes
Real-time clock or timer	Yes	Yes	Yes
INPUT/OUTPUT CONTROL			
Direct memory access channel	Yes	Yes	Yes
Maximum I/O rate, words/sec		2M	
No of external interrupt levels	1	16	-
PERIPHERAL EQUIPMENT			
Floppy disk (diskette) drives	Yes	Yes	Yes
Disk pack/cartridge drives	No	No	No
Drum/fixed-head disk storage	No	No	No
Magnetic tape cassettes/cartridges	No	Yes	No
Magnetic tape, ½-inch	No	Yes	No
Punched card input	Yes	Yes	Yes
Serial printer	Yes	Yes	Yes
Line printer	Yes	Yes	Yes
Data communications interface	Yes	Yes	Yes
CRT	Yes	Yes	Yes
Other standard peripheral units	Yes	Yes	Yes
SOFTWARE			
Assembler	Non resident	Non resident	-
Compilers		Yes	
Operating system		Yes	
Language implemented in firmware		No	
Operating system imolemented in firmware		No	
PRICING & AVAILABILITY			
Price of CPU, power supply, front panel, and min mem. in chasis			$2600
Price of memory increment			
Date of first delivery			
Number installed to date			
COMMENTS			

TABLE 4-3. MINICOMPUTERS

MANUFACTURER & MODEL	Data General Eclipse C/330	Digital Equipment PDP-11/70	General Automation 16/440	Hewlett-Packard General Sys. Div. HP 3000 Series II
DATA FORMATS				
Word length, bits	16 + 5	16 + 2	16 + 2	16 + 5 or + 1
Fixed-point operand length, bits	16	16	16	—
Instruction length, bits	16 32	16, 32 48	16 32, 48	8, 16
MAIN STORAGE				
Storage type	Core, MOS	Core	Core	MOS
Cycle time, microseconds/word	0 8, 0.7	0 98	0 72	0 7
Access time, microseconds/word	0.4, 0 5	0.36	0 225	0 35
Minimum capacity, words	16K	64K	16K	64K
Maximum capacity, words	256K	1024K	1024K	256K
Parity checking	No	Standard	Optional	Standard
Error correction	Optional	No	No	Standard
Storage protection	Optional	Standard	Optional	Standard
CENTRAL PROCESSOR				
No. of accumulators	4	12	16	20
No. of index registers	2	12	8	1
No. of directly addressable words	32K	32K	1M with MAP	None
No. of addressing modes	7	8	11	6
Control storage	ROM 2K x 56 bits	—	PROM 512 x 64 bits	ROM 10K x 32 bits
Add time, microseconds	0 6	0 30-1 20	0.78	0 55
Hardware multiply/divide	Standard	Standard	Standard	Standard
Hardware floating point	Standard	Optional	Optional	Standard
Hardware byte manipulation	Standard	Standard	Standard	Standard
Battery backup	No	No	No	Standard
Real-time clock or timer	Optional	Standard	Standard	Standard
INPUT/OUTPUT CONTROL				
Direct memory access channel	Standard	Standard	Standard	Standard
Maximum I/O rate, words/sec	1 25M	2 9M	1M	4 5M
No. of external interrupt levels	16	Variable	64-unlimited	To 125
PERIPHERAL EQUIPMENT				
Floppy disk (diskette) drives	315K-2 5M bytes	256-512K bytes	500K-2M bytes	No
Disk pack/cartridge drives	Pack & cartridge, 2.5-736M bytes	Cartridge & pack 2.5-1408M bytes	Pack & cartridge 5-2400M bytes	Pack & cartridge 15-376M bytes
Drum-fixed-head disk storage	Fixed-head, 256K-2M bytes	Fixed-head 512K-8M bytes	Fixed head 256K-2M bytes	No
Magnetic tape cassettes/cartridges	Cassette, 1 6 KBS	Cassette 562 cps	No	No
Magnetic tape, ½-inch	10-72 KBS	10-72 KBS	20-60 KBS	72 KBS
Punched card input	150-1000 cpm	285-1200 cpm	400, 1000 cpm	600 cpm
Serial printer	10-165 cps	30-180 cps	10, 165 cps	30 120 cps
Line printer	240-600 lpm	230-1200 lpm	200-600 lpm	200-1250 lpm
Data communications interface	Up to 9600 bps	50-56,000 bps	75-9600 bps	To 4800 bps, syn
CRT	80 char. x 24 lines,	80 char x 24 lines	80 char x 24 lines	80 char x 24 lines
Other standard peripheral units	Modular digital & analog data control & acquisition sub-system optional	DECtape 8325 words/sec., paper tape reader paper tape punch	TTY, paper tape units, card punches A/D converters, digital I/O, plotters	Paper tape units, punched card reader/punch
SOFTWARE				
Assembler	Assembler & macro assembler	Assembler & macro assembler	Macro assembler	Assembler & macro assembler
Compilers	FORTRAN, BASIC, ALGOL	BASIC, FORTRAN, COBOL FOCAL	FORTRAN IV, BASIC, COBOL	COBOL, RPG II, FORTRAN IV, BASIC
Operating system	Batch, real-time time-sharing	Real-time, interactive time-sharing	Batch real-time, time-sharing	Batch, real-time, time-sharing
Language implemented in firmware	No	No	No	Partially
Operating system implemented in firmware	No	No	No	Partially
PRICING & AVAILABILITY				
Price of CPU, power supply, front panel, and min mem. in chassis	$30,000 (32K core)	$60,000 (128K core)	$8,950 (16K words)	$110 000 (64K words)
Price of memory increment	$4 500 (16K core) $8 500 (32K MOS)	$17,700 (64K core)	$3,000 (16K words)	—
Date of first delivery	October 1976	NA	May 1975	June 1976
Number installed to date	1000+ (all models)	NA	400	225 (3000 Series)
COMMENTS	Extended arithmetic processor standard extended memory allocation and protection unit optional error correction std on MOS opt. on core	Uses same technology as PDP-11/45 and includes 2048 bytes of cache memory for increased performance, disk storage & mag. tape periphs avail in packaged system called Datasystem 570	Software and I/O compatible with SPC-16, oriented toward multi-user environment	Asynchronous communications speeds to 2400 bps, 3000 Series II is an upgrade from previous 3000CX Series, sold only as a packaged system

TABLE 4-4. MINICOMPUTERS

MANUFACTURER & MODEL	Interdata 8/32	Prime 400	Systems Engineering Laboratories 32/55	Varian V75
DATA FORMATS				
Word length, bits	32 + 2	16 + 2 or + 5	32 + 4	16 + 2
Fixed-point operand length, bits	32	16, 32	8, 16, 32, 64	8, 16, 32
Instruction length bits	16, 32, 48	16 32, 48	16, 32	16, 32
MAIN STORAGE				
Storage type	Core	MOS, bipolar cache	Core	Core, MOS
Cycle time, microseconds/word	0 3	0 760	0 6	0 99, 0.66, 0.33
Access time, microseconds/word	0 4	0 600	0 3	—
Minimum capacity, words	32K	64K	8K	64K
Maximum capacity, words	256K	4096K	256K	256K
Parity checking	Optional	Standard	Standard	Optional
Error correction	No	Optional	No	No
Storage protection	Standard	Std 3 levels	Standard	Standard
CENTRAL PROCESSOR				
No. of accumulators	32-256	1 (32-bit)	8	8
No. of index registers	30-240	2 (32-bit)	3	7
No. of directly addressable words	256K	64K	128K	2K
No. of addressing modes	7	4	6	8
Control storage	ROM, 1240 x 32 bits	PROM 2K x 64 bits	PROM 4K x 48 bits	WCS, 4K x 64 bits
Add time, microseconds	0.4	0 56	1 2	1 98, 1.32, 0 66
Hardware multiply/divide	Standard	Standard	Standard	Standard
Hardware floating point	Optional	Standard	Standard	Optional
Hardware byte manipulation	Standard	Standard	Standard	Standard
Battery backup	No	No	No	Optional
Real-time clock or timer	Optional	Standard	Standard	Standard
INPUT/OUTPUT CONTROL				
Direct memory access channel	Standard	Standard	Standard	Standard
Maximum I/O rate, words/sec	1 25M	1 25M	6 67M	1M
No of external interrupt levels	4-1024	64	16-128	8-64
PERIPHERAL EQUIPMENT				
Floppy disk (diskette) drives	No	512K-2.0M bytes	No	No
Disk pack/cartridge drives	Pack & cartridge, 2.5-1024M bytes	Pack & cartridge, 2.9-1200M bytes	Pack & cartridge 5-320M bytes	Cartridge & pack, 2.34-373 6M bytes
Drum/fixed-head disk storage	No	Fixed-head, 512K-1M bytes	Fixed-head, 1-4M bytes	Fixed-head; 123-492K bytes
Magnetic tape cassettes/cartridges	Cassette, 1 KBS	No	No	No
Magnetic tape, ½-inch	9-120 KBS	To 72 KBS	25-120 KBS	20, 30 KBS
Punched card input	400, 1000 cpm	300 cpm	300-1000 cpm	300 cpm
Serial printer	10-30 cps	165 cps	No	10, 165 cps
Line printer	60-600 lpm	To 600 lpm	125-600 lpm	300-2000 lpm
Data communications interface	To 9600 bps	To 56K bps	50K bps synch	To 50K bps
CRT	80 char x 24 lines	80 char x 24 lines	80 char x 24 lines	80 char x 24 lines
Other standard peripheral units	Paper tape units, A/D & D/A converters, graphic display	Paper tape A/D and D/A conv , card reader/punch	Paper tape units, card punch, TTY	Status line of printer/plotters, A/D & D/A converters
SOFTWARE				
Assembler	Assembler & macro assembler	Macro and micro assemblers	Assembler & macro assembler	Macro assembler & micro assembler
Compilers	FORTRAN V, BASIC, COBOL	BASIC, FORT RPG II, COBOL ALGOL	RPG, FORTRAN IV, BASIC	FORTRAN, BASIC, COBOL, RPG
Operating system	Batch real-time	Real-time, multi-user virtual mem	Batch, real-time, time-sharing	Batch, real-time, multi-task
Language implemented in firmware	No	Partially	No	No
Operating system implemented in firmware	No	Partially	No	No
PRICING & AVAILABILITY				
Price of CPU, power supply, front panel, and min mem in chassis	$51,900 (32K words)	$48 700 (64K words)	$25,000 (8K words)	$39,000 (64K words)
Price of memory increment	$19 000 (64K words)	$12 000 (32K wds) $22 500 (64K wds)	$6,300 (8K words)	$16,000 (64K core), $5 000 (8K MOS)
Date of first delivery	June 1975	March 1976	October 1975	August 1975
Number installed to date	100	1300 (all models)	NA	NA
COMMENTS	512 words of writable control store optional, features instruction look-ahead TAM software provides remote batch terminal emulators	Basis for Create/4 2 packaged business system virtual memory management system permits addressing up to 512M bytes per user, 2K-byte cache memory std , 2 to 1 memory interleaving std	Asynch communications to 9600 bps	Single- and dual-ported memories, odd/even interleaving for core memories standard TOTAL data base management system available,

TABLE 4-5

MAXICOMPUTERS

MANUFACTURER & MODEL	DEC PDP 10/1088	HONEYWELL 64/60	IBM 370/168
DATA FORMATS			
Word length, bits	36	32	32
Fixed-point operand length, bits	36 or 18 (½ word)	32 or 16	32 or 16
Instruction length, bits	36	32	16,32,48
MAIN STORAGE			
Storage type	Magnetic core	MOS	MOS
Cycle time, microseconds/word	95/1 0	74/ 94	48
Access time, microseconds/word	-	-	-
Minimum capacity, words	256K	196, 608 bytes	1,048, 576
Maximum capacity, words	4096K	786, 432 bytes	8,388, 608
Parity checking	Yes	Yes	Yes
Error correction	Yes	Yes	Yes
Storage protection	Yes	Yes	Yes
CENTRAL PROCESSOR			
No. of accumulators	8	8	8
No of index registers	8	8	8
No. of directly addressable words	4M	4M	
No of addresssing modes	386	195	
Control storage	8 x 15		
Add time, microseconds			
Hardware multiply/divide	Standard	Standard	Standard
Hardware floating point	Std	Std	Std
Hardware byte manipulation	Std	Std	Std
Battery backup	No	No	No
Real-time clock or timer	Std	Std	Std
INPUT/OUTPUT CONTROL			
Direct memory access channel	Std	Std	Std
Maximum I/O rate, words/sec	4M	4 25M	16M
No of external interrupt levels	7 levels, 135 trap instructions		
PERIPHERAL EQUIPMENT			
Floppy disk (diskette) drives	Yes	Yes	Yes
Disk pack/cartridge drives	Yes	Yes	Yes
Drum/fixed-head disk storage	Yes	Yes	Yes
Magnetic tape cassettes/cartridges	Yes	Yes	Yes
Magnetic tape, ½-inch	Yes	Yes	Yes
Punched card input	Yes	Yes	Yes
Serial printer	Yes	Yes	Yes
Line printer	Yes	Yes	Yes
Data communications interface	Yes	Yes	Yes
CRT	Yes	Yes	Yes
Other standard peripheral units	Yes	Yes	Yes
SOFTWARE			
Assembler	Macro Assembler		
Compilers	COBOL, FORTRAN IV, ALGOL-60, BASIC, APL		
Operating system			
Language implemented in firmware			
Operating system implemented in firmware			
PRICING & AVAILABILITY			
Price of CPU, power supply, front panel, and min mem. in chasis	$1,760,700	$542 835	
Price of memory increment	(32K words) $40K		
Date of first delivery	Mat 1976		Aug 1973
Number installed to date	--		
COMMENTS			

TABLE 4-6

MAXICOMPUTERS

MANUFACTURER & MODEL	UNIVAC 1100/40	CYBER 172
DATA FORMATS		
Word length, bits	36	60
Fixed-point operand length, bits	36	60 or 18
Instruction length, bits	36	15,30
MAIN STORAGE		
Storage type	Magnetic Core	MOS
Cycle time, microseconds/word	38	4
Access time, microseconds/word	-	-
Minimum capacity, words	32,768	32,768
Maximum capacity, words	524,288	262,144
Parity checking	Yes	Yes
Error correction	Yes	Yes
Storage protection	Yes	Yes
CENTRAL PROCESSOR	16	
No of accumulators	15	7
No of indeX registers		
No of directly addressable words		
No of addresssing modes		
Control storage		
Add time, microseconds		
Hardware multiply/divide	Standard	Standard
Hardware floating point	Std	Std
Hardware byte manipulation	Std	Std
Battery backup	No	No
Real-time clock or timer	Std	Std
INPUT/OUTPUT CONTROL		
Direct memory access channel		
Maximum I/O rate, words/sec		4M
No. of external interrupt levels		1
PERIPHERAL EQUIPMENT		
Floppy disk (diskette) drives	Yes	Yes
Disk pack/cartridge drives	Yes	Yes
Drum/fixed-head disk storage	Yes	Yes
Magnetic tape cassettes/cartridges	Yes	Yes
Magnetic tape, ½-inch	Yes	Yes
Punched card input	Yes	Yes
Serial printer	Yes	Yes
Line printer	Yes	Yes
Data communications interface	Yes	Yes
CRT	Yes	Yes
Other standard peripheral units	Yes	Yes
SOFTWARE		
Assembler		
Compilers		
Operating system		
Language implemented in firmware		
Operating system implemented in firmware		
PRICING & AVAILABILITY		
Price of CPU, power supply, front panel, and min mem. in chasis		$1,732,400
Price of memory increment		
Date of first delivery	Jan 1972	
Number installed to date		
COMMENTS		

TABLE 4-7

COMPUTER CLASS CHARACTERISTICS

COMPUTATION CLASS COMPUTATIONAL UNIT NAME	I MICROPROCESSOR	II MINI C	III MAX C
DATA FORMATS			
Word length, bits	8	16,32	36
Fixed-point operand length, bits	8	16,32	36
Instruction length, bits	8	16,32	36
MAIN STORAGE			
Storage type	RAM,ROM	CORE,MOS	CORE,MOS
Cycle time, microseconds/word	5	7	6
Access time, microseconds/word	5	4	-
Minimum capacity, words	1K	16K	100K
Maximum capacity, words	64K	1024K	2500K
Parity checking	OPT	Optional	Yes
Error correction	OPT	Optional	Yes
Storage protection	OPT	Optional	Yes
CENTRAL PROCESSOR			
No. of accumulators	1	12	10
No. of index registers	1	8	10
No. of directly addressable words	64K	190K	4M
No. of addresssing modes		7	
Control storage		Yes	
Add time, microseconds	2	7	
Hardware multiply/divide	No	Yes	Yes
Hardware floating point	No	Yes	Yes
Hardware byte manipulation	No	Yes	Yes
Battery backup	Yes	No	No
Real-time clock or timer	Yes	Yes	Yes
INPUT/OUTPUT CONTROL			
Direct memory access channel		STD	
Maximum 1/0 rate, words/sec	2M	2 5M	4M
No. of external interrupt levels		100	
PERIPHERAL EQUIPMENT			
Floppy disk (diskette) drives	Yes	Yes	Yes
Disk pack/cartridge drives	No	Yes	Yes
Drum/fixed-head disk storage	No	Yes	Yes
Magnetic tape cassettes/cartridges	No	Yes	Yes
Magnetic tape, ½-incn	No	Yes	Yes
Punched card input	Yes	Yes	Yes
Serial printer	Yes	Yes	Yes
Line printer	Yes	Yes	Yes
Data communications interface	Yes	Yes	Yes
CRT	Yes	Yes	Yes
Other standard peripheral units	Yes	Yes	Yes
SOFTWARE			
Assembler		Macro Assembler	
Compilers			
Operating system			
Language implemented in firmware			
Operating system implemented in firmware			
PRICING & AVAILABILITY			
Price of CPU, power supply, front panel, and min mem in chasis		46K	
Price of memory increment			
Date of first delivery			
Number installed to date			
COMMENTS			

4.1.3 Computer Peripherals

Table 4-8 presents the salient characteristics of those devices which would (probably) be chosen in an SOPS design. Each row and column of the table is indexed (1-12 and a-f), so that one may see (in Table 4-9) the rationale used for each data entry.

TABLE 4-8

SOPS COMPONENTS

		1	2	3	4	5	6	7	8	9	10	11	12
	Device	Sustained Transfer Rate (Mb/s)	Instat. Transfer Rate (Mb/s)	Typical Data Block Sizes (Bytes)		Average Block Size (Bytes)	Typ. Reel Size (ft)	Typ. Write Speed (ips)	Typ. Rewind Speed (ips)	Typ. Write Time (min)	Typ. Rewd Time (min)	Average Cost / Device ($k)	Average Cost / Device ($k)
				Min.	Max.								
a	HDT	.5 → 20	.5 → 20	180 per minor frame	1024 per minor frame	—	9200	3.75 → 120	180	15.3	10.2	70	40
b	6250 bpi	10.0	10.0	.5k	32k	—	2400	200	640	2.4	.75	30	38.6
c	1600 bpi	2.56	2.56	.5k	32k	—	2400	200	640	2.4	.75	30	38.6
d	56 Kb/s Comm.	.056	.056	128	512	128	n.a.	n.a.	n.a.	n.a.	n.a.	—	—
e	Candidate Mass Store System	5.6	9.6	100K	130K	130K to 100K	3800	248 (1000 search)	n.a.	—	—	$ 1 15 M	
f	Itel 7330 disk 7830 contr (3330 Type Disk)	2.6 to 4.5	6.5	10k	13k	13k to 10k	n.a.	n.a.	n.a.	n.a.	n.a.	22.5	75.6

TABLE 4-9

RATIONALE FOR DATA ENTRY ON TABLE 4-8

a-1	Typical HDT capability
a-2	Typical HDT capability
a-3	Typical HDT capability
a-4	Typical HDT capability
a-5	Any size between 180 and 1024 bytes is acceptable.
a-6	Typical large reel size
a-7	Typical HDT capability
a-8	Typical HDT capability
a-9	(9200 ft/reel x 12 in/ft)/120 ips = 920 sec/reel
a-10	(9200 ft/reel x 12 in/ft)/180 ips = 613 sec/reel
a-11	Modified Martin-Marietta transport
a-12	Includes cost of Serial Controller Interface unit
b-1	For IBM 3420-8 equivalent (STC 3670): 1.25 Mb/s x 8 bits/byte = 10 Mb/s.
b-2	For IBM 3420-8 equivalent (STC 3670): 1.25 Mb/s x 8 bits/byte = 10 Mb/s.
b-3	Typical values
b-4	Typical values
b-5	Any size within range is acceptable.
b-6	Typical
b-7	Typical
b-8	(2400 ft/reel x 12 in/ft)/45 sec = 640 ips
b-9	(2400 ft/reel x 12 in/ft)/200 ips = 144 sec/reel
b-10	As given in specifications (2400 ft/reel x 12 in/ft)/45 sec/reel = 640 ips)
b-11	Typical costs
b-12	Up to 8 units/controller, typical costs
c-1	For IBM 3420-8 equivalent (STC 3670) 320 Kbytes/sec.
c-2	For IBM 3420-8 equivalent (STC 3670) 320 Kbytes/sec.
c-3	Typical values
c-4	Typical values
c-5	Any size within range is acceptable.
c-6	Typical
c-7	(320 Kbytes/sec)/1600 bpi = 200 ips
c-8	(2400 ft/reel x 12 in)/45 sec = 640 ips
c-9	Same as b-9

TABLE 4-9 (CONT.)

c-10	As given in specifications (2400 ft/reel x 12 in/ft)/45 sec/reel = 640 ips)
c-11	Use dual density tape units; same as 6250 bpi
c-12	Use dual density tape units; same as 6250 bpi
d-1	56K bits/sec.
d-2	56K bits/sec.
d-3	1024 bits/(8 bits/byte)
d-4	4096 bits/(8 bits/byte)
d-5	Good size for easy error recovery
d-6	Not applicable
d-7	Not applicable
d-8	Not applicable
d-9	Not applicable
d-10	Not applicable
d-11	
d-12	
e-1	For Ampex TBM, given specification ($\approx$ 9.6 x .58 = 5.6 mb/s)
e-2	1.2 M bytes/sec $\div$ 8 bits/byte = 9.6 mb/s.
e-3	Assumed (based on system utilization history)
e-4	Given specification (approximately 10 x 13,030)
e-5	Given specification
e-6	Given specification
e-7	Given specification
e-8	Not available
e-9	Not available
e-10	Not available
e-11	Based on 1.15 M dollars for basic system*
e-12	Based on 1.15 M dollars for basic system*
f-1	For software system that takes advantage of overlap disk operations: .7 (efficiency) x 6.448 Mb/s=4.515 Mb/s For non optimized systems. .4 (efficiency) x 6.448 Mb/s = 2.575 Mb/s
f-2	806 K Bytes/sec x 8 bits/byte = 6.448 Mb/s
f-3	Assumed (based on F-5)
f-4	" " " "

* Note Contains a System Controller Processor (with disk controller and two disc drives), Data Channel Processor, Transport Driver, Data Channel, and a dual transport

TABLE 4-9 (CONT.)

f-5	For IBM 3330 or Itel 7330+7830 : 13,030 bytes/track (19 tracks/cyl.; 2 x 404 cyl/drive; 200 Mbytes/drive) [For IBM 3350: 19,069 bytes/track (30 tracks/cyl.; 555 cyl/drive; 317.5 Mbytes/drive)]*
	For a realistic utilization of a 3330 type device, the following parameters are typically used:
	Data bytes/sector — 256
	Sectors/track — 42
	Data bytes/track — 10752
	Tracks/cylinder — 19
	Data words/cylinder — 204,288
	Number of cylinders — 411
	Data words/disk unit — 83,962,368
	Rotation time — 1/60 sec ±2%
	Head move time/cylinder — 10.00 ms. (max)
f-6	Not applicable
f-7	Not applicable
f-8	Not applicable
f-9	Not applicable
f-10	Not applicable
f-11	Itel 7330
f-12	Itel 7830

*Note. 3350 Characteristics presented for information purposes only.

4.2 SOFTWARE

This section presents an overview of the software required to run the SOPS facility. This presentation is functional in nature and defines the requirements for one software system. Table 4-10 summarizes the estimates of the number of instructions required to perform the activities required by the specifications presented in Section 2.

It should be pointed out that Table 4-11 presents a first-order of magnitude estimate for the software that is envisioned to be implemented on the SOPS. It is worthwhile to include at this point (for information purposes only) the software statistics from the HEAO-A data processing system. The HEAO system was estimated to perform five times as many operations per data point (i.e., 8 bit bytes) when compared to the SOPS system design. The data rate from Spacelab is estimated to be 1.25×10^3 times greater than HEAO.

Applying experience from HEAO, Table 4-12 is offered as another software estimate for the SOPS. When one uses this table, the figure of merit (operations per data point) is computer to be "6". This is very close to the previously estimated value to "5"

The following four computations project a "figure of merit" for the SOPS:

- For all minor frames:

$$\frac{5 \times 10^{12} \ \frac{\text{bits}}{\text{mission}}}{4096 \ \frac{\text{bits}}{\text{minor frame}}} \cong 1.22 \times 10^9 \ \frac{\text{minor frame}}{\text{mission}}$$

$$\therefore \ 1275 \ \frac{\text{lines}}{\text{m.f.}} \times 1.22 \times 10^9 \ \frac{\text{m.f.}}{\text{mission}} = 1.56 \times 10^{12} \ \frac{\text{lines executed}}{\text{mission}}$$

- For all major frames (M.F.):

$$\frac{1.22 \times 10^9 \ \frac{\text{m.f.}}{\text{mission}}}{(\approx) \ 100 \ \frac{\text{m.f.}}{\text{M.F.}}} = 1.22 \times 10^7 \ \frac{\text{Major Frame}}{\text{mission}}$$

$$\therefore \ 500 \ \frac{\text{lines}}{\text{m.f.}} \times 1.22 \times 10^7 \ \frac{\text{MF}}{\text{mission}} = 6.10 \times 10^9 \ \frac{\text{lines executed}}{\text{mission}}$$

TABLE 4-10

SOFTWARE ESTIMATES

FUNCTION	Estimated Lines of Code Executed Per: DATA POINT	MINOR FRAME	MAJOR FRAME	ORBIT GROUP	EXPERIMENT FILE
.1 Input Data Accounting		50	100	1000 x E	10,000
.2 Output Data Accounting		50	100	5000 x E	50,000
.3 Quality Check		50(normal)/200 abnormal	50/200	500 x E	5,000
.4 Decommutate		50 per Exp. Per MP	0	0	0
.5 Data Store		0	0	5,000 x E	10,000
.6.1 Time Validate		75	0	0	0
.6.2 Overlap Removal		0	0	20,000 x E	0
.7 Ephemeris		0	0	20,000 x E	0
.8 O&A		0	0	5,000 x E	0
.9 Merge Ancill.		0	0(?) 100	10,000 x E	0
Data Output		0	20	10,000 x E	10,000
Quick Look		500	50	(100,000 x E)AR	(100,000 X E) AR
GSFC POCC		500	50	(5,000 x E) AR	0
Approximate Sub-Total		1275 Lines / Minor Frame	500 Lines / Major Frame	(81,000 x E) Lines / Orbit Group	85,000 Lines / Experiment File

E = No. of Experiment
AR = As Required

TABLE 4-11. ESTIMATED COMPUTER TIME TO PROCESS ONE DAY'S HEAO-A DATA

Computational Process	Percentage	Total Time to Process One Day's HEAO-A Data Data (Minutes)
EDIT	28.3	80
ATTITUDE	10.6	30
ORBIT	00.4	01
DECOM & TAPE CHECK	33.1	94
RAW ATTITUDE DECOM	08.1	25
RAW PRECISION TIME	00.4	01
FINAL PRECISION TIME	00.7	02
MASTER DATA TAPE	13.1	37
QUICK LOOK	04.6	13
	100.	4 Hrs. 43 Min.
CPU	10.6	0 Hrs. 30 Min.
I/O	89 4	4 Hrs. 13 Min.
	100.	4 Hrs 43 Min.

TABLE 4-12. SPACELAB OUTPUT PROCESSOR SYSTEM SOFTWARE ESTIMATES BASED ON THE HEAO OUTPUT PROCESSING

FUNCTION	ESTIMATED LINES OF CODE PER TIME REQUIRED				
	Data point 8 bits	Minor frame 4096 bits	Mission 5×10^{12} bits	CPU (seconds) 700ns cycle	Days for 1 CPU
Accounting and Quality Checking	Ø.1	51	6.25×10^{10}	$.0436 \times 10^{6}$	Ø.5
Edit and Time Validation	1.5	768	9.37×10^{10}	$.66 \times 10^{6}$	7.59
Ephemeris/ Attitude	Ø.5	256	31.2×10^{10}	$.219 \times 10^{6}$	2.53
Decom/Merge/ Remove Overlap	2.5	128	156×10^{10}	1.09×10^{6}	12.65
Transmission	Ø.1	51	6.25×10^{10}	$.0436 \times 10^{6}$	Ø.5
Quick Look	1.Ø	512	62.5×10^{10}	$.437 \times 10^{6}$	5.Ø
GSFC POCC	Ø.3	153	18.7×10^{10}	0.13×10^{6}	1.52
TOTAL	6.Ø	3071	374.6×10^{10}	2.62×10^{6}	30.29

- For all orbit groups:

$$81 \times 10^3 \ \frac{\text{lines}}{\text{orbit group}} \times 100 \ \frac{\text{orbits}}{\text{mission}} = 8.1 \times 10^6 \ \frac{\text{lines executed}}{\text{mission}}$$

- For all experiment files:

$$8.5 \times 10^4 \ \frac{\text{lines}}{\text{exp. files}} \times 40 \ \frac{\text{files}}{\text{orbit}} \times \frac{\text{100 orbits}}{\text{mission}} = 3.4 \times 10^8 \ \frac{\text{lines extended}}{\text{mission}}$$

The sum of all lines executed = $1.57 \times 10^{12} \ \frac{\text{lines}}{\text{mission}}$

Therefore, the system will have a figure of merit =

$$\frac{1.57 \times 10^{12} \ \frac{\text{lines}}{\text{mission}} \times 16 \ \frac{\text{bits}}{\text{data point}}}{5 \times 10^{12} \ \frac{\text{bits}}{\text{mission}}} \cong 5 \ \frac{\text{lines executed}}{\text{data point}}$$

The software is divided into two major items, namely Data Base Management and Query and Executive Software.

4.2.1 Data Base Management and Query Software

A data base management system is defined as a software system that manages and maintains data that is to be processed by multiple applications. Such a system organizes data elements in some predefined structure, and retains relationships between different data elements within the data base.

The system encompasses a data management system, which is intended primarily to permit access to, and retrieval from, already existing files.

Data Base Management Systems should provide the following functions:

- Organize data in a predefined structure
- Maintain access to storage and retrieval of data from multiple user programs
- Maintain file accounting data
- Have a report/request language that is easy to learn and use, and that will provide on-line interactive query and retrieval, as well as hardcopy reports provided on demand.
- Make information in computer files directly available to non-programmers
- Relieve programmers of simple repetitive report generation and file maintenance tasks
- Relieve users of the need to be concerned with device types, I/O processing and control, and file structures
- Have computational capabilities
- Support a variety of file structures
- Handle multi-file processing
- Provide for the batching of a number of report requests during a single pass of the file(s)
- Supply exits to the user's "own code" routines
- Supply error diagnostics
- Be available in special versions (e.g. auditing) to meet specialized application requirements and in a version that supports an interactive mode of operation and produces routine special purpose reports in predefined format

The remainder of this subsection is a table (Table 14-11) which describes the characteristics of a number of commercially available Data Base Managers. This table is intended to show typical capabilities of modern Data Base Management systems without reference to the computer systems in which they are intended to be installed.

Given the preceding DBM definitions, it appears that a conventional DBM system may be excessively powerful for the data bases within the SOPS. This unnecessary power would add significant overhead costs. The experiment data files are known before data enters the SOPS; they are ordered, time-tagged, and not shared by multiple experimenters. Only orbit and attitude data are envisioned to be shared by multiple experimenters. The experiment data "map" may be illustrated (figuratively) in Figure 4-1.

In Figure 4-1, the GMT time-tag runs continuously and uniquely throughout the mission. The assignment of storage locations may be done dynamically as the data enters the system, or it may be predetermined by the SOPS resource monitor. When non-chronological data enters the system (i.e., tape recorded data that is transmitted at a latter time), the time-tag embedded in the data itself will be used in the EDIT function to reorder the experiment data.

TABLE 4-13

DBM CHARACTERISTICS

System	IDMS	IMS	INQUIRE
DATA BASE FEATURES			
Data base organization	Hierarchical, network	Hierarchical (sequential and direct)	Hierarchical network relational
Application languages	COBOL, PL/1, ASM, FORTRAN, RPG II	COBOL PL/1, Assembler	COBOL FORTRAN, PL/1, Assembler
Data base languages	DDL DNL	Data Language/1	Inquire Command Language
Variable length segments	Yes	Yes, with VSAM	Yes
Data base security	Password protection and subschema	Password and terminal access limitation	Encryption and password protection
System accounting facilities	Automatic logging of system statistics	System Log Analysis tape and utilities	Data base for usage accounting routines
RECOVERY FEATURES			
Checkpoint/restart	Utilities supplied automatic with TP	With IMS/DC only	None
Data base integrity	Via prohibitive access	Transaction backout logging	Backout and image logging
OTHER SYSTEM FEATURES			
Concurrent batch/on line	Yes	Yes	Yes
Concurrent application program access	Yes	Yes, in DB/DC mode	Yes
Inquiry/retrieval facility	No one is planned for delivery in 1976	IQF, GIS/VS	INQUIRE Command Language
Report generator	CULPRIT, EDP/AUDITOR	GIS/VS, GIS-2	Command Language
Data dictionary support	User defined	An FDP is available for IMS 2 users	User-defined
Telecommunication interfaces	Most standard TP monitors	CICS and IMS/DC	CICS TSO IMS/DC, CMS and others
COMMENTS	CODASYL-type DBMS. Compression feature and user entry points Forms Approach retrieval due in 1976	Up to 255 segment types per logical record with 15 levels. Fine tuning utilities included	Data reference by multiple keys Multi Data base Processor feature

TABLE 4-13 (CONT'D.)

System	MODEL 204	SYSTEM 2000	TOTAL
DATA BASE FEATURES			
Data base organization	Hierarchical, network	Hierarchical network	Network
Application languages	COBOL, FORTRAN, PL/1, Assembler	FORTRAN, COBOL PL/1, Assembler	COBOL FORTRAN, PL/1, Assembler, RPG II
Data base languages	IFAM/II	DDL, IMMEDIATE	DBDL, DML
Variable-length segments	Yes	Yes	Physical—no logical—yes
Data base security	Password lockout, log-in protection	Password lockout, assigned authority	None
System accounting facilities	Multi user accounting log and utilities	Logs, statistics, and estimation tools	None
RECOVERY FEATURES			
Checkpoint/restart	Yes	Yes	Yes (with TP monitor)
Data base integrity	Rollback and audit trail	Transaction log and activity audit	Logging, dump and restore
OTHER SYSTEM FEATURES			
Concurrent batch/on line	Yes	Yes	Yes
Concurrent application program access	Yes	Yes	Yes
Inquiry/retrieval facility	User Language	System 2000 Query/ Update facility	For Honeywell systems only
Report generator	User Language	Yes	SOCRATES
Data dictionary support	User-defined	DDL	None
Telecommunication interfaces	CICS, Intercomm and self-contained DC	TP 2000, CICS, TSO Intercomm	ENVIRON/1 CICS, TASK/ MASTER, Intercomm
COMMENTS	Supports 250 physical files which can be cross referenced by a single user Multi threadng and data independence	Can handle up to 9 strings simultaneously with Multi-Thread option	A CODASYL-Type DBMS Supports up to 32 levels of data elements and up to 65,000 files

GMT INTERVAL	EXPERIMENT NUMBER							
	1	2	3	4	5	6	....	50
a-b	none	none	none	none	none	none		none
b-c	A_1	none	none	E_1	F_1	G_1		Z_1
c-d	A_2	none	none	E_2	F_2	none		Z_2
d-e	none	B_1	C_1	E_3	none	none		Z_3
e-f	A_3	B_2	C_2	none	none	none		Z_4
f-g	none	B_3	none	none	F_3	none		Z_5
g-h	none	B4	C_3	none	F_4	none		none
h-i	A_4	B_5	C_4	E_4	none	G_2		none
i-j	A_5	none	C_5	none	none	G_3		none
⋮	⋮	⋮	⋮	⋮	⋮	⋮		⋮

FIGURE 4-1. MASS STORAGE SYSTEM LOCATION INDEX

4.2 2 Executive Software

This body of software should provide the capability for software development as well as for system operation, resource allocation and monitoring and failure detection.

For software development the following capabilities must be provided:

- Assemblers
- Linkers
- Loaders
- Editor for debugging
- File Managers
- High Level Language Compilers
- Desk Editor
- Reassignment of Peripherals
- Interactive Capability

A full discussion of the requirements of exectuive system management will be found in Section 6.2.4, which describes the Resource Monitor.

5.0 DATA ANALYSIS

The following analysis lays the foundation for alternative architectures as presented in Section 6 of this study.

5.1 OPERATIONAL SCENARIOS

Under NASA/GSFC contract NAS5-23438, Mod. 31, ORI performed a tracking and data satellite coverage study for the Spacelab. In the final technical report (dated Sept. 16, 1977), numerous detailed mission timelines were constructed. The Shuttle/Spacelab missions selected for that study included Solar Physics (SP), three different Earth Observations (EO) missions, and a High Energy Astrophysics (HEA) mission. These missions provided a diverse set of timelines and are representative of the Shuttle/Spacelab missions to be flown in the early and mid-1980's.

The first mission scenario developed was for the Solar Physics (SP) mission, one of the least complex of the missions studied. Twelve experiments were projected to constitute the SP payload. The second mission analyzed was Earth Observations (EO). This mission presents a unique problem for the Shuttle/TDRS system, because the targets for this mission are highly localized, and any break in the Shuttle-TDRS link could result in the irretrievable loss of data on a particular target. Therefore, because the EO mission is so critical for the Shuttle/TDRS system, two additional EO missions were analyzed. The third type of mission studied was a High Energy Astrophysics (HEA) mission involving the viewing of celestial targets and a generally anti-solar orientation for the orbiter.

High-rate data bursts were projected to last between 2 and 20 minutes (with an average of about 5 minutes per burst), the time projected between bursts was typically in units of hours. Assuming a seven-day mission, about 8.9 hours of real-time for high-rate data transmissions (at 50 Mb/s) and 5 minute burst durations, approximately (8.9 x 60 / 5 = 106.8) 100 bursts per mission would not be unlikely. If these bursts were equally distributed throughout the seven day mission, then the average time between bursts (including the 5 minutes of the burst itself) would be approximately (7 x 24 x 60 / 100 = 100.8) 100 minutes.

This projection and previous information suggests that data entering the SOPS could be conveniently grouped in large units corresponding to orbits* of the Spacelab. The distribution of data as a function of orbit is illustrated in Figure 5-1. In this figure, the high-rate data transmissions are placed in the segments of the time line that correspond to lulls in low-and medium-data transmissions. These high-rate data bursts could contain those low-and medium-experiment data that could not be transmitted via TDRS due to orbital position. Therefore, it would be very wise to defer processing low-and medium-rate data until the next or succeeding orbit. As is shown in Figure 5-1, the data captured during orbit 1 is output processed while orbit 3 data is being captured. Thus, the data from each orbit is processed at the best time. In addition, normal high-rate data (i.e., not playback) may consist of low-, medium-, and high-rate data channels.

Therefore, three operational scenarios are possible. These are illustrated in Figures 5-2 and 5-3. The first scenario shows that low and medium-rate data is processed in real-time (between 0+ days and D days). After real-time data acquisition is completed, the high-rate data is processed. However, since low- and medium-rate data gaps have a high probability of showing up in the form of high rate-bursts, operationally no low-and medium-rate output products could be fully processed until all high-rate data were searched and processed. This scenario can be discarded.

To compensate for the above scenario's deficiencies, scenario number 2 is proposed (as illustrated in the lower half of Figure 5-2). In this scenario, one would process all data in pseudo-parallel; i.e., low-and medium-rate with high-rate fill. This scenario is acceptable on all counts except that quick-look and near-real-time analyses are excluded.

---

*Note: A Spacelab orbit is projected to be in the neighborhood of 100 minutes.

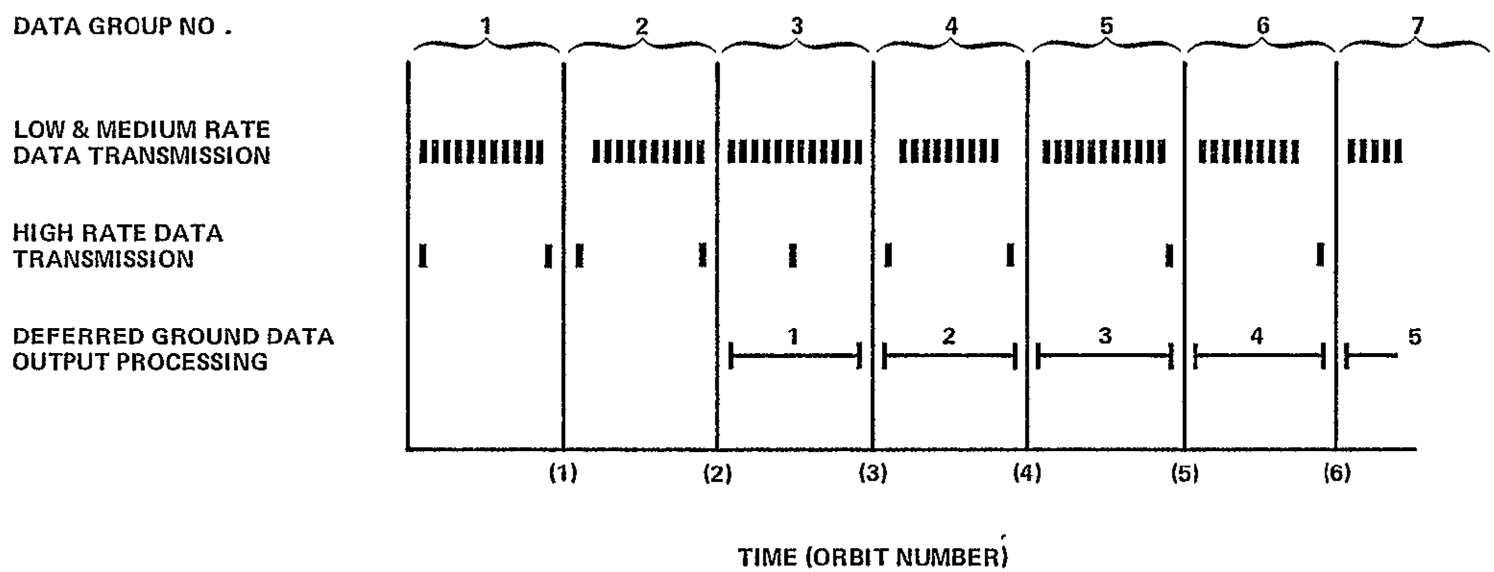
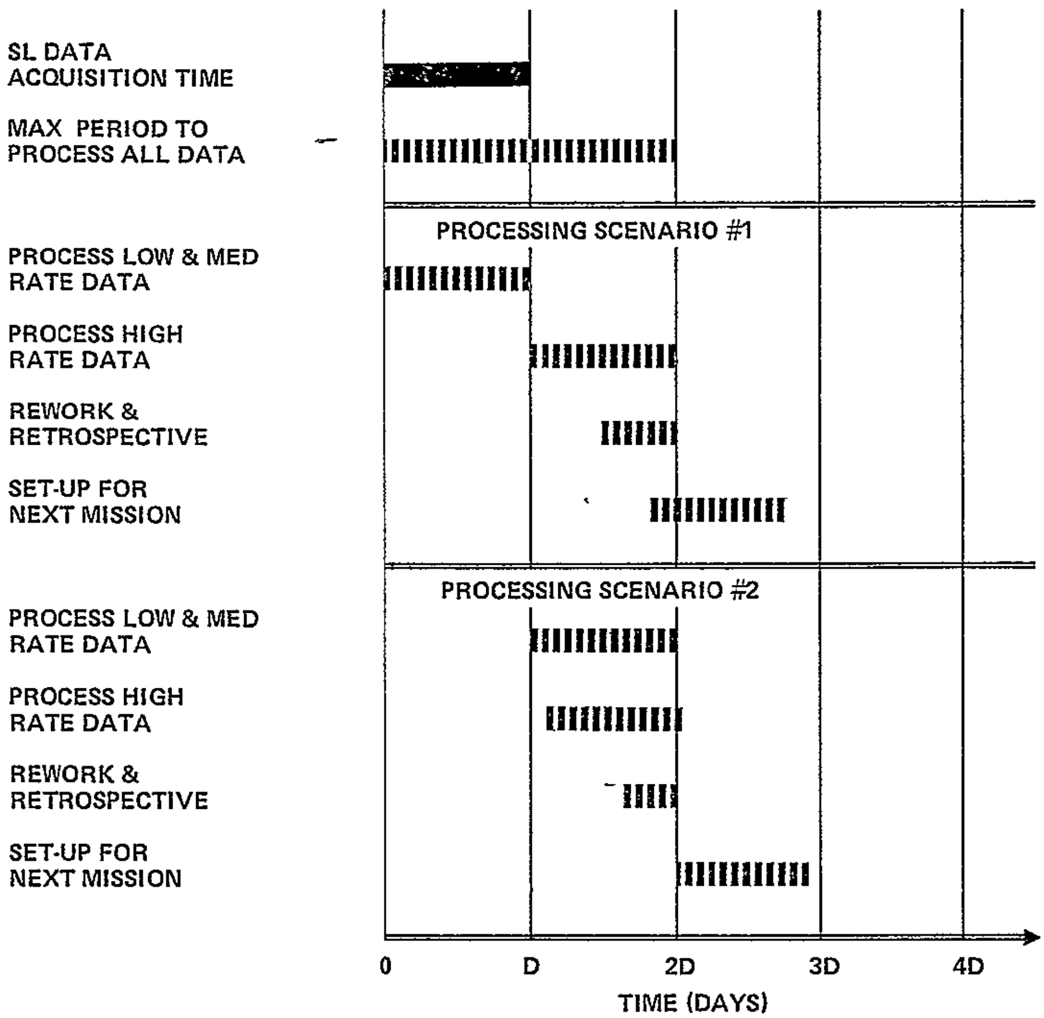


FIGURE 5-1. HYPOTHETICAL DISTRIBUTION OF LOW, MEDIUM, AND HIGH RATE INCOMING DATA AND GROUND PROCESSING TIME



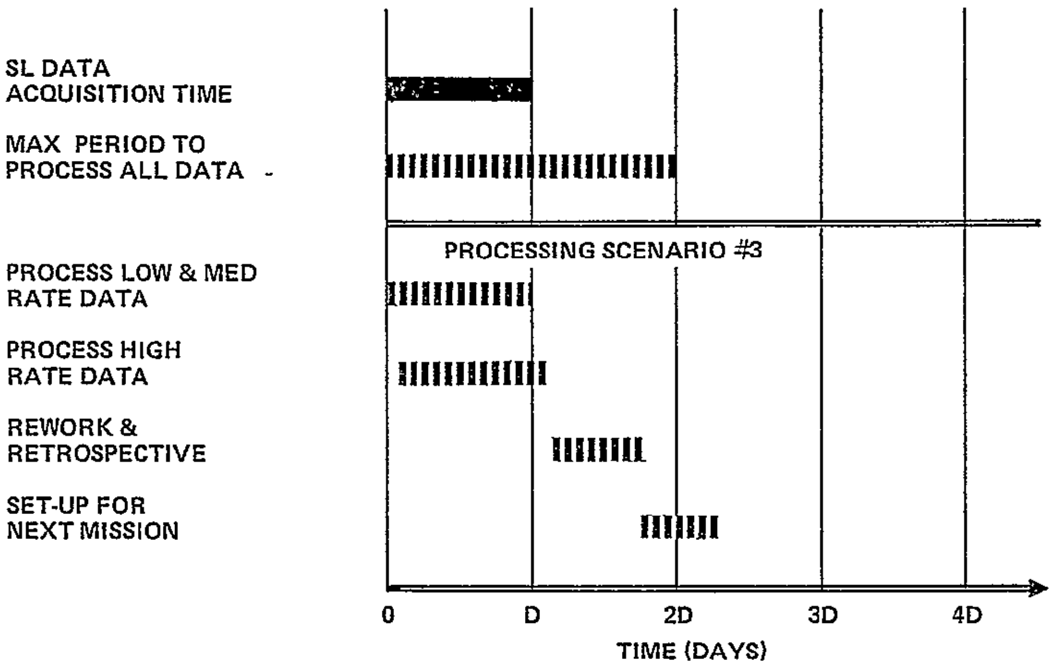
OD = MISSION START

D = MISSION END, REPRESENTS A POST PROCESSING RATE OF 1 X AVERAGE DATA RATE

2D = REPRESENTS A POST PROCESSING RATE OF 5X AVERAGE DATA RATE, LAST DAY OF SCHEDULED DATA PROCESSING, AND FIRST DAY OF SET-UP FOR NEXT MISSION

3D = END OF SET-UP FOR NEXT MISSION

FIGURE 5-2. OPERATIONAL SCENARIOS



OD = MISSION START

D = MISSION END, REPRESENTS A POST PROCESSING RATE OF 1 X AVERAGE DATA RATE

2D = REPRESENTS A POST PROCESSING RATE OF 5X AVERAGE DATA RATE, LAST DAY OF SCHEDULED DATA PROCESSING, AND FIRST DAY OF SET-UP FOR NEXT MISSION

3D = END OF SET-UP FOR NEXT MISSION

FIGURE 5-3. OPERATIONAL SCENARIOS

Thus, scenario number 3 is proposed (as illustrated in Figure 5-3). This scenario has the advantage of supporting near real-time data processing, POCC communications, very short data turn-around time, and a minimum amount of personnel staffing since facilities have to be operational (3 shifts/day) during the data acquisition period (0+ to D days).

5.2 INCONSISTENCIES OF GIVEN DATA

On Table 2-1, there seems to be an inconsistency in the last column Bit Rate (mission average): the total of the column is 4Mb/s, while the specifications indicate an upper bound of 8Mb/s, which is consistent with a volume stated at 5×10^{12} bits.

This table can be amended in two ways. First, if the following computation is performed on the existing data:

Mission Average Bit Rate (MABR) = Average bit rate of experiment group x number of experiments x% of time on.

Thus, for group A

$$MABR = 20 \times 10^6 \times 2 \times 0.05$$
$$= 2 \text{ Mb/s}$$

Performing this computation for all groups yields·

A	2 Mb/s
B	2 Mb/s
C } D	4 Mb/s
E	.4 Mb/s
F	.1 Mb/s
TOTAL	8.5 Mb/s

The second method involves a complete recomputation, which affects both the average bit rate per experiment group and the mission bit rate average. This appears as follows

Given a bit rate range (BR_1 through BR_2) and assuming a uniform distribution of rates in this range, the average bit rate is:

$$\text{Average group rate} = \frac{BR_1 + BR_2}{2} \text{ bits/sec}$$

Now, if N is the number of experiments in the group, and P is the percentage of time, each is on then.

$$MABR = \frac{BR_1 + BR_2}{2} \quad NP \text{ bits/sec}$$

Table 5-1 is a composite of the givens plus the amendments. Consider the case where incoming high-rate data must be slowed down to a point where the SOPS can handle it. Considering a DMA rate of 2 5M words/sec, then 16 bit words = 40 Mb/s, and allowing an overhead of 50% to handle the data, we will use 20 Mb/s as the peak available transfer rate.

If we now assume that all incoming rates are cumulative, then construct a table of the highest peak rates which can occur per group.

= highest rate x # of experiments

A	50 Mb/s	This is the highest the S/C supports
B	40 Mb/s	
C*	4 Mb/s	
D*	8 Mb/s	
E	1 Mb/s	
F	0.2 Mb/s	

*Note Either C or D

Now starting from F and summing backwards, we find that there is a threshold at 13.2 Mb/s, which is F + E + D + C. It can also be seen that A and B may not be summed as they would exceed the peak threshold. Therefore, they must occur on separate lines. So, we will consider a single playback slowed down such that A is at the defined SDPF peak rate of Mb/s, giving a factor of 2.5 to 1, which makes the B playback at 16 Mb/s.

Reconsidering now the average rates for the mission,

$$C + D + E + F = 4.8 \text{ Mb/s}$$

$$A = \frac{2.0}{2.5} = 0.8 \text{ Mb/s}$$

$$B = \frac{1.8}{2.5} = 0.72 \text{ Mb/s}$$

$$\text{Total} = 6.320 \text{ Mb/s}$$

If one were to consider a serial chain of events, i.e., low-rate data accumulated first in real-time, and high-rate data next slowed down; then this process would take (5×10^{12} bits/mission of 7 days) 9.157 days.

TABLE 5.1 A TYPICAL EXPERIMENT PROFILE

EXP GROUP	BIT RATE RANGE Bb/S	RANGE NO. OF EXP PER GROUP	AVERAGE BIT RATE OF GROUP Mb/S			% TIME ON	MISSION AVERAGE BIT RATE Mb/S		
			GIVEN	MOD1	MOD2		GIVEN	MOD1	MOD2
A	10-30	1-2	20	20	20	2.5-5	1.0	2.0	2.0
B	1-10	1-4	5	5	4.5	2.5-10	.5	2.0	1.8
C	.1-1	4	.5	.5	0.55	100	2.0	4.0	2.2
D	1-1	8			0.55	50			2.2
E	.01-.1	10	.04	.04	0.06	100	.4	.4	0.6
F	.01	20	.005	.005	0.01	100	.1	.1	0.2
						TOTALS	4.0	8.5	9.00

It is instructive now to assume that the mission average can be applied to a per orbit scenario and to discuss what percentage of total data the high-rate data can be per orbit.

We know that the orbit is a 100 minute orbit, with 70 - 80% of real-time contact and 20 - 30% of black time when the high-rate data can be played back for early missions only.

Now the average high-rate playback rate of A & B combined is 1.5 Mb/s, and we will use 20% of the orbit as a worst case black time. This is 20 minutes. Therefore, the number of bits which can be played back is:

$$20 \text{ minutes} \times 60 \text{ secs/min} \times (1.5 \times 10^6) \text{ bits/sec} = 1.8 \times 10^9 \text{ bits}$$

And for the remaining 80 minutes, the average rate is 4.8 Mb/s. Therefore, the number of bits of real-time low-rate data is:

$$80 \text{ minutes} \times 60 \text{ secs/min} \times (4.8 \times 10^6) \text{ b/s} = 23.04 \times 10^9 \text{ bits plus}$$
normal high-rate data

Therefore, the percentage of data/orbit which is high-rate data, that <u>can be</u> made available is:

$$\left(\frac{1.8}{23.04 + 1.8}\right) \times 100 = 7\ 246\%$$

Now it is shown elsewhere in this study that on the average, there will be a burst of high-rate data once per orbit, and that this represents 5.21% of the total data.

Therefore, because $5.21 < 7.246$ it is shown that scenario number 3 can be accommodated with a high-rate slow down of 2.5:1 and low-rate real-time acquisition.

5 3 INPUT DATA

We will now compute an approximation of the typical experiment data file. This can be obtained from the previously given information as tabulated in Table 5-1. Summing the BIT RATES in the last column of Table 2-1, an average mission bit rate of 4 Mb/s is confirmed. Thus, group A experiments would consume ¼ of the total bit volume. Group B experiments would likewise consume 0.5/4 of the total bit volume. These values are tabulated in the second column of Table 5-2 under % OF MISSION AVERAGE BIT RATE. Since a total of 5 x 10^{12} bits are collected per mission, applying the computed percentages, the NO. OF BITS PER MISSION FOR THE EXPERIMENT GROUP is then derived (i.e , 25% of 5 x 10^{12} = 1.25 x 10^{12} for group A experiments). Dividing the number of bits per experiment group by the number of experiments, yields the NO. OF BITS or BYTES PER EXPERIMENT as shown in Table 5-2. It should be pointed out that the computed groups C and D consist of 4 full-or 8 part-time experiments and are equivalent in volume to 8 full-time experiments. Thus, each full-time experiment equals (approximately) 313 x 10^9 bits or 39 x 10^9 bytes. A half-time experiment is assumed to be half of the volume of a full-time experiment. To visualize the relative volumes of experiment data, Figure 5-4 is offered.

TABLE 5-2

A HYPOTHETICAL MIX OF EXPERIMENT DATA FOR A 7-DAY MISSION

	NO. OF EXPERIMENTS & (Exp. Group Designator)	% OF MISSION AVERAGE BIT RATE (%)	NO. OF BITS PER MISSION FOR EXP. GROUP ($x10^{12}$)	NO. OF BITS PER EXP. ($x10^9$)	NO. OF BYTES PER EXP. ($x10^9$)
	2 (A)	25.0	1.25	625	78
	4 (B)	12.5	0.625	156	20
	4 (C)	50.0 (C and D)	2.50 (C and D)	313	39
	8 (D)			156	20
	10 (E)	10.	0.50	50	6
	20 (F)	2.5	0.125	6	1
Sum:	48	100.0	5.00		

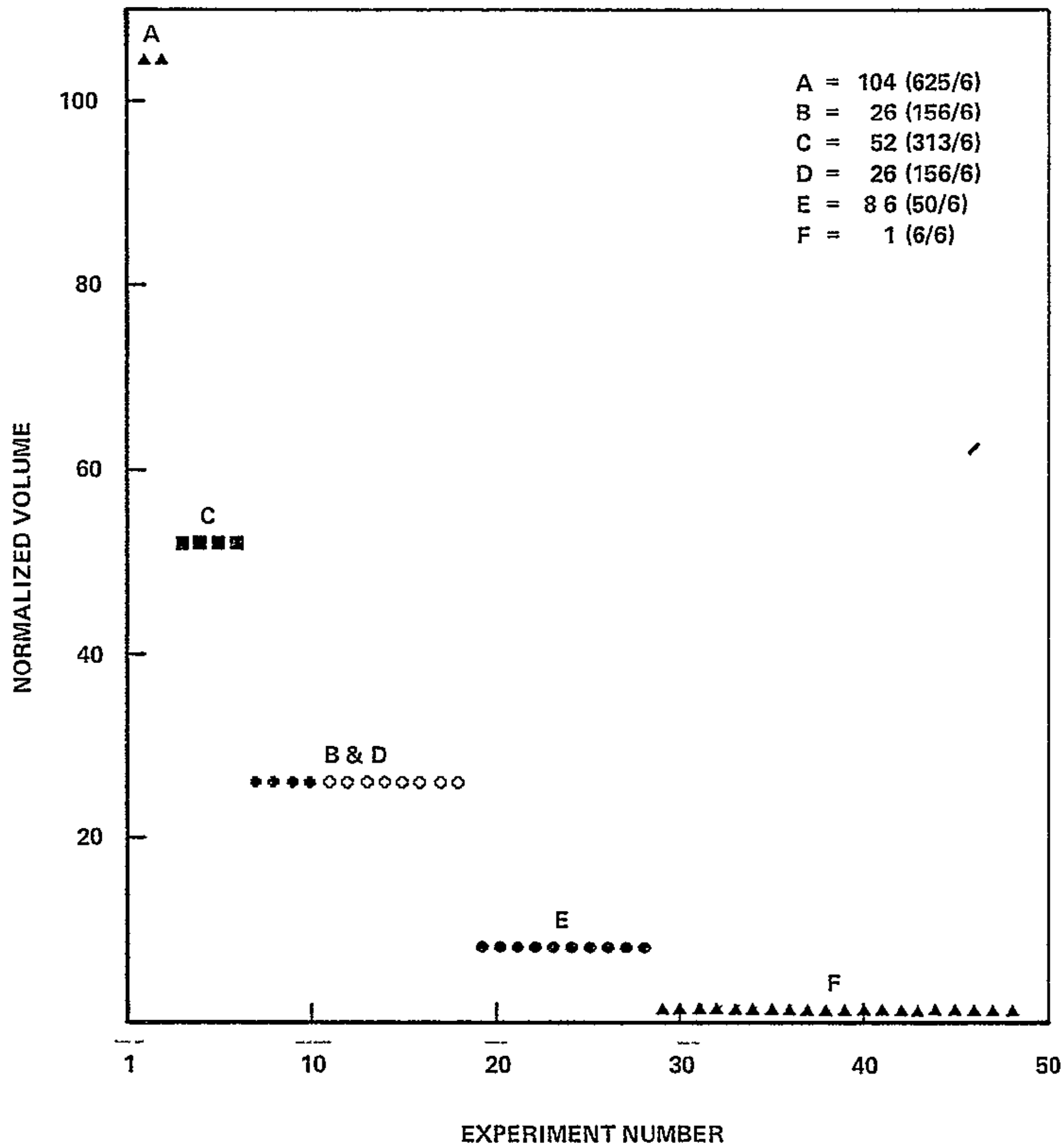


FIGURE 5-4. NORMALIZED DISTRIBUTION OF EXPERIMENT VOLUMES

Since the average data rate for low-and medium-data rate experiments (R_{LM}) is assumed for the purposes of this analysis to be between 4 and 8 Mb/s, the instantaneous average data rate for low-and medium-rate experiments (R_{LM}) can be (arbitrarily) defined as:

$$R_{LM} = (4 + 4f(t)) \text{ Mb/s} \quad \text{and}$$

$$\overline{R_{LM}} = 6 \text{ Mb/s.}$$

where:

$\overline{R_{LM}}$ = average data rate for low-& medium-data rate experiments

R_{LM} = instantaneous data rate for low-& medium-data rate experiments

$f(t)$ = a random walk function that has its mean value and sigma defined as:

$m=2$

$(5s=2)$

$s=.4$

Since the total data volume (D_T) equals 5×10^{12} bit/mission, let:

$$D_T = D_{LM} + D_H = 5 \times 10^{12} \text{ bits/mission}$$

where:

D_{LM} = data volume due to the average steady state data rate $\overline{R_{LM}}$

D_H = data volume due to high rate experiment data rate R_H

D_{LM} can be computed to be.

$$D_{LM} = 7 \frac{\text{day}}{\text{mission}} \times 24 \frac{\text{hr.}}{\text{day}} \times 3600 \frac{\text{sec.}}{\text{hr}} \times (6 \times 10^6) \frac{\text{bits}}{\text{sec.}}$$

$$D_{LM} = 3.63 \times 10^{12} \text{ bits/mission}$$

Therefore D_H can be computed by:

$$D_H = D_T - D_{LM}$$

$$D_H = (5-3.63) \times 10^{12} \text{ bits/mission}$$

$$D_H = 1.37 \times 10^{12} \text{ bits/mission}$$

The average data rate associated with the high-rate experiments $\overline{R_H}$ can be derived from the following expression:

$$R_T = \overline{R_{LM}} + \overline{R_H}$$

where:

R_T = highest SDPF input data rate

$\overline{R_{LM}}$ = average low and medium data rate contribution

Since:

R_T = 50 Mb/s and

$\overline{R_{LM}}$ = 6 Mb/s

Then:

$$\overline{R_H} = 50-6 = 44\text{Mb/s}$$

Since:

R_T = 50 Mb/s and

R_{LM} = (4+4f(t)) Mb/s

Then the instanteous data rate for the high rate experiments (R_H) is defined by:

$$R_H = R_T - R_{LM}$$

$R_H = 50-(4+4f(T))$ Mb/s

$R_H = 46 - 4f(t)$ Mb/s

Therefore.

$\overline{R_H} = 44$ Mb/s

Since:

$R_H = R_{LM} + 44+6 = 50$ Mb/s $+ R_{LM}$

The next task is to compute the contribution of the high-rate data experiments to the total data volume. Since $\overline{R_H} = 44$ Mb/s and $D_H = 1.37 \times 10^{12}$ bits/mission, then the total time on (T_H) would be derived from the expression·

$$T_H = D_H / \overline{R_H}$$

$$T_H = \frac{1.37 \times 10^{12} \text{ bits/mission}}{44 \times 10^6 \text{ bits/sec}}$$

$$T_H = 8.65 \text{ hours/mission}$$

This amount of time, it should be noted, represents 5.21% (8.65 /(7x24)) of the total mission time. This estimate checks with earlier estimates in the study.

Because the 50 Mb/s data is captured in the DCS and the SOPS is sized to handle 4-8 Mb/s, a slow down of 4/50 or 8/50 could solve the processing problem. As high-rate data slows, so the processing time is correspondingly multiplied. The high-rate data represents approximately 8.65 hours of real-time. Slowing down the data to 4-8 Mb/s would therefore mean the total time to process this data (excluding physical stop, starts, mounting, etc.) would be (50/4) x 8.65 108.13 or (50/8) x 8.65 54.06 hours. This represents 4.51 or 2.25 twenty-four hour days of continuous data processing.

5.4 OUTPUT DATA PRODUCTS

This section shall describe some general computations on the nature of the output products generated by the SOPS. Four output media are envisioned (1600 bpi, 6250 bpi, HDT, 56 Kb/s transmission line), their salient characteristics (bit capacity per reel and data transfer rates to create such products) are tabulated in Tables 5-3 and 5-4. A useful computation is the number of reels of magnetic tape that would be required to hold the entire mission data base (5×10^{12} bits). These values are shown in the fourth column of Table 5-3.

Based on the given two-volume mix earlier stated (Section 2.1.1.2), two-volume mixes are tabulated in columns 5 and 6 of Table 5-3. It will be assumed for the sake of simplicity that these volumes support the indicated number of experiments and that the minimum number of reels to contain this data is at least as shown in columns 7 and 8 (Table 5-3). Table 5-5 provides a cross reference to how many reels of 1600 bpi, 6250 bpi, HDT, or how many seconds on a 56 Kb/s line would be required to handle <u>one</u> experiment.

At this time, it is not known precisely how most of these output products would be distributed, but one can tabulate the distribution as shown in Table 5-6. Only the two "A" group experiments are known to be transcribed onto HDT.

The foregoing accounts only for experiment data, we must also add attitude and ephemeris data. (Section 5.3.3 projects about four 1600 bpi reels or one 6250 bpi reel for one complete set).

TABLE 5-3

TWO-VOLUME DISTRIBUTIONS

1	2	3	4	5	6	7	8
MEDIA.	Media Bit Capacity	Data XPer Rate in bits/s.	No. of Reels to hold $5x10^{12}$ bits	Vol. 1 in 10^{12} Bits	Vol. 2 in 10^{12} Bits	Minimum No. of Reels of Tape for Vol. 1*	Minimum No. of Reels of Tape for Vol. 2*
1600 bpi	3×10^8	2.0 M	16,667	2.5	0.5	8334	1667
6520 bpi	1.2×10^9	10.0M	4,167	1.0	1.25	834	1041
HDT	1.4×10^{10}	0.5→20.0 M	357	0.5	0.75	35.	53
Comm. Lines	N.A.	56 K	N.A.	1.0	2.5	*Hours of Comm Time over 1 line for Vol.1* 5556	*Hours of Comm. Time over 1 line for Vol.2* 13,889
				Sum = 5×10^{12} bits			

*Note: These values are "minimum, i.e., packed experiment data.

TABLE 5-4

COMPARISON OF MAGNETIC TAPE SPECIFICATIONS

Characteristics	High Density Digital Tape	Computer-Compatible Tape	
		1600 bpi*	6250 bpi**
Nominal Length			
(meters)	$\leq$ 2195	732	732
(feet)	$\leq$ 7200	2400	2400
Data Capacity (bits/reel)	1.4×10^{10}	3×10^{8}	1.2×10^{9}
Data Transfer Rates (megabits/second)	0.5 - 20	2	10
Error Rates (bits)	$1/10^{6}$	$1/10^{9}$	$1/10^{9}$

*At 125 inches per second; 3600 bytes per block (80% packing efficiency).

**At 200 inches per second; 7500 bytes per block (80% packing efficiency).

TABLE 5-5

ESTIMATED EXPERIMENT VERSUS MEDIA CROSS REFERENCE

Experiment Group Designator	No. of Bits/Exp. ($x10^9$)	No. of Reels of Tape To Hold 1 Experiment			No. of Sec. of Comm. Time on One 56 Kbps Line to Transmit One Experiment
		1600 bpi	6400 bpi	HDT	
A	625	2083.3	520.8	44.6	1.12×10^7
B	156	520.0	130.0	11.1	2.79×10^6
C	313	1043.3	260.8	22.4	5.59×10^6
D	156	520.0	130.0	11.1	2.79×10^6
E	50	166.7	41.7	3.6	8.93×10^5
F	6	20.0	5.0	0.4	1.07×10^5

TABLE 5-6

POSSIBLE DISTRIBUTION
OF OUTPUT PRODUCTS

Experiment Group Designator	No. of Bits/Exp. $(x10^9)$	Total No. of Exps. in Group	Possible Distribution Of Output Products.			
			1600 bpi	6250 bpi	HDT	Comm. Line
A	625	2	0	0	2	0
B	156	4	0	i	j	0
C	313	4	0	k	l	0
D	156	8	0	m	n	0
E	50	10	p	q	0	r
F	6	20	s	t	0	u

Notes: $i + j = 4$

$k + l = 4$

$m + n = 8$

$p + q + r = 10$

$s + t + u = 20$

5.4.1 Tape Products

It would be worthwhile at this point to compute the approximate number of tape recorders to output the required data volume. One can start this computation by defining the number of reels (n_r) to contain the projected volume as:

$$n_r = \frac{V_T}{V_R} \qquad (1)$$

where n_r = number of reels of tape per mission

V_T = total volume of data on tape in bits per mission

V_R = volume of data on a reel in bits per reel

Using the linear expression D= RT (distance = rate x time) and the fact that D also equals the product of n_r times the length (L) of a reel, the time (T) in seconds to record (at R_{rec} ips) and rewind (at R_{rwd}) ips) on a single tape recorder would be:

$$T = \frac{D}{R_{rec}} + \frac{D}{R_{rwd}} = D \cdot \left[\frac{R_{rec} + R_{rwd}}{R_{rec} \cdot R_{rwd}}\right] \qquad (2)$$

$$T = L \cdot n_r \cdot \left[\frac{R_{rec} + R_{rwd}}{R_{rec} \cdot R_{rwd}}\right] \qquad (3)$$

where

T = time in seconds

L = length of a reel in inches

n_r= number of reels

R_{rec} = Record speed in inches per second

R_{rwd} = Rewind speed in inches per second

Since 1600 and 6250 bpi tapes are recorded and rewound at the same speeds, it is legitimate to combine the number of reels of 1600 and 6250 bpi. At this point, in a preceding table (Table 5-5.), it was stated that 2 volumes are projected. It was also computed that for the first volume, (8334 + 834) 9168 and (1667 + 1041) 2708 reels could be produced in the facility. This represents the projected CCT tape volume only. To see what time would be consumed on only one (1) transport for these 9168 and 2708 reels, let:

$$L = 2400' = 2400 \cdot 12''$$

$$n_r = 9168 \text{ or } 2708$$

$$R_{rec} = 200 \text{ ips}$$

$$R_{rwd} = 640 \text{ ips}$$

Then for a continuous record and rewind on ONE tape transport with no mount or demount considerations for 9168 reels:

$$T \cong \frac{2400 \cdot 12 \cdot 9168\ (640 + 200)}{640 \cdot 200} \cong 1.73 \times 10^6 \text{ seconds}$$

$$T \cong \frac{1.73 \times 10^6 \text{ sec}}{3600 \frac{\text{sec}}{\text{hr}}} \cong 481 \text{ hours}$$

$$T \cong \frac{481 \text{ hr}}{24 \frac{\text{hr}}{\text{day}}} \cong 20.1 \text{ days}$$

For 2708 reels:

$$T \cong \frac{2400 \cdot 12.2708\ (640 + 200)}{640 \cdot 200} \cong 0.51 \times 10^6 \text{ seconds}$$

$$T \cong \frac{0.51 \times 10^6 \text{ sec}}{3600 \frac{\text{sec}}{\text{hr}}} \cong 142 \text{ hours}$$

$$T \cong \frac{142 \text{ hr}}{24 \frac{\text{hr.}}{\text{day}}} \cong 5.9 \text{ days}$$

From the above, it is obvious that multiple transports will be required. With multiple units, the time lost due to rewinding disappears since a rewind will take place during write operation.

The task at hand is to determine how many tape transports would be required to handle the programmed volume. To compute the number of tape drives and operators required for a 7-day mission

Write time per tape $= \frac{2400 \text{ feet} \times 12 \text{ secs}}{200 \text{ ips}}$

$= \underline{144 \text{ secs}} = 0.04 \text{ hrs}$

Rewind time per tape $= 0.75 \text{ min} = 0.012 \text{ hrs}$

Allow 3 min for search and mount $= 0.05 \text{ hrs}$

Total tape handling time per tape $= 0.04 + 0.012 + 0.05 \text{ hrs}$

$= \underline{0.102 \text{ hrs.}}$

No of tapes that can be handled in one day

$= \frac{24 \text{ hrs}}{0.102 \text{ mins/tape}} = 235.29 \text{ tapes}$

For a seven-day operation, the number of tapes/day for each of the volumes previously calculated is 1310 and 386.86.

number of drives for each volume is

$\frac{1310}{235.29}$ and $\frac{386.86}{235.29}$

$=$ 5.57 and 1.64

6 2

showing that we require one (1) operator per tape drive, allowing a net time between mounts of 0.0025 hrs or 9 secs. But with 2 operators to attend a tape drive, each would have 0.052 hrs (3.15 mins rest) with three operators per tape drive 0.104 (6.30 mins), etc. Therefore the number of operators required to handle tapes is entirely a function of real time.

Consider having 12 drives for volume #1

Then time to mount -

= 12 x 0.05
= 0.600 hrs

and time to run -
= 12 x 0.052
= 0.624 hrs

giving a rest time

= 0.024 hrs
= 1.44 mins

Performing this for 24 drives gives a rest time of 2.88 mins.

Thus, in this case the trade-off for similar rest times is the number of tape drives versus the number of operators.

Note that in order to obtain about a 3 min average rest time we had to either double the number of operations (in 6 drive case, from 6 to 12), or quadruple the number of drives (from 6 to 24).

Consider using the calcomp ATL system, which has a 15 sec retrieve and mount time, i.e., 30 sec total tape handling time we have -

30 secs = 0.0083 hrs

Now, total tape time = 0.04 + 0.012 + 0.008
= 0.06 hrs

Number of tapes which can be handled in one day = 400

$$\text{No. of drives} = \frac{1316}{400} \quad \text{and} \quad \frac{386.86}{400}$$

$$= 3.724 \qquad\qquad = 0.967$$

Or 4 Or 1

If we consider 25% down time, we get -

5 and 2

The cost of the ATL can now be traded off against the cost of operations.

5.4.2 Communications

As can be seen from Table 5-5, a number of experiment file groups are candidates for telecommunication transmission in lieu of tapes. These are groups F, E, D, B, and C. Assuming one line to each experimenter, what are the possibilities (in terms of time)? Table 5-7 provides a quick reference to how many seconds are in each full 7-day work week by 1, 2, and 3 full shifts. Table 5-8 provides a cross matrix of the possibilities. As can be seen in the table, only selected experiments groups E and F can be serviced.

TABLE 5-7

MAXIMUM NUMBER OF SECONDS IN WORK WEEKS

WEEKS	SHIFTS* PER DAY	TOTAL TIME IN SECONDS
1	3	6.05×10^5
	2	4.03×10^5
	1	2.02×10^5
2	3	1.21×10^6
	2	8.06×10^5
	1	4.03×10^5
3	3	1.81×10^6
	2	1.21×10^6
	1	6.05×10^5
4	3	2.42×10^6
	2	1.61×10^6
	1	8.06×10^5

* 8 hours continuous time per shift

TABLE 5-B

POSSIBLE EXPERIMENT COMMUNICATION COMBINATIONS

Exp. Group	No. of Exps. in Group	No. of Sec. to Xmit. 1 Exp. File on 1 56 Kb/s Line	1-4 weeks @ 1-3 shift/day 1w			2w			3w			4w		
			3S	2S	1S	3S	2S	1S	3S	2S	1S	3S	2S	1S
A	2	1.12×10^7	N	N	N	N	N	N	N	N	N	N	N	N
B	4	2.79×10^6	N	N	N	N	N	N	N	N	N	N	N	N
C	5	5.59×10^6	N	N	N	N	N	N	N	N	N	N	N	N
D	8	2.79×10^6	N	N	N	N	N	N	N	N	N	N	N	N
E	10	8.93×10^5	N	N	N	Y (1.35)	N	N	Y (2.03)	Y (1.35)	N	Y (2.71)	Y (1.80)	N
F	20	1.07×10^5	Y (5.65)	Y (3.77)	Y (1.89)	Y (11.3)	Y (7.53)	Y (3.77)	Y (16.9)	Y (11.3)	Y (5.65)	Y (22.6)	Y (15.0)	Y (7.53

N = NO

Y = YES

( ) = LINE UTILIZATION TOTAL TIME IN SEC. DIVIDED BY ONE FILE SIZE

5.4.3 Ephemeris & Attitude Data

Generally stated, the volume (v) of ephemeris and ancillary data that will be computed and subsequently written into CCTs are:

$$V = D \frac{\text{days}}{\text{mission}} \times \frac{24 \text{ hours}}{\text{day}} \times \frac{3600 \text{ sec.}}{\text{hr.}} \times \frac{B \text{ bytes data}}{S \text{ sec.}}$$

or

$$V = \frac{D \cdot B}{S} \times 8.64 \times 10^4 \frac{\text{bytes data}}{\text{mission}}$$

where

D = No. of days for mission

B = No. of bytes per data point

S = No. of seconds per data point

Based on previous data in Section 2, D=7, B=400, and S=2.

Therefore

$$V = \frac{7 \cdot 400}{2} \times 8.64 \times 10^4 \frac{\text{bytes}}{\text{mission}}$$

$$V = 1.21 \times 10^8 \frac{\text{bytes}}{\text{mission}}$$

It shall be noted that this volume of data is projected to be recorded on 1600 or 6250 bpi tape for each experimenter. A typical reel of 1600 bpi tape holds about (3/8) 0.38×10^8 bytes and a reel of 6250 bpi tape holds (12/8) 1.5×10^8 bytes. Thus, about (1.21/.38) 3.18 reels of 1600 bpi tape or (1.21/1.5) 0.81 reels of 6250 bpi tape would be required to hold the volume of data. It is envisioned that each experimenter will get one 1600 bpi 9-track tape per day per experiment.

6.0 ALTERNATE ARCHITECTURES

In order to arrive at a set of potentially feasible architectures which will satisfy the mandatory requirements of the SOPS, the alternate flows of data within the system must first be considered. The major functions in the system are to decommutate experiment data, to archive it, and to present experimenters with orderly and complete information. The following sections examine two possible data flows which accomplish these. Each data flows positions the decommutation function and the Mass Storage System (MSS) differently. The high-level data flows are shown in Figures 6-1 and 6-2 respectively.

6.1 DATA FLOWS

In Figure 6-1, the data flow shows that the work units are assembled and keyed to the (DCS) data lines rather than to the experiments. The operations performed on the data are executed after storing the data into the MSS.

In Figure 6-2, the data flow indicates that the decommutation function is performed in the front end of the system and the data is subsequently assembled into work units which by definition are unique for each experiment. Thus, the data stored in the MSS would be in a format related to experiments (as shown in Figure 6-3 under DECOMMUTATED DATA), and would be ready for further data operations and formatting into output experiment data files.

It can be readily seen that these two flows exhibit a difference not only in the formats of the files in the MSS, but also in the allocation of time in the performance of work on the data itself.

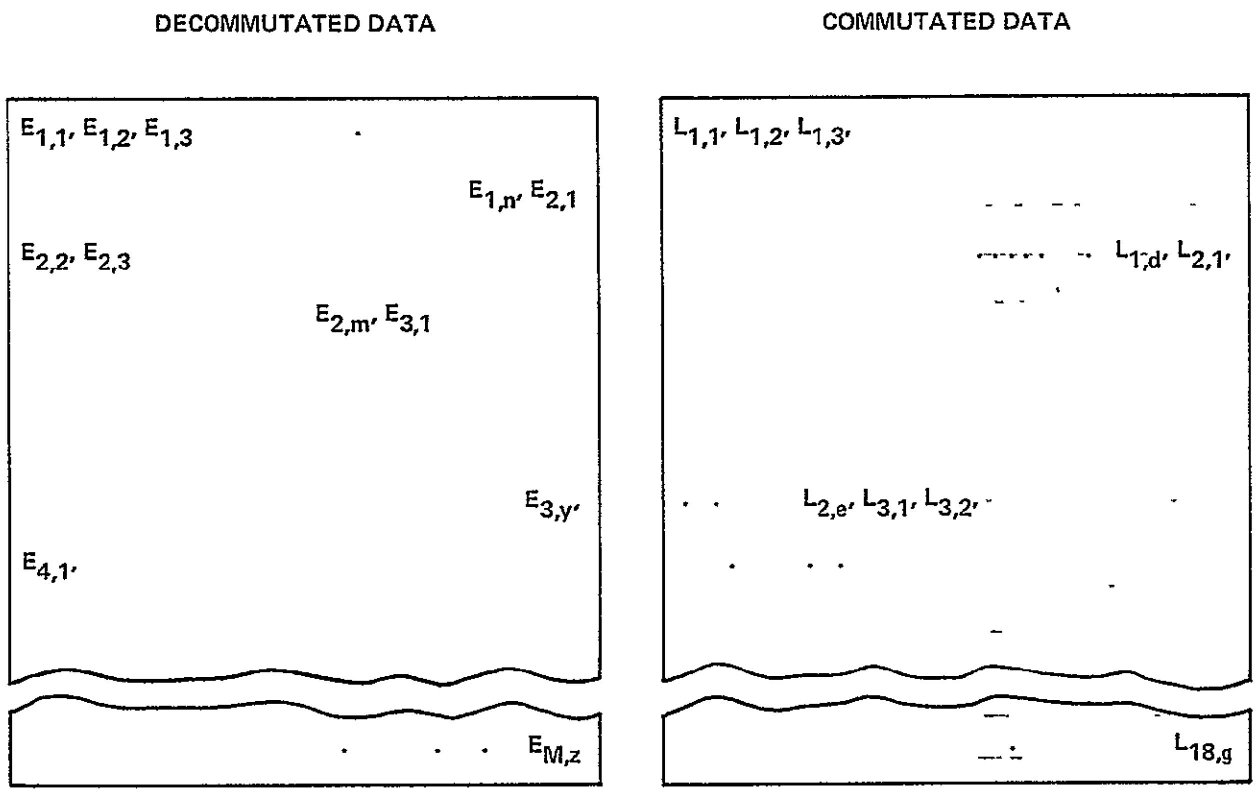
Table 6-1 shows that either of these data flows and their subsequent implementations satisfy all of the mandatory requirements outlined in Section 2 of this study. From these data flows, it was possible to derive two architectural families which will perform the required functions. Each architecture will be analyzed in terms of each data flow.

	LOGIC OPERATION	COMMENTS
1	ENTER	
2	INPUT ALL DATA	ACCEPT ALL DATA RATES
3	ASSEMBLE WORK UNITS	ASSEMBLE CONVENIENTLY LARGE WORK UNITS (MAYBE IN UNITS COMPATIBLE WITH THE MASS STORAGE SYSTEM)
4	MSS STORE	STORE COMMUTATED DATA ON A DATA LINE BASIS (CORRESPONDING TO DATA LINES FROM THE SIPS) IN MSS
5	EDIT	PERFORM TIME VALIDATION, OVERLAP REMOVAL, GENERATE FILL, ETC
6	EXTRACT AND STORE ANCILLARY	SEGREGATE ANCILLARY DATA IN EITHER LOCAL STORE OR MSS FOR EASE OF DATA FLOW
7	REFORMAT ATTITUDE AND ORBIT DATA	REFORMAT ORBIT AND ATTITUDE DATA AND PERFORM COORDINATE TRANSFORMATIONS, OUTPUT O/A TAPES
8	DECOMMUTATE	DECOMMUTATE "j" EXPERIMENTS FROM "k" INPUT LINE FILES AGAINST A KNOWN MAP
9	MERGE ANCILLARY DATA	WHEN REQUIRED, MERGE ANCILLARY DATA WITH EXPERIMENT DATA
10	FORMAT AND OUTPUT	WRITE TAPES, SETUP COMMUNICATIONS, ETC
11	EXIT	NOTE PERFORM ACCOUNTING AND QUALITY CHECK FUNCTIONS AT EACH STEP

FIGURE 6-1 DATA FLOW NUMBER 1

	LOGIC OPERATION	COMMENTS
1	ENTER	
2	INPUT ALL DATA	ACCEPT ALL DATA RATES
3	EDIT	PERFORM TIME VALIDATION, OVERLAP REMOVAL, GENERATE FILL, ETC.
4	DECOMMUTATE	DECOMMUTATE "j" EXPERIMENTS FROM "k" INPUT LINES AGAINST A KNOWN MAP MAY BE DONE IN EITHER HARDWARE OR SOFTWARE ENVIRONMENT
5	EXTRACT AND STORE ANCILLARY	SEGREGATE ANCILLARY DATA IN EITHER LOCAL STORE OR ON MSS FOR EASE OF DATA FLOW.
6	ASSEMBLE WORK UNITS	ASSEMBLE CONVENIENTLY LARGE WORK UNITS (MAY BE IN UNITS COMPATIBLE WITH THE MASS STORAGE SYSTEM (MSS)
7	MSS STORE	HAVE THE MSS PREDEFINED FOR EXPERIMENT FILE ALLOCATION (THIS IS DONE WITH THE EXPERIMENT MAP)
8	REFORMAT ATTITUDE AND ORBIT DATA	REFORMAT ORBIT AND ATTITUDE DATA AND PERFORM COORDINATE TRANSFORMATIONS, OUTPUT O/A TAPES
9	MERGE ANCILLARY DATA	WHEN REQUIRED, MERGE ANCILLARY DATA WITH EXPERIMENT DATA
10	FORMAT AND OUTPUT	OVERLAP REMOVAL, (GENERATE FILL IF REQUIRED), GENERATE TAPES AND SET UP COMMUNICATIONS
11	EXIT	NOTE *PERFORM ACCOUNTING AND QUALITY CHECK FUNCTIONS AT EACH STEP

FIGURE 6-2 DATA FLOW NUMBER 2



EXPERIMENT DATA (E) IS STORED SEQUENTIALLY BY THE FOLLOWING INDICES

$E_{\text{EXPERIMENT NO, DATA ELEMENT NO}}$

LINE DATA (L) IS STORED SEQUENTIALLY BY THE FOLLOWING INDICES

$L_{\text{DCS LINE NO, DATA ELEMENT NO}}$

TO CONSTRUCT AN EXPERIMENT DATA FILE, A ONE-TO-ONE MAPPING OF THE ABOVE LINE DATA SHALL BE PERFORMED.

FIGURE 6-3. SIMPLIFIED ILLUSTRATION OF DATA ELEMENTS IN THE MASS STORAGE SYSTEM

TABLE 6-1

A CROSS REFERENCE TO THE FUNCTIONAL REQUIREMENTS/SPECIFICATIONS IN CANDIDATE ARCHITECTURES

STEP NUMBER	ARCHITECTURE NUMBER 1	ARCHITECTURE NUMBER 2
3	2.1.2.1, 2.1.2.3	2.1.2.6
4	2.1.2.5	2.1.2.4
5	2.1.2.6	2.1.2.9
6	2.1.2.9	2.1.2.1; 2.1.2.3
7	2.1.2.7; 2.1. .8	2.1.2.5
8	2.1.2.4	2.1.2.7; 2.1.2.8
9	2.1.2.9	2.1.2.9
10	2.1.4; 2.1.5, 2.1.2.3; 2.1.2.2	2.1.6, 2.1.7, 2.1.2.3, 2.1.2.2

The following alphabetic notations shall apply uniformly in the discussions of the proposed systems:

A = Number of identical incoming Work Assembler (WA) subunits
B = " " bytes of buffer in each WA buffer
C = " " buffers in each WA
D = " " Buffer Analayzers (BA)
E = (not used)
F = (not used)
G = Number of Mass Storage Units (MSU)
H = " " bytes of storage in each MSU
I = (not used)
J = (not used)
K = Number of identical Computational Subsystems (CS)
L = " " Memories in CS
M = " " bytes of storage in each CS memory
O = (not used)
P = Number of 1600 bpi tape transports
Q = Number of 6250 bpi tape transports
R = " " HDT transports
S = " " Communication modems
T = Number of Staging Disks (SD)
U = Number of bytes of storage per (SD)
V = (not used)
W = (not used)
X = (not used)
Y = (not used)
Z = (not used)

6.2 ARCHITECTURE NUMBER 1

Architecture number 1 is illustrated in Figure 6-4. This architecture fully supports data flow number 1 (as previously illustrated in Figure 6-1). A brief system utilization walkthrough is presented below.

Spacelab and GMT data enter the system via multiple SIPS output lines. It is assumed that all data on these lines are commutated (viz. lines 1 through 18). The data enters a Work Assembler (WA) where conveniently large buffers are built. When the appropriate Mass Storage Unit is available, a large buffer load of data is written out. This process continues in time to roughly correspond to one orbit (approximately 100 minutes). During this interval precise information concerning the layout of experimenter data is collected and sent to the Resource Monitor (RM). This data collection and temporary buffering of data continues in units of "orbits" until the end of the mission.

At some chosen point in time (i.e., corresponding to either the 2nd or 3rd orbit), the output processing of data begins. The output subsystems receive scheduling information from the Resource Monitor for editing the data, extracting the ancillary data necessary for each experiment, reformatting and outputting ephemeris and attitude data, decommutating the data base, merging ancillary data, and final formating/outputting of data products. Peripherals, as required, are selected from a pool (as shown in detail in Figure 6-5) and are assigned to any of the "K" subsystems (as shown in Figure 6-6).

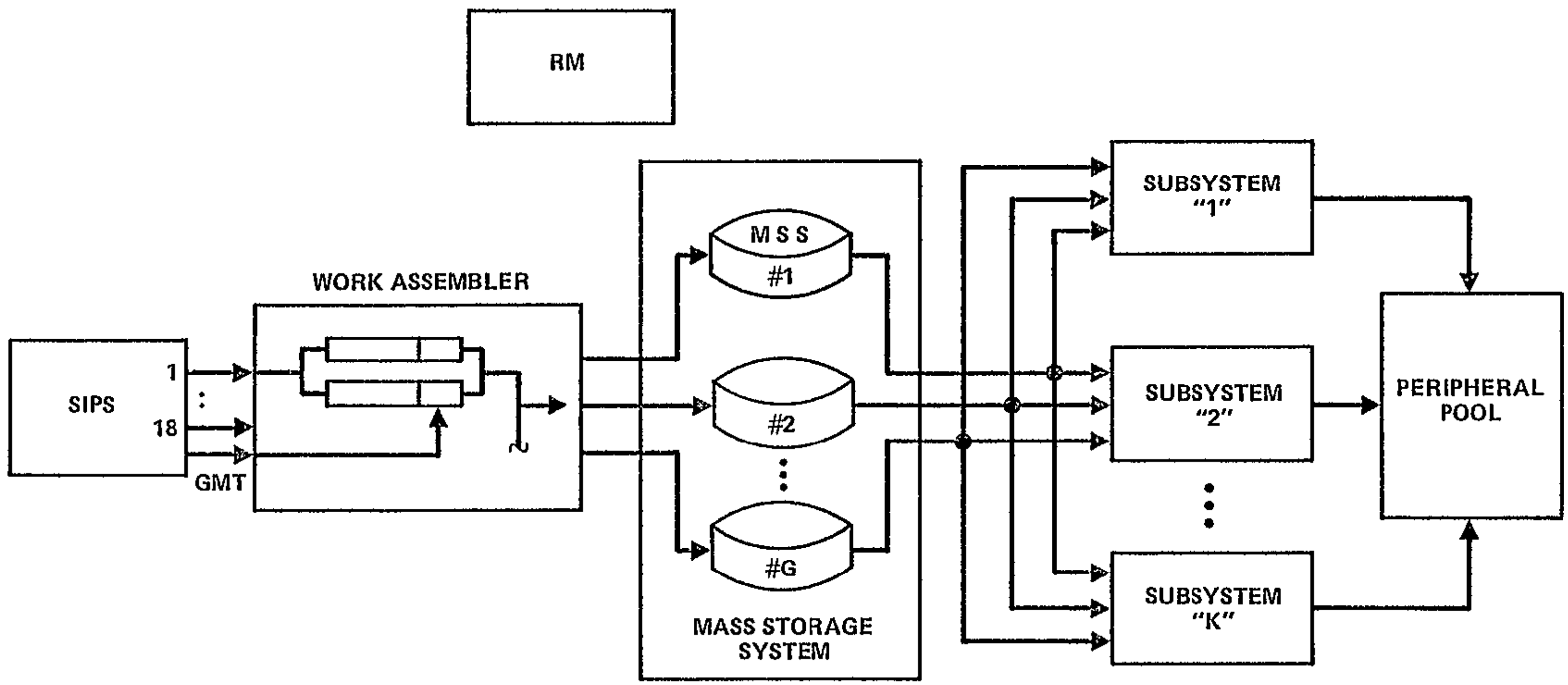


FIGURE 6-4. ARCHITECTURE NO. 1. (DYNAMIC CONFIGURATION)

6.2.1 Work Assembler

The first major assembly of equipment is the Work Assembler (WA), which is illustrated in Figure 6-7. As shown, it has 19 primary inputs - 18 data input lines (a one-to-one correspondence with the 18 SIPS output lines). and one (1) GMT line from the SIPS. Associated with each SIPS data input line is an interrupt line which notifies the WA of incomplete data frames, error situations, end of data frames, etc.

The major function of the WA is to smooth the incoming data stream so that data can be subsequently transferred to the Mass Storage System (MSS). As part of this function, the WA also dispatches larger groups of data to the MSS at a (MSS) compatible data rate. This is illustrated in Figure 6-8. At the top of Figure 6-8 the 18 input lines are shown in time so that one can see the 16 bit data words entering the system. This upper time slice illustrates the fact that input data are not necessarily periodic. However, as the WA collects data, it will transmit the data to subsequent portions of the system when larger groupings are advantageous (this is shown in the middle portion of the figure). If one were to merge the individual WA outputs, they would appear as illustrated at the bottom of Figure 6-8.

In Figure 6-7, an individual WA consists of C buffers and an associated Buffer Analyzer (BA, which may be either a dedicated CPU dedicated microprocessor or a shared CPU). Each WA subunit should be identical so that any system reconfiguration can take place with the least number of problems. The BAS receives data from the SIPS and transmits it to the Resource Monitor. This data exchange consists of "data maps", quality information, error messages, etc.

Since quantities have to be estimated in order to size the entire WA system, let:

A = The number of identical incoming WA subunits

B = The number of bytes in each WA buffer

C = The number of buffers in each WA subunit

D = The number of Buffer Analyzers (BA)

Based on given materials, it appears that A has to be set to at least 18. One cannot assume that certain lines are going to be inactive during

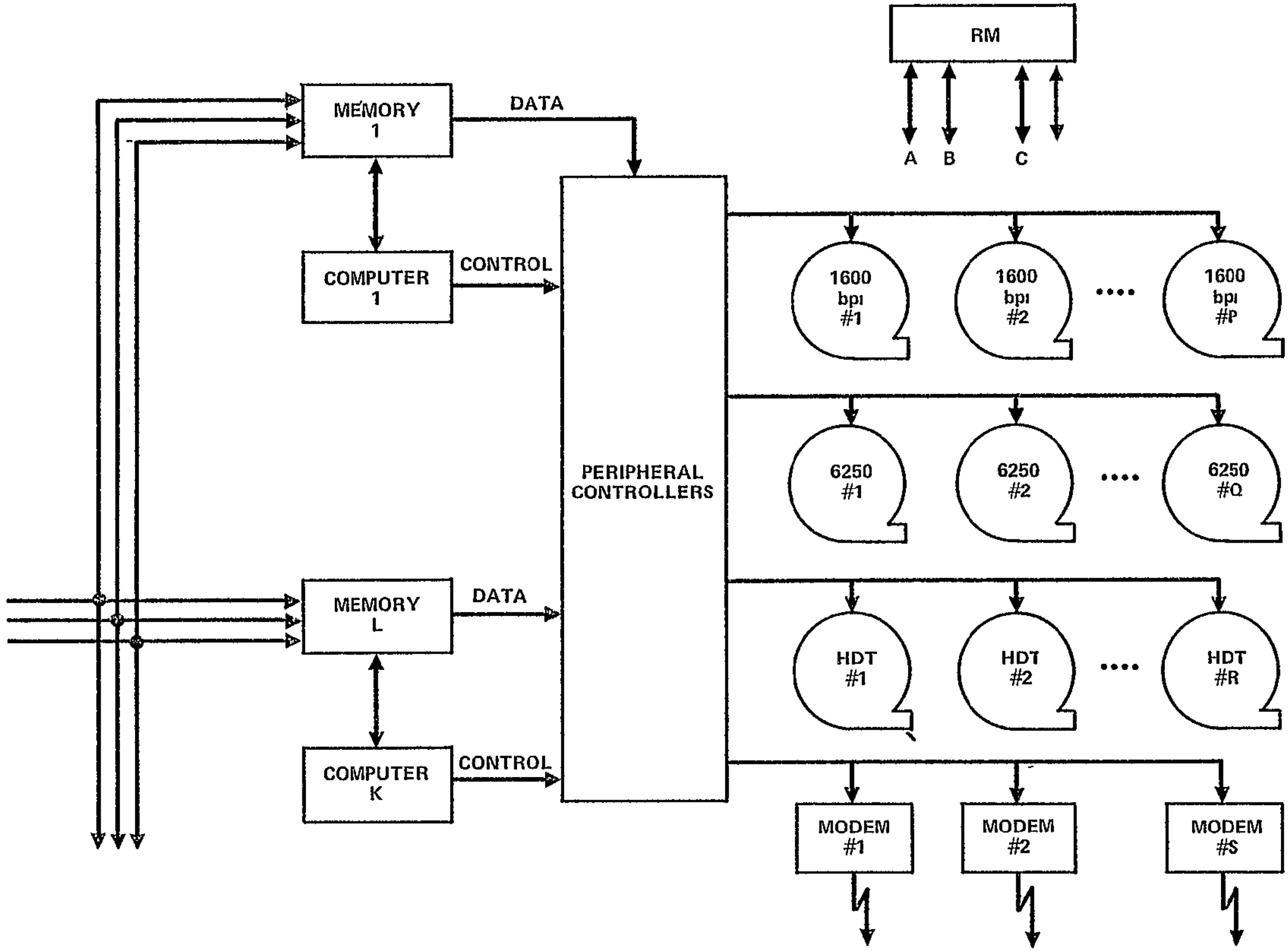


FIGURE 6-5. SUBSYSTEMS AND UNASSIGNED PERIPHERAL POOL

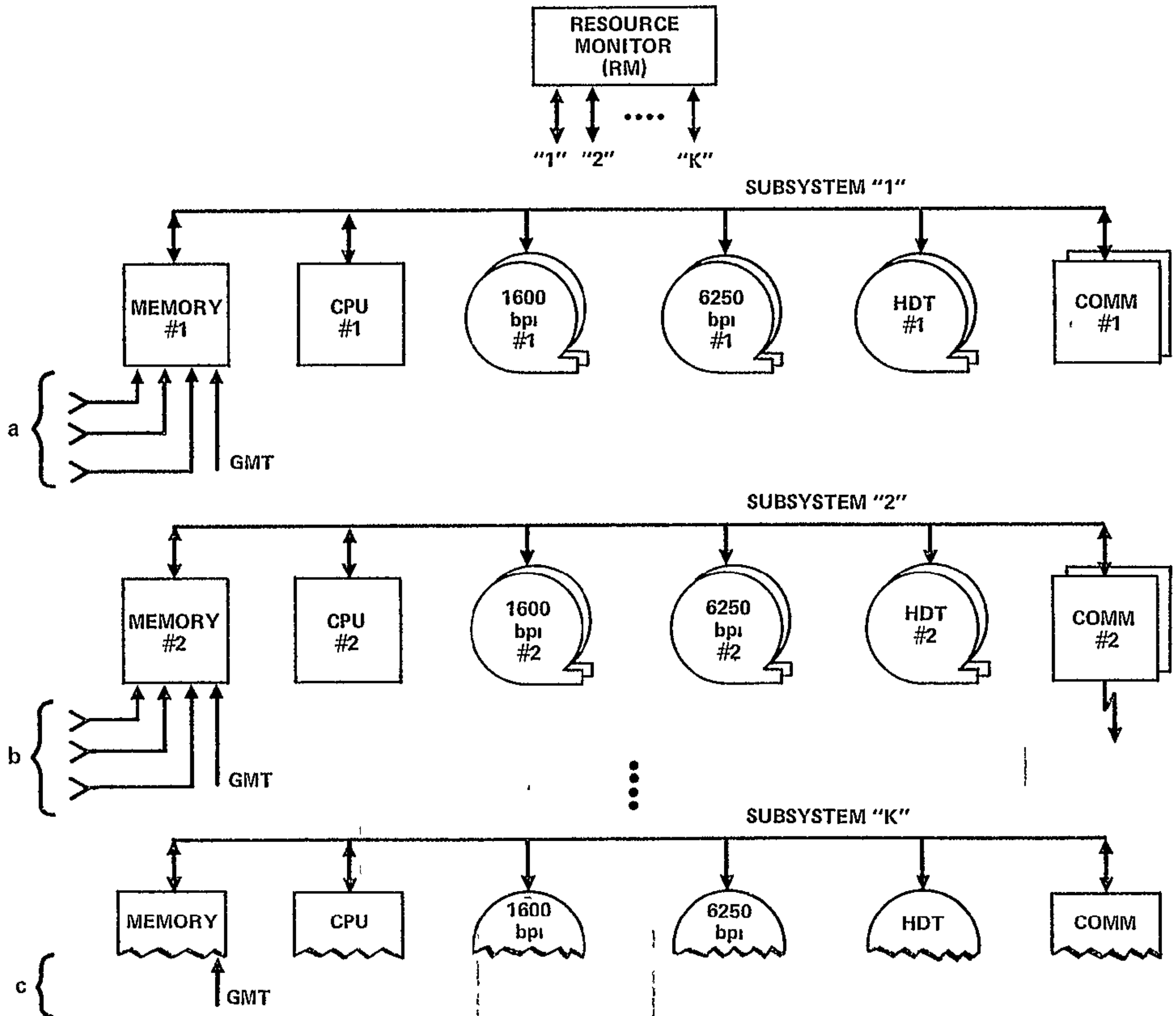


FIGURE 6-6. HARDWARE SYSTEM NO. 1 DETAIL (ASSIGNED CONFIGURATION)

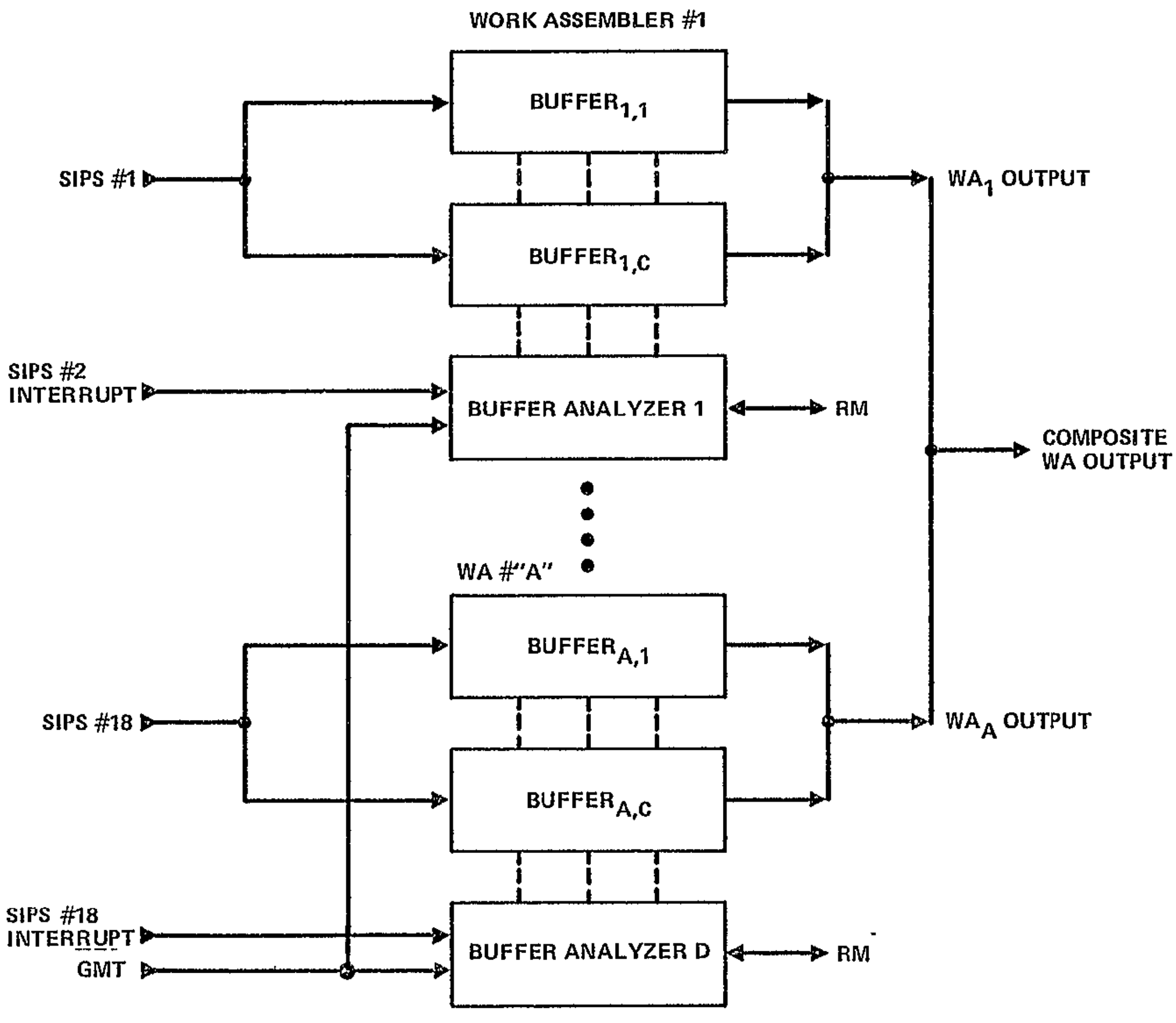


FIGURE 6-7. GENERAL BLOCK DIAGRAM FOR WORK ASSEMBLER SUBUNITS

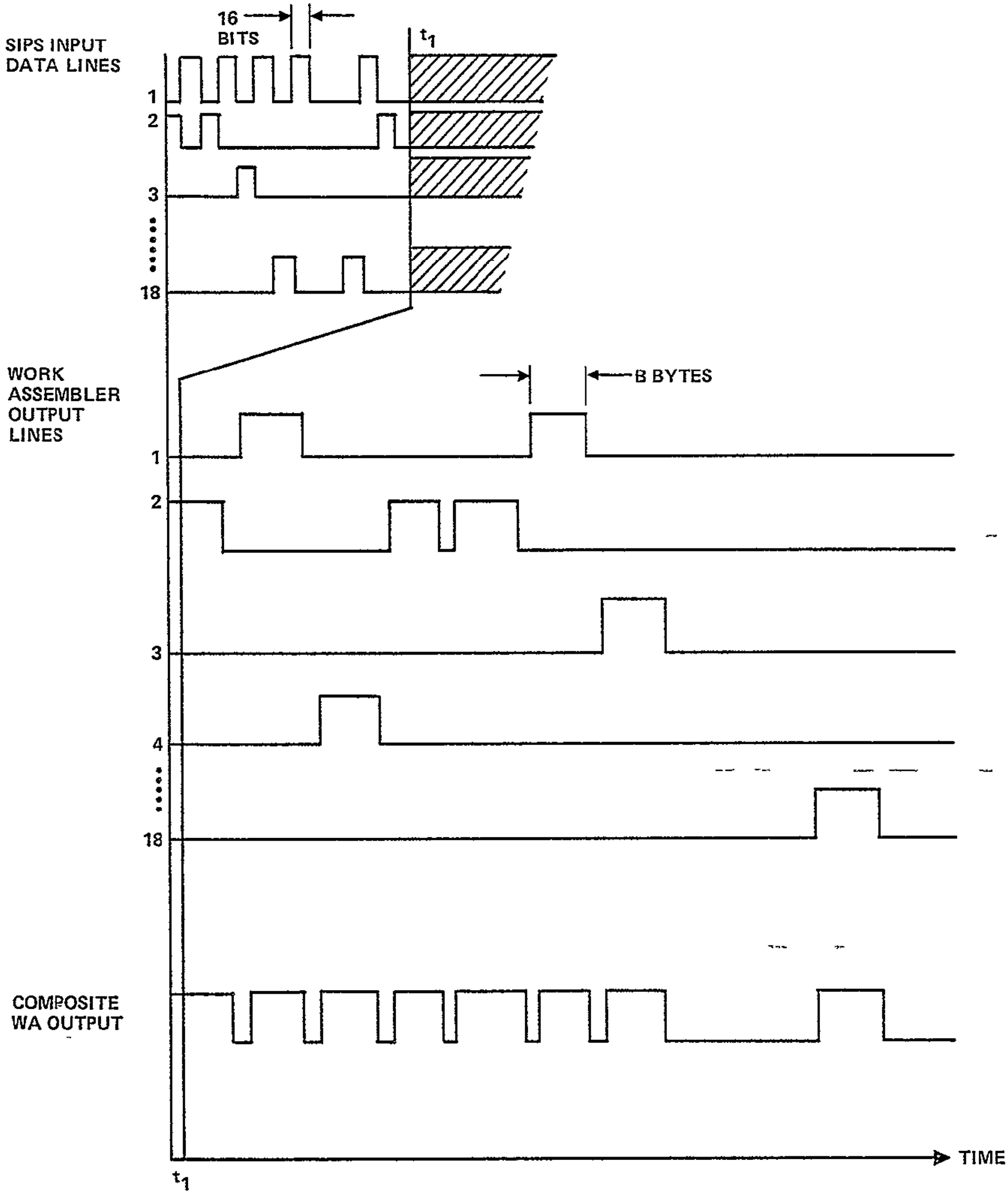


FIGURE 6-8. TIMING DIAGRAM OF WORK ASSEMBLER INPUTS AND OUTPUTS

an orbit at this point in time. Operational modes may change, and the system must be capable of supporting the full SIPS output. The number of UA subunits (A) should have either 1 spare unit or 5 to 10% spares as a good backup. Thus, either 1, .9, or 1.8 units could be designated for spares.

System or Device Utilization

The question that arises at this point is: "What analytical expression is used to determine the capacity of a device to perform a known unit of work?". For example, a 1000 byte buffer that is only used to hold 500 bytes is intuitively said to be operating at 50% capacity. This capacity or utilization is simply the ratio of the work load divided by the maximum resources available. For a computational system, one can apply the same basic concept, i.e., divide the number of operations to be performed by the maximum capability of the device to perform those operations. This approach can be seen in the following examples.

Suppose that a computer were to be required to perform only load and store operations on a closed data set. In a unit period of time (say one second) the work load to be performed would be 10^6 operations. Suppose that the device performing this work would be capable of operating at 10^7 operations per second. The expression $(10^6 \div 10^7) \times 100$ would yield the information that the device is operating at only 10% of its full capacity.

The preceding is an example of an uncomplicated situation. Suppose that for the same work load (10^6 operations per second) the machine were only capable of performing 10^6 operations per second. The quotient then would indicate a 100% utilization. The question then is: "Does one rely on that single device to perform that work?" The answer would be yes if, and only if, no deviations were allowed in both load and device capability. But suppose that a small number of other operations were to be present but not included in the computation. Then at least two devices would be required to perform that work load.

Going one step further, suppose that a mix of operations were to be performed over a unit period of time and the quotient indicated that the utilization factor would be, for example, equal to 560%. First, the 560% asserts that 5.6 devices working in parallel are required. Does one round up to 6 devices or some other number between 6 and 12? No general rule answers this question; any answer has to be qualified as with all given and assumed data. It has been found (among a representative number of computer facility managers) that for scientific applications, at a 40 to 50% utilization, one device is chosen. Between 50 to 100% two devices are usually used, because transient changes in the work load, interrupts, and initiations usually consume the last 50% of a machine's capacity.

For purposes of this short discussion, assume that the system should support an input data rate of 8 Mb/s. For purposes of this analysis, let the minor frame size be set to 4096 bits. Thus, the number of minor frames per second is (8×10^6 bits/sec)/(4096 bits/minor frame). This product is 1953 minor frames per sec. Also, assume that there are 100 frames per major frame. Thus, 195 3 major frames per second will also have to be processed by the WA.

Using the software estimates previously seen in Table 4-11, the BA will perform approximately 100 operations (lines of code executed) on each minor frame (input data accounting and quality checking) and approximately 200 operations on each major frame. Thus, taking the products of the number of minor frames per second (and major frames per second) times the number of operations per frame, we have a total of:

$$(1953 \frac{mf}{sec} \times 100 \frac{op}{mf} + (19.53 \frac{MF}{sec} \times 200 \frac{op}{MR}) = 2.34 \times 10^5 \frac{\text{operations}}{\text{second}}$$

The work load to perform the functions in the WA as a whole is approximately 2.34×10^5 operations per second (or 4.27×10^{-6} seconds per operation). A typical minicomputer as profiled in Table 4-7 was shown earlier to be capable of performing at a rate of 0.7 μs per cycle (or 1.43×10^6 operations per second). Since the operations to be performed are of the Load/Store type, one should multiply the cycle time by a factor of about 3 to make the cycle time effective. Thus, the number of operations per second for the minicomputer is $(3 \times .7us)^{-1}$ which is 4.76×10^5 operations per second.

To formalize the above concept, it would be helpful to express analytically the ratio of work to be done versus system capability, as "u". Thus, one of the tools to determine the acceptability of the candidate computation unit is a determination of the system utilization (u) factor. The relationship can be expressed as:

$$u = \frac{\left(\frac{r_i}{s_{mf}} \times j\right) + \left(\frac{r_i}{s_{MF}} \times k\right)}{\frac{1}{f \times c}} \times 100$$

Where:

u = computer utilization (%)

r_i = input data in Mb/s.

s_{mf} = Size of a minor frame in bits

s_{MF} = Size of a major frame in bits

j = total number of lines of code executed for each minor frame of data

k = total number of lines of code executed for each major frame of data

f = multiplicative factor (to convert cycle time to instruction time)

c = cycle time in seconds of candidate CPU

And: $s_{MF} = n(s_{mf})$

Where: n = integer number of minor frames per major frame

For ease of data manipulation, the expression for u reduces to:

$$u = \frac{100 \cdot c \cdot f \cdot r_i}{s_{mf}} \left(j + \frac{k}{n}\right)$$

Since the nature of the input data stream is not narrowly defined as yet, it would be advisable to examine u with different factors being varied. The above compact expression is obviously very sensitive to certain combinations of driving factors. The objective is to determine the worst case which drives up the system utilization. The factors that are relatively fixed are "c" at .7 us (from the minicomputer characterization section), "f" at 3 (to very closely approximate load and store operations), "j" at 100 (best known approximation), and "k" at 200 (best known approximation).

The expression for "u" can be simplified (just for the previous case) to:

$$u = \frac{(100)\ (.7\times10^{-6})\ (3)(r_i)}{s_{mf}} \left(100 + \frac{200}{n}\right) = 2.1 \times 10^{-2}\ \frac{r_i}{s_{mf}} \left(1+\frac{2}{n}\right)$$

Before searching for the worst case, u should be evaluated to establish a baseline operating point.

Typical values are as follows:

s_{mf} = 4096, 2048, 1024, 512 bits

r_i = 8, 12, 20 Mb/s

n = 100, 50, 10

Table 6-2 provides a range of values for "u" as a function of s_{mf}, r_i, and n.

As can be seen from Table 6-2, as the input data rate goes up, so the number of processors to handle the work goes up, and as the buffer size (the minor frame size) goes up, so the amount of work to be done goes down. Additionally, the number of minor frames to a major frame has relatively little effect on changing the magnitude of utilization factor. (i.e., it takes the form of 1/n). Table 6-2 is presented graphically in Figure 6-9.

The next step is to determine the size of the buffers in each WA subunit. As will be seen in the next section, it will be wise to set the buffer size to some value between 10 and 13K bytes. This range of buffer size will permit the WA to interface easily with either disks, MSS' (like the Terabit), or HDT. As shown earlier, disks operate efficiently when data is sent to them in units as close to a data track. (The Terabit system uses disks to stage data onto and off of its magnetic tape. Additionally, the Terabit system's best unit of data transfer to magnetic tape is ten times a 3330 data track).

To summarize, the WA can be defined in terms of hardware and capital expenditure as shown in Table 6-3. Using the information in Tables 6-2 and 6-3, an illustration showing the projected system (WA only) costs are presented in Figure 6-10 as a function of input data rates. A detailed block diagram of the WA is found on Figure 6-11.

Evaluation of the expression.

$$u = \frac{100 \cdot c \cdot f \cdot r_i}{s_{mf}} \left(j + \frac{k}{n} \right)$$

where: $c = .7$ us

$f = 3$

$j = 100$ operations per minor frame

$k = 200$ operations per major frame

and.

r_i (Mb/s)	s_{mf} (bits)	n	u (%)
8	512	10	393.8
8	512	50	341.3
8	512	100	334.7
8	1024	10	196.9
8	1024	50	170.6
8	1024	100	167.3
8	2048	10	98.4
8	2048	50	85.3
8	2408	100	83.7
8	4096	10	49.2
8	4096	50	42.7
8	4096	100	41.8
12	512	10	590.6
12	512	50	512.0
12	512	100	502.1
12	1024	10	295.4
12	1024	50	255.9
12	1024	100	251.0
12	2048	10	147.6
12	2048	50	128.0
12	2048	100	125.6
12	4096	10	73.8
12	4096	50	64.1
12	4096	100	62.8

r_i (Mb/s)	s_{mf} (bits)	n	u (%)
20	512	10	984.3
20	512	50	853.3
20	512	100	836.8
20	1024	10	492.3
20	1024	50	426.5
20	1024	100	418.4
20	2048	10	246.0
20	2048	50	213.3
20	2048	100	209.2
20	4096	10	123.0
20	4096	50	106.8
20	4096	100	104.6

TABLE 6-2. BUFFER ANALYZER UTILIZATION FACTOR

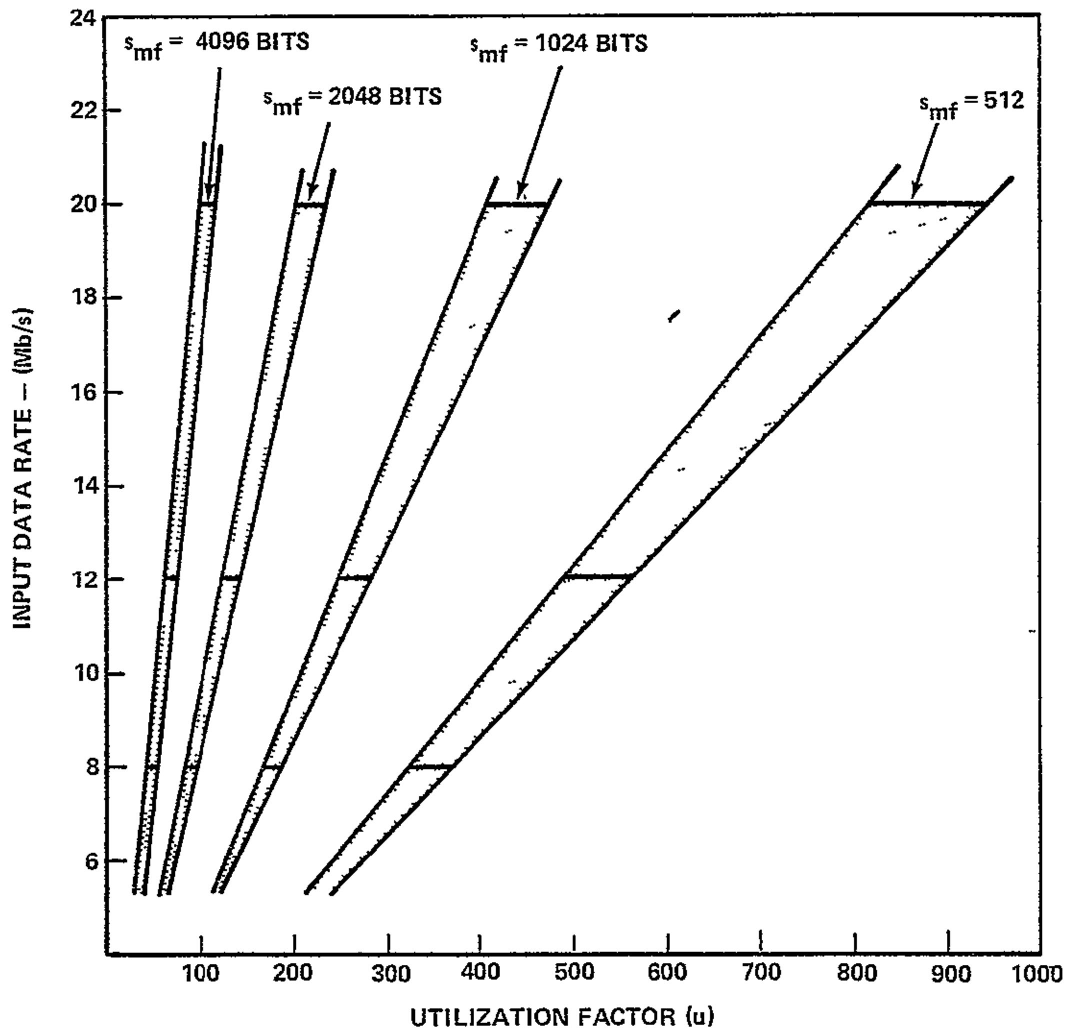


FIGURE 6-9. BUFFER ANALYZER UTILIZATION FACTOR CURVES

Work Assembler Attribute:	Parameter	Units	Projected Cost ($)
Number of Identical WA Subunits	A	18	Not Applicable
Number of Bytes in Each WA Buffer	B	3	Not Applicable
Number of Buffers in Each WA Subunit	C	10 to 13K[1]	Not Applicable
Number of Buffer Analyzers	D	1 to 18	$46K ea.[2]
Total Buffer Costs[3]	Not Applicable	Not Applicable	$5,616 to $8,912[4]
Misc. Hardware	Not Applicable	1	$10,000
Total System Cost	Not Applicable	1	20K+ (D)($46K)[5]

Notes:

1. Costs are based on 13K bytes
2. Average price for minicomputer surveyed
3. (3 buffers/unit) x (18 units/sys) x (13K bytes/buffer) = 702K bytes/system = 5.62×10^6 bits/system
4. At .1 cents/bit (= $.001.bit = $$10^{-3}$/bit): $5.62 \times 10^6 \times 10^{-3}$ = $5,616. If 4096 bit RAM ICs were used at $6.50 each; then ($5.6 \times 10^6$ / 4096 =) 1372 x $6.50 = $8,912.
5. Total buffer costs (almost [5]10K) + Misc. Hardware ($10K) = 20K

TABLE 6-3. DETAILED WORK ASSEMBLER COSTS

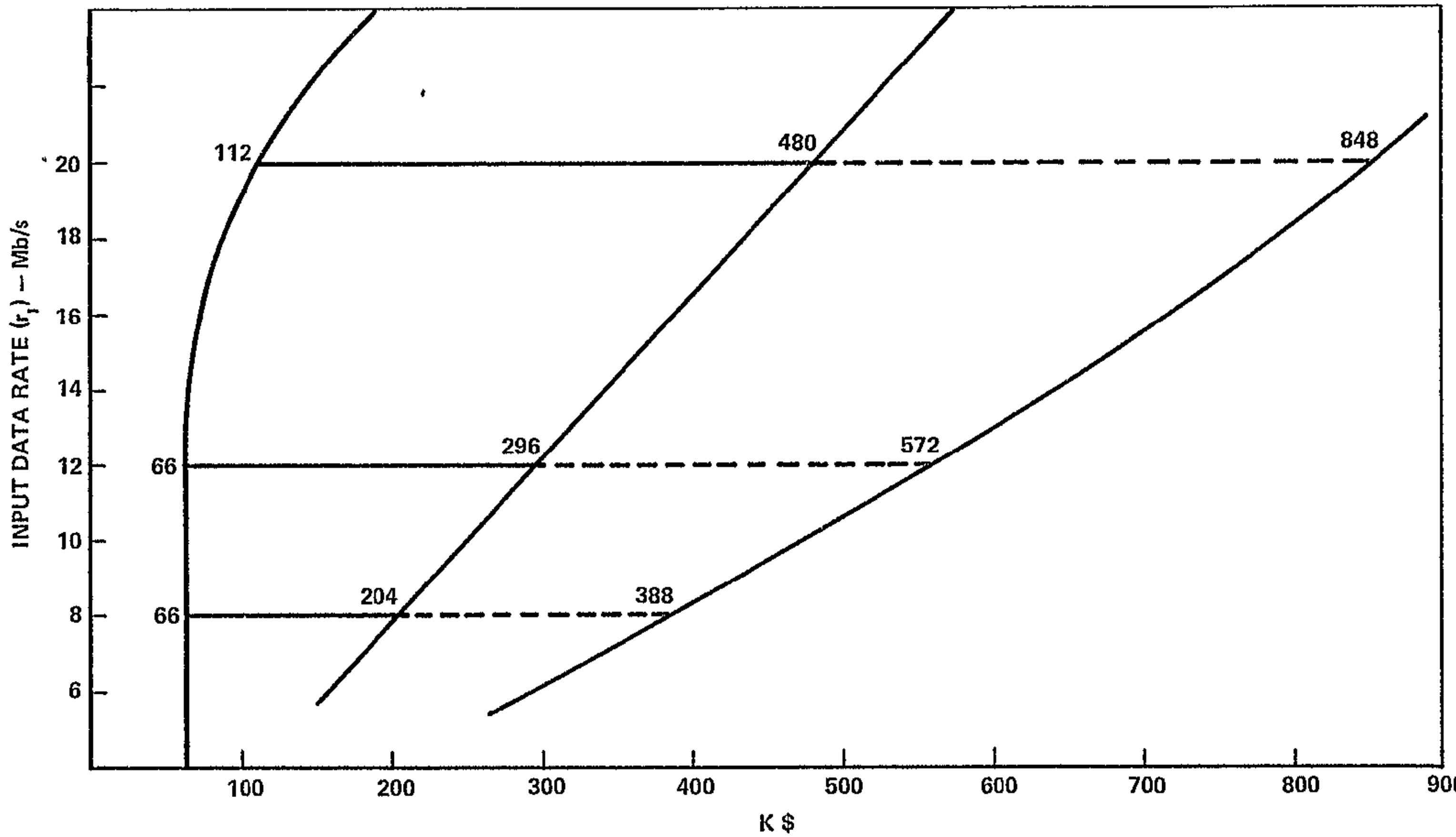


FIGURE 6-10. TOTAL WORK ASSEMBLER COSTS

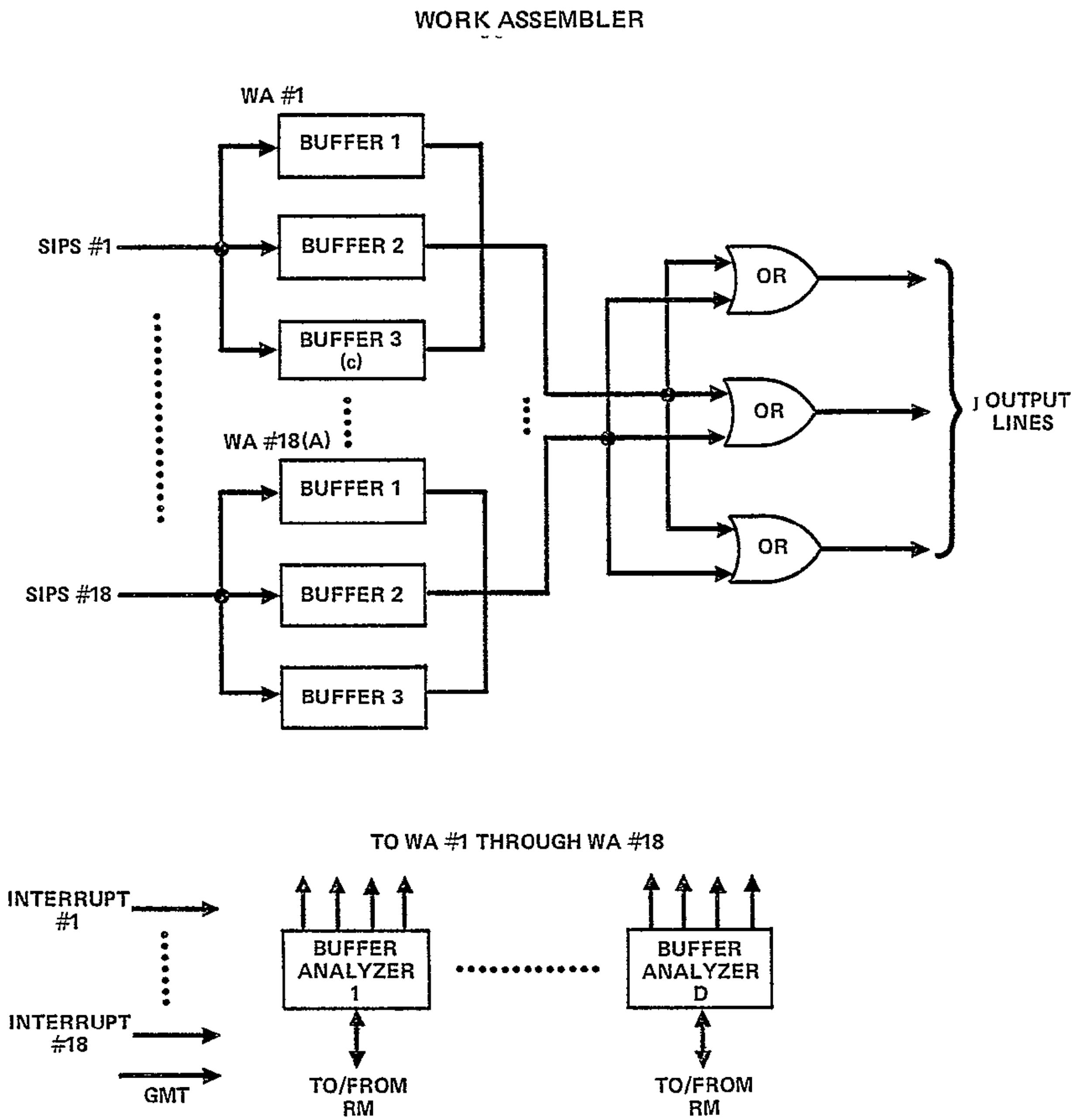


FIGURE 6-11. DETAILED WORK ASSEMBLER BLOCK DIAGRAM

6.2.2 <u>MSS Considerations</u>

The next step is to consider what possibilities exist for the MSS. Under NASA/GSFC contract NAS5-24033 Mod 51, ORI submitted a technical report on 28 June 1976, entitled "Interfacing a High Density Tape Recorder (HDTR) to a Disk Unit." This report presented a detailed study of techniques for interfacing a synchronous data device with a high capacity disk unit. The specific synchronous device considered was a high-density tape recorder (HDTR). An HDTR is not a stop/start device such as a standard 7 or 9 track computer compatible tape (CCT) drive. A CCT can stop and start within .6 inch interrecord gaps, thus greatly facilitating buffer design and timing for the data transfers. However, an HDTR once started continues to run and transfer data synchronously. It does not have the fast stop/start capability of a CCT. Even though the study looks at the HDTR as the input data source, the technical thrust of the report concerns itself with how a disk imposes <u>its</u> requirements in buffering and timing. It is permissible, therefore, to consider the HDTR as being equivalent to the Work Assembler (WA) since the WA was previously designed to drive a device like a disk.

The disc unit considered was of the IBM 3330 type. All the disk parameters and example problems in the report were based on 3330 parameters, such as rotation speed, head step times, etc. However, the characteristics of any other moving head disk unit could be substituted in the developed equations if the user wishes to use a different type disc unit.

Likewise, although the synchronous device considered in the study was an HDTR, the material contained in the study is applicable to any synchronous device. For example, this material would be useful in establishing a data transfer system between a disk and a laser beam image recorder.

Specifically, the HDTR/disc interface consisted of a large buffer constructed of computer memory. A computer with sufficient memory and software to control the buffer operation is used to interface the HDTR controller and the disk unit controller.

Two buffer schemes were found to be practical:

- <u>Double Buffer.</u> Data is written into one buffer while data is read out of the other buffer. The buffers are then interchanged.

- Rolling Single Buffer. Data is written into a read-out of the same buffer continuously. Care must be taken that the write and read data locations do not overrun each other.

In general, a buffer will hold enough data for 2 or more disk tracks. The data throughput rate will be maximized for increasing buffer size, increasing number of words per disk track, and increasing number of disk tracks per buffer. For a fixed buffer size, the maximum throughput rate results from increasing the number of words per disk track and reducing the number of disk tracks per buffer.

The transfer system is transparent to the data format. Thus, there is no need to make the number of words per disc track a multiple or submultiple of the data major frame size, since the data major frame format is purely a software format. (The HDTR data is fully synchronous.)

Data transfer in both directions was considered. The throughput rate is independent of the direction of data flow.

Several different disc data formats were also considered; fixed-sector start and staggered sector start. The latter is usually preferable from the point of view of throughput rate.

Table 6-4 summarizes the salient findings of this study.

If 3330 type disks were used in the SOPS, the most convenient scheme would be to collect "orbit" groups of data. Given 5×10^{12} bits/mission, assume approximately 100 orbits/mission. This implies approximately 5×10^{10} bits/orbit, or 0.63×10^{10} bytes/orbit. Since a 3300 disk unit holds about 83.9×10^{6} bytes, the product of (0.63×10^{10} bytes/orbit) / (83.9×10^{6} bytes/unit) yields 75.09 disk units/orbit. This, for obvious reasons, rules out 3330 type disks.

The next option centers on using HDT's as the MSS. Since an orbit's worth of data is approximately 5×10^{10} bits, and since a reel of HDT can hold

TABLE 6-4. DISK & HDTR INTERFACE ATTRIBUTES

A	Total Buffer Size (Bytes)	32768			65536		
B	Bytes/Disc Track	4012	8024	10752	4012	8024	10752
C	Disc Tracks/Buffer	8	4	3	16	8	6
D	Data Throughput (Mb/s.)	3.39	3.54	3.64	3.82	4.02	4.14
E	Disc Utilization (%)	84	84	95	84	84	95

Note:

A = B x C (i.e., Total Buffer Size = (Bytes/Disc Track) x (Disc Tracks/Buffer) approximately 1.4 x 10^{10} bits, the product (5 x 10^{10} bits/orbit) / (1.4 x 10^{10} bits/reel) yields 3.57 reels of HDT/average orbit. This option is further enhanced when one considers that the HDT can handle a data rate of up to 20 Mb/s.

To determine the best way to handle bursts of high-rate data, assume a worst-case burst at 50 Mb/s for 10 minutes. This hypothetical worst-case burst represents (50 x 10^6 x 60 x 10) 3 x 10^{10} bits of high rate per orbit! This could represent up to (3/5) 60% or an orbit data group. To transfer this volume of data (originally entering the SIPS at 50 Mb/s), a slow down of only (20 Mb/s)/(50 Mb/s.) 1 to 2.5 is required to capture it from the DCS's tape recorder. Thus, if the biggest burst of 10 minutes occurs, 25 minutes of SIPS playback time is required. Since an orbit's worth of data will occur during 70 to 80% of the projected 100 minute interval, a SIPS lull period of between 20 and 30 minutes per orbit could easily be utilized for recording the high-rate data for better use, and any unprocessed data could be easily deferred until the next lull.

Operationally, it would be advantageous to keep the high rate data on separate reels (3 x 10^{10} bits/orbit) / 1.4 x 10^{10} bits/reel) = 2.14 reels/orbit so that during deferred output processing, this data base can be merged.

Two parameters (viz. G and H) and the resulting costs have to be derived before comparing HDTR to devices like the Terabit System. The two parameters are (G) how many MSS units are required and (H) how many bytes of storage are in each unit.

For the recording HDTR's it appears that G equals 3. Two units should be on-line all of the time, and a third unit should serve as a spare on-line unit. The data rates would be no problem because each HDTR could handle up to 20 Mb/s. H would be equal to 1.4 x 10^{10} bits, as previously discussed. (For the sake of completeness, it will be shown later that 2 HDTR's plus 1 spare HDTR are required for playback. Thus, the total number of HDTR's will equal 5 (G=5).

With a device such as the Terabit System, the primary limiting factor restricting its easy utilization is the input data rate - at best 9 6 Mb/s, (instantaneous) and realistically 5.6 Mb/s. If the average incoming data rate were 9 Mb/s., at least two units would have to be connected to the WA. Operationally, this would not be any problem since the WA output is easily switched. Because the Terabit system uses tapes that hold 46.8 x 10^9 bits, one orbit's worth of data would be held on (5 x 10^{10} bits/orbit) / (46.8 x 10^9 bits/reel) 1.07 reels. (This is clearly an advantage over HDTs.). Therefore, one would have to have 2 units plus 1 spare on-line for recording. (As in the case of HDTRs, it would be required to have 2 additional output units plus 1 spare--a total of 5 units.)

The tradeoff between the two appears to be straightforward in favor of HDTRs. For the price of just 1 Terabit System (approximately $1.5M), one could obtain at least 13 HDTRs plus 13 bidirectional SCIs (13 x (70 + 40)K = $1.43M). The proposed intermediate MSS should contain five (5) HDTRs plus five (5) SCIs (5 x (70 + 40) = $550K). It is also recommended that a small disk (the size of which has not been determined) be present to facilitate quick-look and future POCC requirements. The proposed MSS is illustrated in Figure 6-12.

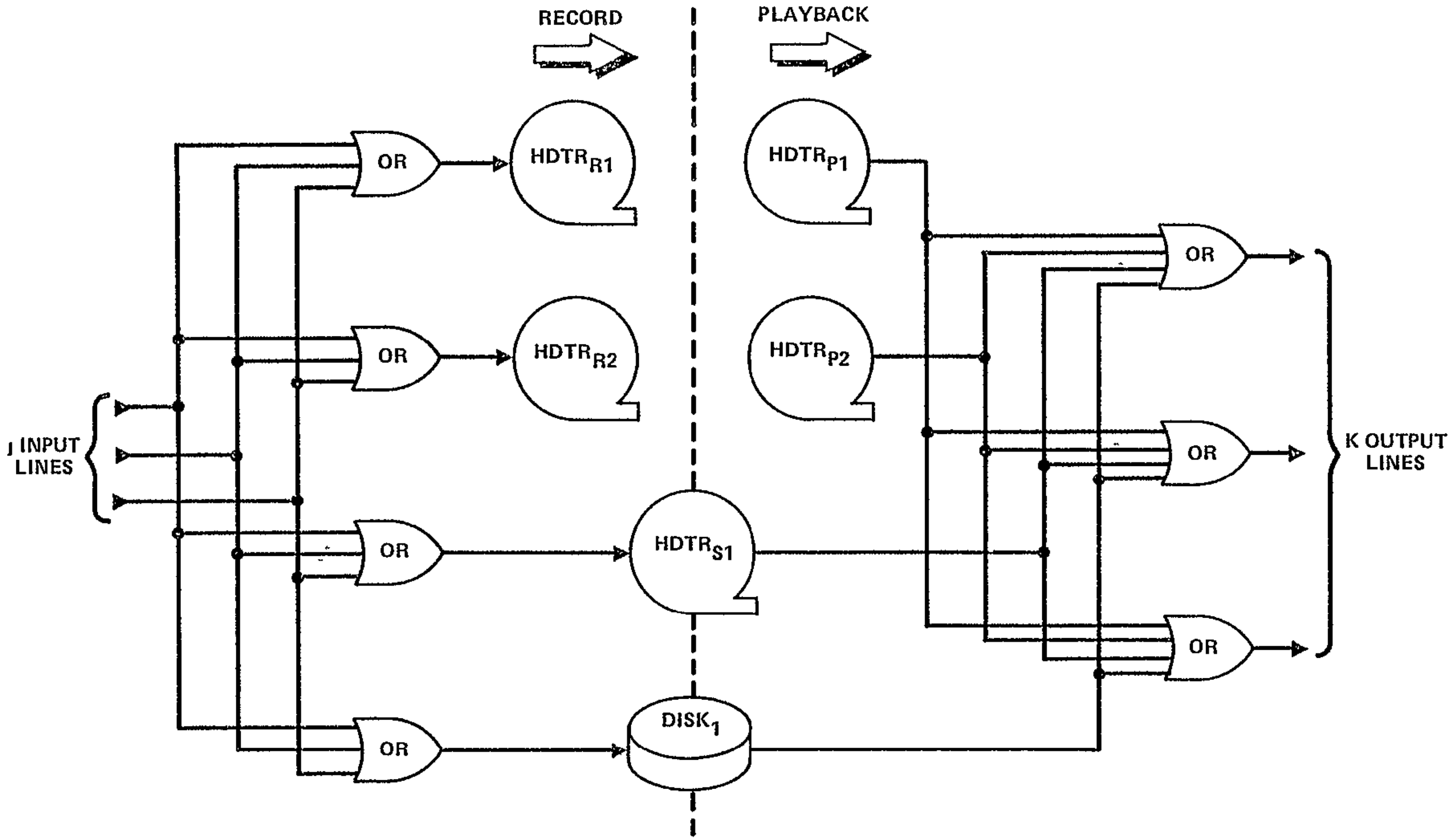


FIGURE 6-12. INTERMEDIATE MSS

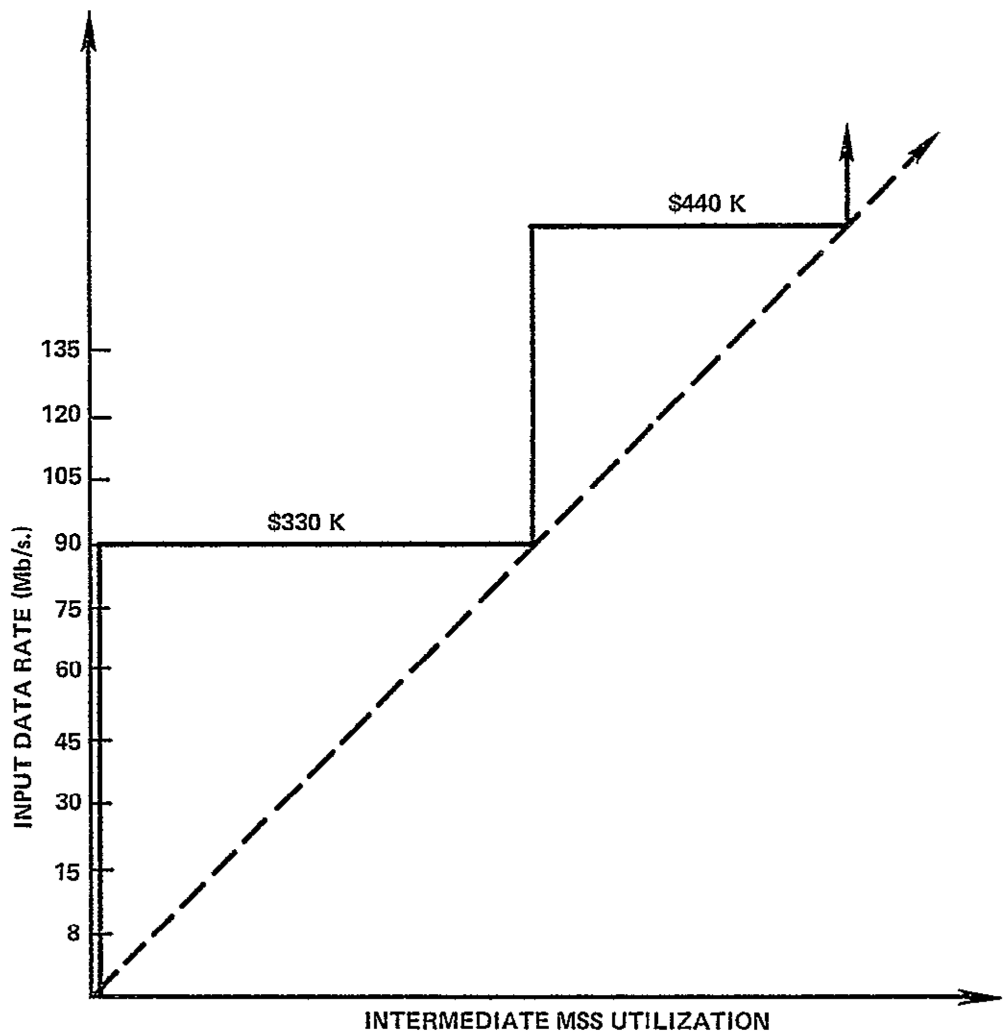


FIGURE 6-13. INTERMEDIATE MSS COST CURVE

6.2.3 Output Processor

At this point in the processing system we have the following:

- A precise (byte-by-byte) map of all experiment (and ancillary) data
- Quality control information that may have come in at some time after reception and intermediate storage of experiment data
- Uniform work units (same size)
- High-rate bursts of data (both overlapped data that was recorded and transmitted latter; and high bit rate experiment data) blocked into uniform work units

All of the preceding allow for an output processor configuration as illustrated in Figure 6-14. As shown, it is highly modular, flexible, and resistant to single-point failure. A general data walkthrough is presented in the following paragraphs, which are followed by detailed design considerations.

Blocks (or work units) of data are transfered from the HDTRs (units 1 through G) to waiting memories (units 1 through L) via a DMA channel. Since the exact decommutation map is known, incoming data can either be decommutated upon entry, or the entire work unit can be buffered and decommutated as soon as the CPU (units 1 through K) set up the memory-to-memory operations. The decommutation process takes place with the creation or buildup of experiment unique data buffers. As soon as a conveniently large experiment data file is assembled, the experiment file is sent to a staging disk. When a significant amount of experiment data is built up on the staging disk, an output data product is written.

To set broad operations limits, it shall be assumed that 5×10^{12} bits/mission are to be processed. With approximately 100 orbits/mission, then 5×10^{10} bits/orbit is derived. If this data were to go through the facility, (viz. the output processor) in about 100 minutes (100 minutes/orbit), then the statistical data note would be $(5 \times 10^{10}$ bits/orbit)/(100 x 60 sec/orbit) = 8.33 Mb/s. It would therefore be prudent to design to at least 16 Mb/s (on 20 mb/s.) to allow for adequate operator rest periods, repairs, etc.

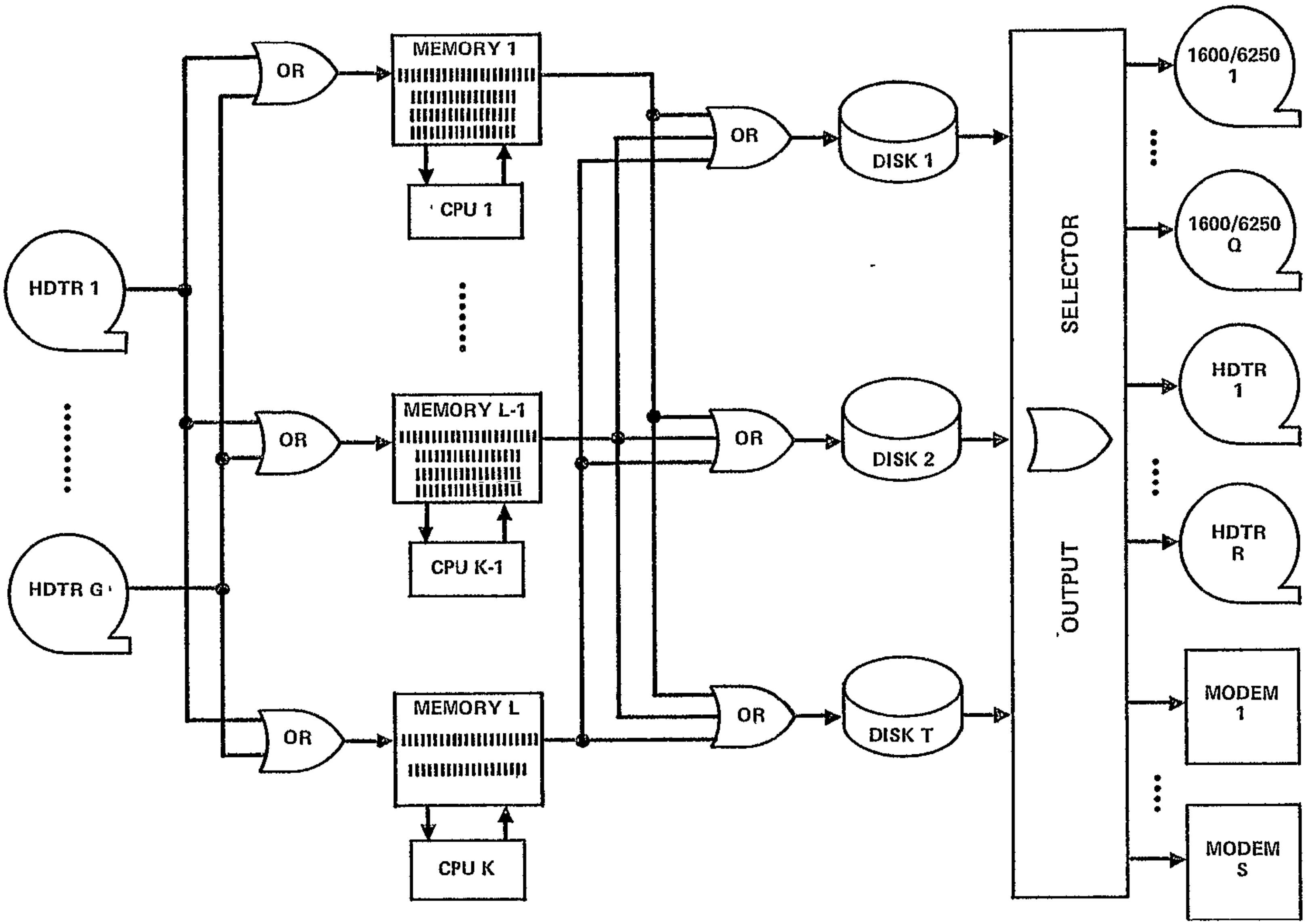


FIGURE 6-14. OUTPUT PROCESSOR BLOCK DIAGRAM

Detailed Data Flow

A set of HDTs containing a set of orbit data are selected and mounted for playback. The data are on between 4 and 6 reels (normally 3.57 reels) All of the reels except one or two contain the regular low and medium-rate experiment data. The regular data for example would be played back on HDTR #1 and the high-rate burst data on HDTR #G. The RM would set up the playback of high-rate data so that its data would be placed approximately in the GMT time slot and so that the removal of overlapping data and chronological ordering functions could be performed. This is illustrated in Figure 6-15. The intent at this point is to line up work units for processing so that a minimum amount of data handling is required.

For this study, it is not known how the experiment data will show up on SIPS lines. To insure a robust SOPS design, one must then formulate a reasonable set of worst-case situations. In Table 2-1, a hypothetical experiment mix is given. Line assignments can be made according to two different schools of thoughts. The alternatives are:

I. - Assign all high-rate experiments to separate lines
- Assign all medium-rate experiments to separate lines
- Assign low-rate experiments to separate lines
- Spread out all remaining experiments uniformly over all used lines.

II. - Assign all experiments to the minimum number of lines so long as the maximum bandwidth is not exceeded.

The advantages and disadvantages of each alternative need not be presented here: the first option would have 48/18 = 2.67 experiments per line and the second could have as few as 3 or 4 lines active and consequently up to 42 or 44 experiments on one line. Table 6-5 presents a hypothetical mix with the worst attributes of both approaches. In this table, each line is active at least 50% of the time, and since the two "A" experiments only occur at most 5% of the time, the very low-rate experiments (which collect data 100% of the time) are also assigned to lines 1 and 2. Even if all "E" and "F" experiments were on at their highest rates, they would only represent [(10 x 0.1) + (20 x 0.01) = 1 + 0.2 =] 1.2 Mb/s. Thus the memory system would be illustrated as shown in Figure 6-16.

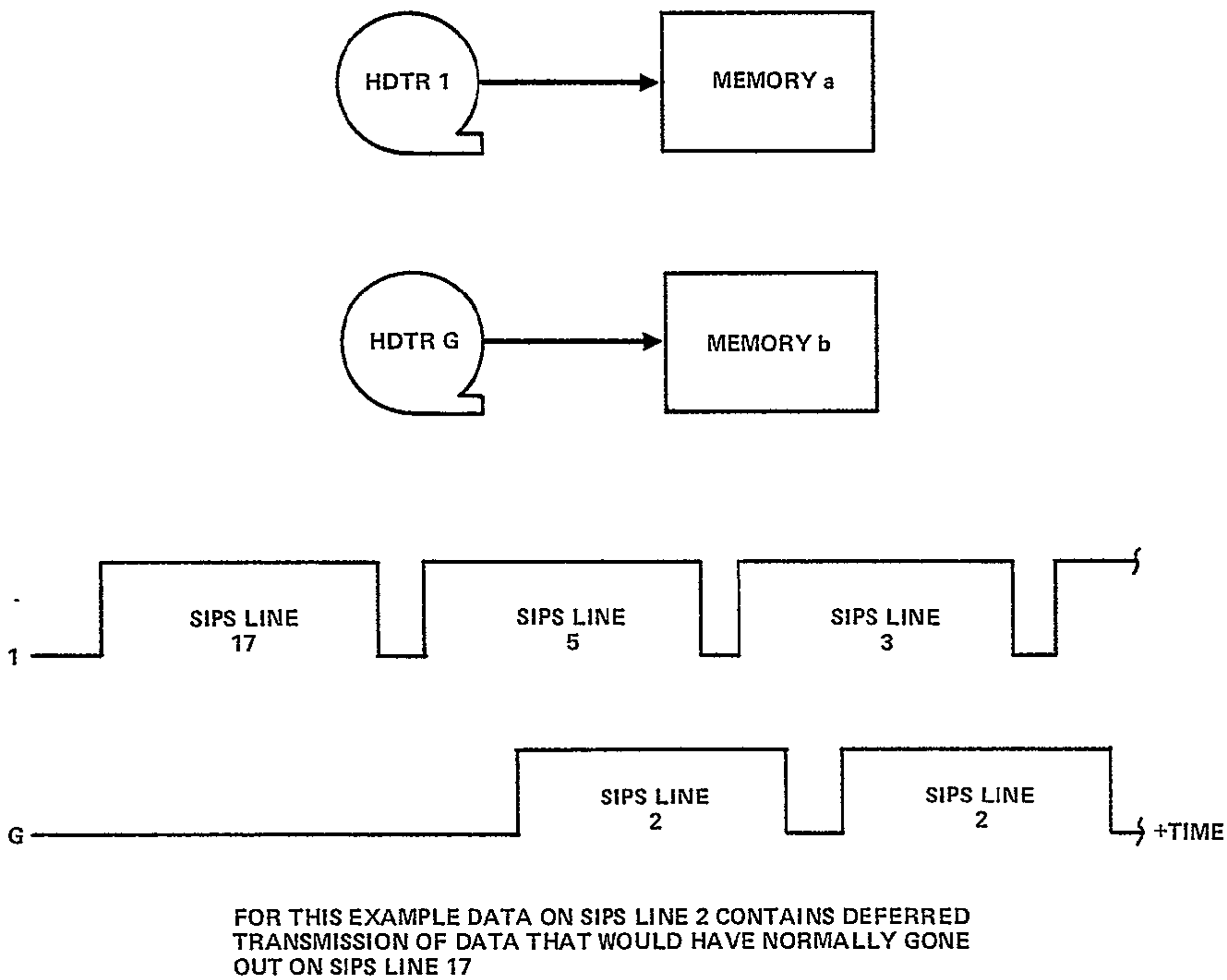


FIGURE 6-15. PLAYBACK OF BURST DATA FROM HDTRS.

TABLE 6-5
A HYPOTHETICAL DISTRIBUTION OF EXPERIMENTS OVER
18 SIPS LINES

SIPS OUTPUT DATA LINE	EXPERIMENT QUANTITY & CLASS	% OF TIME ON FOR EACH EXPERIMENT	MAXIMUM (PRERECORDED) BIT RATE ON EACH SIPS LINE (Mb/s)
1	1A + 10E	< 5 + 100	30 ; (10 x .1 =) 1
2	1A + 20F	< 5 + 100	30 , (20 x .01 =) .2
3	1B	< 10	10
4	1B	< 10	10
5	1B	< 10	10
6	1B	< 10	10
7	1C	100	1
8	1C	100	1
9	1C	100	1
10	1C	100	1
11	1D	< 50	1
12	1D	< 50	1
13	1D	< 50	1
14	1D	< 50	1
15	1D	< 50	1
16	1D	< 50	1
17	1D	< 50	1
18	1D	< 50	1

The next step is to examine the attributes and functions of the "L" memories as shown in Figure 6-14. If these memories are linked to the "K" CPU's (K does not necessarily equal 1), the maximum I/O Rate (as selected from Table 4-7) is (2.5 M words/sec. x 16 bits/word = 40 Mb/s.) It should be pointed out that this value is a computed coverage, and many mini-computers (for example) could be faster.. In general, the I/O rates can be expressed as.

$$R_{DMA} = R_{IN} + R_{OUT} + R_{OVERHEAD}$$

where:

R_{DMA} = DMA channel rate (40 Mb/s)

R_{IN} = Input channel rate (20 Mb/s)

R_{OUT} = Output channel rate (20 Mb/s)

It has been found in past experiences that $R_{OVERHEAD}$ can amount to up to 10% of R_{DMA} in most good memory systems. Thus for a steady state situation, $R_{IN} = R_{OUT} = 18$ Mb/s. This would appear to limit the size of the memory subsystems. So that the proposed design may accommodate this constraint, movement of data in the memory subsystem must be understood.

Each buffer is fully packed with a "set" of data. Upon entry into the memory (as shown in Figure 6-17), data elements a_1 through a_7 are initially set into buffer number 1 with data elements $b_1 \rightarrow b_2$ and $c_1 \rightarrow c_2$. These three groups must be separated (decommutated) into their own separate buffers (1, 2, and 3 as illustrated in Figure 6-17). The next data group may or may not contain the next buffer group. Therefore, it must take less time to process and handle a data block than to either write or read these data elements. The time to process a memory-to-memory operation can be defined as:

$$T_p = \frac{8}{f \cdot c}$$

T_p = process time

f = multiplicative factor (to convert cycle time to a memory to memory move instruction)

c = cycle time.

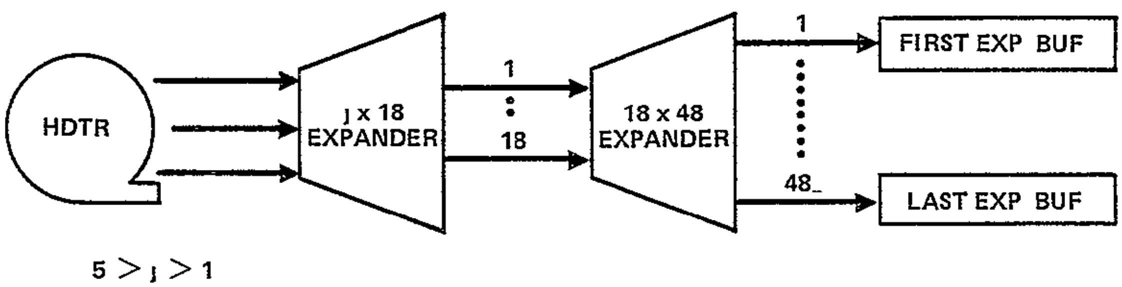


FIGURE 6-16. SIMPLIFIED MEMORY HIERARCHY DIAGRAM

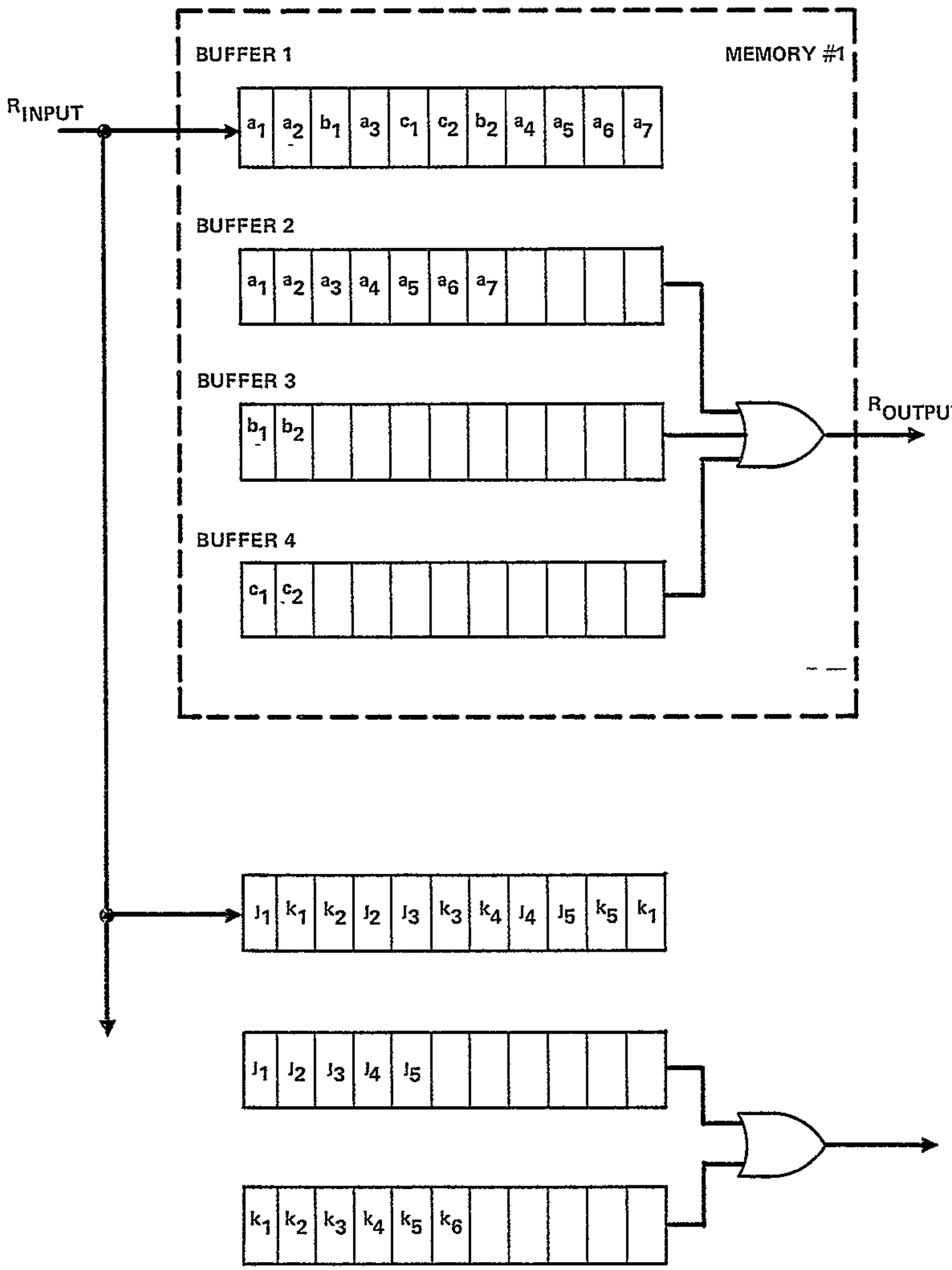


FIGURE 6-17. DATA ENTRY INTO MEMORY

Let $f = 1, 1.5, 2, 2\ 5, \text{ or } 3$ and

$c = 0.7 \times 10^{-6}$ sec

Then for $f = 1$ and

$c = 0.7\ \mu s$

$$T_p = \frac{8\ \frac{\text{bit}}{\text{byte}}}{1 \times .7 \times 10^{-6}\ \frac{\text{sec}}{\text{byte}}} = 11.4 \times 10^{-6} \text{ bits/sec}$$

for $f = 1.5$; $T_p = 7.62$ Mb/s

for $f = 2.0$; $T_p = 5.21$ Mb/s

for $f = 2.5$, $T_p = 4.57$ Mb/s

for $f = 3.0$; $T_p = 3.81$ Mb/s

It is evident from the above computations that the candidate memory/CPU must be as fast as possible on a memory-to-memory instruction. (For a point of interest, if $T_p = 20$ Mb/s, and $f = 2$, then c would have to equal 0.2 µs). Another approach to this problem would be to have high-speed, solid-state (RAM) devices as used in the WA.

It appears that the only safe way to be prepared for any mix experiments is to double-buffer 18 lines and triple-buffer each experiment to ensure compatible HDTR - DISK interfacing. At 10752 bytes/buffer then ((2 x 18) + (3 x 48)) x 10752 bytes = 1.94×10^6 bytes (which also equals 15.48×10^6 bits). At 0.1 cents/bit this buffer would cost $15,480, and at .01 cents/bit, this buffer would only cost $1,548.

The output processor CPUs (1 through k) as illustrated in Figure 6-14 shall perform the following operations on data within the previously discussed memories:

- Output data accounting
- Quality checking
- Decommutation
- Data Store
- Time Validation
- Overlap removal
- Data fill
- Memory ancillary

It would now be appropriate to consider the type of computational unit used in the Work Assembler, i.e., the average minicomputer as specified in Table 4-7.

The workload for the output processor was specified earlier in Table 4-11 and is summarized below:

Function	Estimated lines of code executed per: m.f.	M.F.	Orb.G.	Exp. File
Output data accounting	50	100	5000 x E	50,000
Quality check	50/200	50/200	500 x E	5,000
Decommutation	50	0	0	0
Data store	0	0	50000 x E	10,000
Time Validation	75	0	0	0
Overlap removal	0	0	20000 x E	0
Data fill	0	0	5000 x E	10,000
Merging ancillary data	0	0	5000 x E	0
Subtotals	275	200	40500 x E	75,000

The above concept can be formalized analytically as "u", to express the ratio of work to be done versus system capability. Thus, one of the tools to determine the acceptability of the candidate computation unit is a determination of the system utilization (u) factor. This relationship can be expressed as:

$$u = \frac{\left(\frac{r_i}{s_{mf}} \times j\right) + \left(\frac{r_i}{s} \times k\right) + \left(\frac{r_i}{s_{OG}} \times l\right) + \left(\frac{r_i}{s_{EF}} \times m\right)}{\frac{1}{f \times c}} \times 100$$

Where: u = computer utilization (%)

r_i = input data in Mb/s.

s_{mf} = size of a minor frame in bits

s_{MF} = size of a major frame in bits

j = total number of lines of code executed for each minor frame of data

l = total number of lines of code executed for each orbit group

m = total number of lines of code executed for each experiment file

s_{OG} = size of an orbit group in bits

s_{EF} = size of an experiment file in bits

k = total number of lines of code executed for each major frame of data

f = multiplicative factor (to convert cycle time to instruction time)

c = cycle time in seconds of candidate CPU

And: $s_{MF} = n\, s_{mf}$

Where: n = integer number of minor frames per major frame

For ease of data manipulation, the expression for u reduces to:

$$u = 100 \cdot c \cdot f \cdot r_i \left[\frac{1}{s_{mf}} \left(j + \frac{k}{n} \right) + \frac{l}{s_{OG}} + \frac{m}{s_{EF}} \right]$$

Because the nature of the input data stream is not narrowly defined as yet, it would be advisable to examine u with different factors being varied. The above compact expression obviously is very sensitive to certain combinations of driving factors. The objective is to determine the worst-case which drives up the system utilization. The factors which are relatively fixed are "c" at .7 us (from the minicomputer characterization section), "f" at 3 (to very closely approximate load and store operations), "j" at 275 (best known approximation), "k" at 200 (best known approximation), "l" at 40,500 x E (best known approximation), and "m" at 75,000 x E (best known approximation).

The expression for "u" can be simplified (just for the previous case) to:

$$u = (100)(.7 \times 10^{-6})(3)\, r_1 \left[\frac{1}{s_{mf}} \left(275 + \frac{200}{m} \right) + \frac{40500 \times 48}{5 \times 10^{10}} \times \frac{75000 \times 48}{5 \times 10^{12}/48} \right]$$

$$= (2.1 \times 10^{-4})\, r_1 \left[\frac{1}{s_{mf}} \left(275 + \frac{200}{m} \right) + 7.34 \times 10^{-5} \right]$$

Before searching for the worst case, u should be evaluated to establish a baseline operating point.

Typical values are as follows:

s_{mf} = 4096, 2048, 1024, 512 bits

r_1 = 8, 12, 20 Mb/s

n = 100, 50, 10

Table 6-6 and Figure 6-x illustrate these findings.

TABLE 6-6.
OUTPUT PROCESSOR UTILIZATION FACTOR

r_i (Mb/s)	s_{mf} (bits)	n	u (%)	r_i (Mb/s)	s_{mf} (bits)	n	u (%)
8	512	10	968	20	512	10	2420
8	512	50	915	20	512	50	2289
8	512	100	908	20	512	100	2272
8	1024	10	454	20	1024	10	1210
8	1024	50	457	20	1024	50	1144
8	1024	100	454	20	1024	100	1136
8	2048	10	242	20	2048	10	605
8	2048	50	228	20	2048	50	572
8	2408	100	227	20	2048	100	568
8	4096	10	121	20	2048	10	605
8	4096	50	114	20	4096	50	286
8	4096	100	113	20	4096	100	284
12	512	10	1452				
12	512	50	1373				
12	1024	100	682				
12	2048	10	363				
12	2048	50	343				
12	2048	100	341				
12	4096	10	181				
12	4096	50	172				
12	4096	100	170				

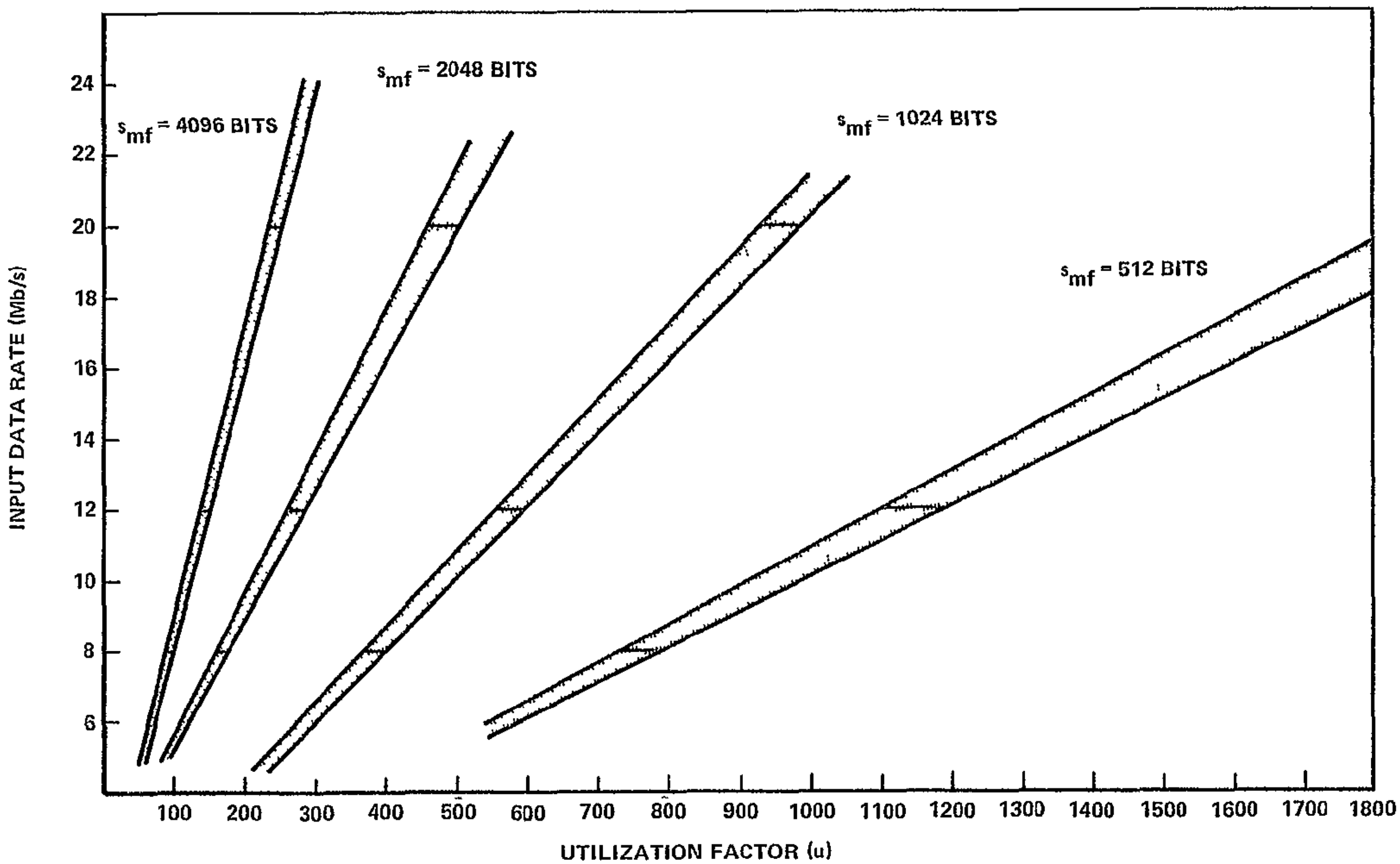


FIGURE 6-18. UTILIZATION CURVES FOR THE OUTPUT PROCESSOR

TABLE 6-7. OUTPUT PROCESSOR TITLE COSTS

Attribute:	Parameter	Units	Projected Cost ($)
Number of Identical Buffers	L		Not Applicable
Number of Bytes in Each Buffer		10K	Not Applicable
Total Buffer Costs[3]	Not Applicable	Not Applicable	($5,616 to $8,912[4]) Approx. $10,000
Number of Output Processors	K	2 to 24[1]	$46K ea.[2]
Misc. Hardware	Not Applicable	1	50,000
Total System Cost	Not Applicable	1	60K + (K) ($46K)[5]

Notes:

1. Estimated range
2. Average price for minicomputer surveyed
3. (3buffers/unit) x (18 units/sys) x (13K bytes/buffer) = 702K bytes/system = 5.61×10^6 bits/system
4. At .1 cents/bit (= $.001.bit = $\$10^{-3}$/bit): $5.62 \times 10^6 \times 10^{-3}$ = $5,616. If 4096 bit RAM IC's were used at $6.50 each; then ($5.6 \times 10^6$/4096 =) 1372 x $6.50 = $8,912.
5. Total buffer costs (almost 10K) + Misc. Hardware ($50K) = $60K

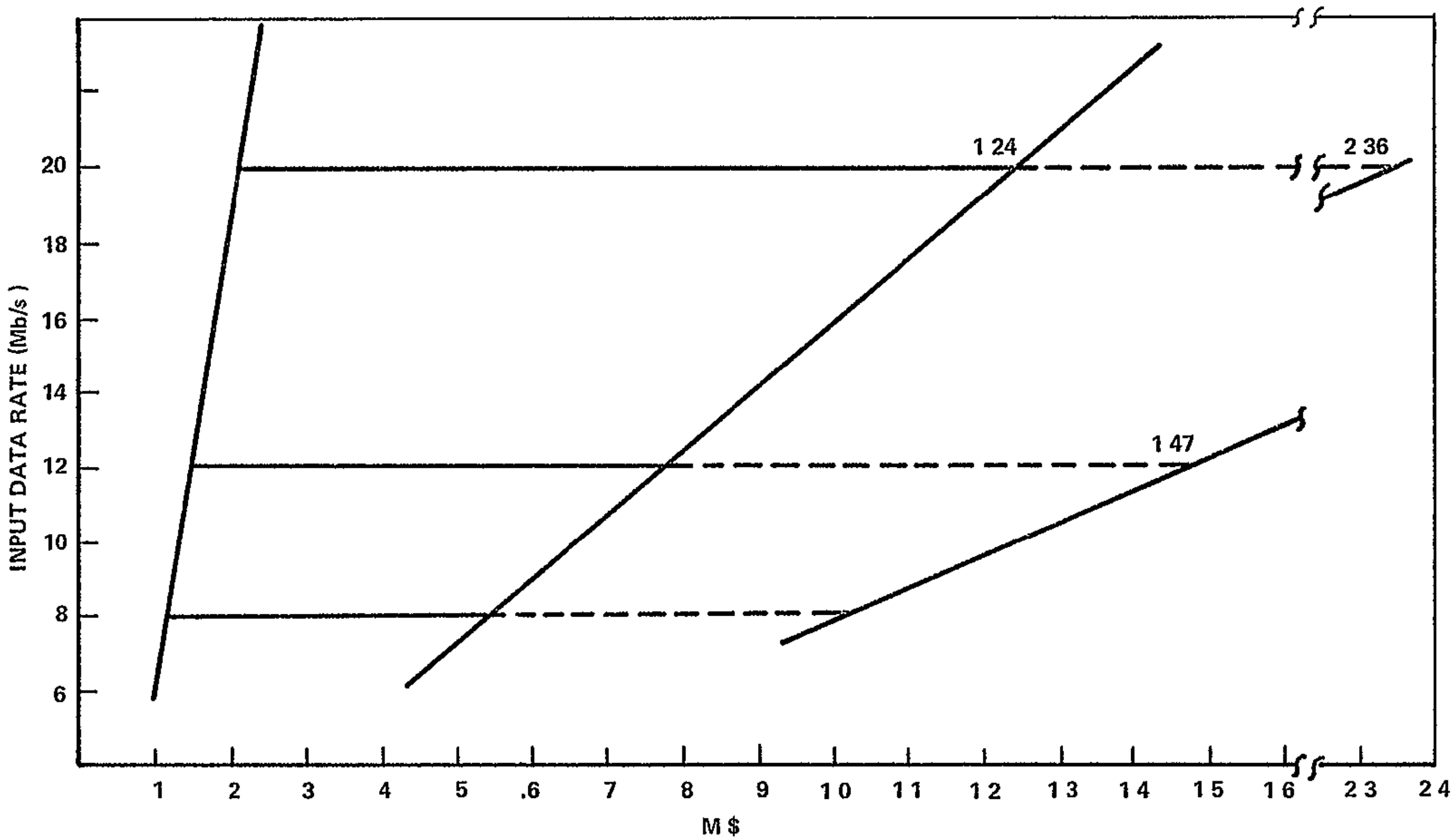


FIGURE 6-19. COST CURVES FOR OUTPUT PROCESSOR

Staging Devices

As illustrated earlier in Figure 6-14, a number (T) of devices are required to stage the output data files for either 1600 bpi, 6250 bpi, HDT, or communication lines. As buffers become ready from the "L" memories (as shown in Figure 6-14), the buffers should be placed into various staging positions so that an experiment data file can be conviently built up. One major candidate for this role would be a large disk. It will be assumed that a good starting point would be to consider the type of disks as highlighted in Table 4-8.

Since the buffering of data and the operations on it are essentially transparent when the output processor is in operation, the minimum number of discs required to sustain the system throughput would be defined as·

$$T = \frac{R_{MR}}{R_{DW}}$$

where:

T = number of disk units

R_{MR} = Maximum total data rate from all MSS devices being read into the output processor

R_{DW} = Maximum sustained write rate of a single disk

where:

$R_{DW} = P_{MAX} - D_{DR}$

R_{DR} = Maximum sustained read rate of a single disk

R_{MAX} = Maximum sustained total I/o rate of a single disk

Based on data entries in Table 4-8, the range of sustained data rates ($R_{DW} + R_{DR}$) for 3330 type of disks is between 2.6 and 4.5 Mb/s. If no overflow or underflow is a set design goal, then $R_{DW} \cong 2.25$ Mb/s $\cong R_{DR}$. Figure 6-20 illustrates the relationship between R_{MR} and T. The figure does not reflect consideration for spares.

As illustrated in Figure 6-20, two sets of curves are illustrated--a computed "T" curve and a practical "T" curve. For example, at 8 Mb/s., the

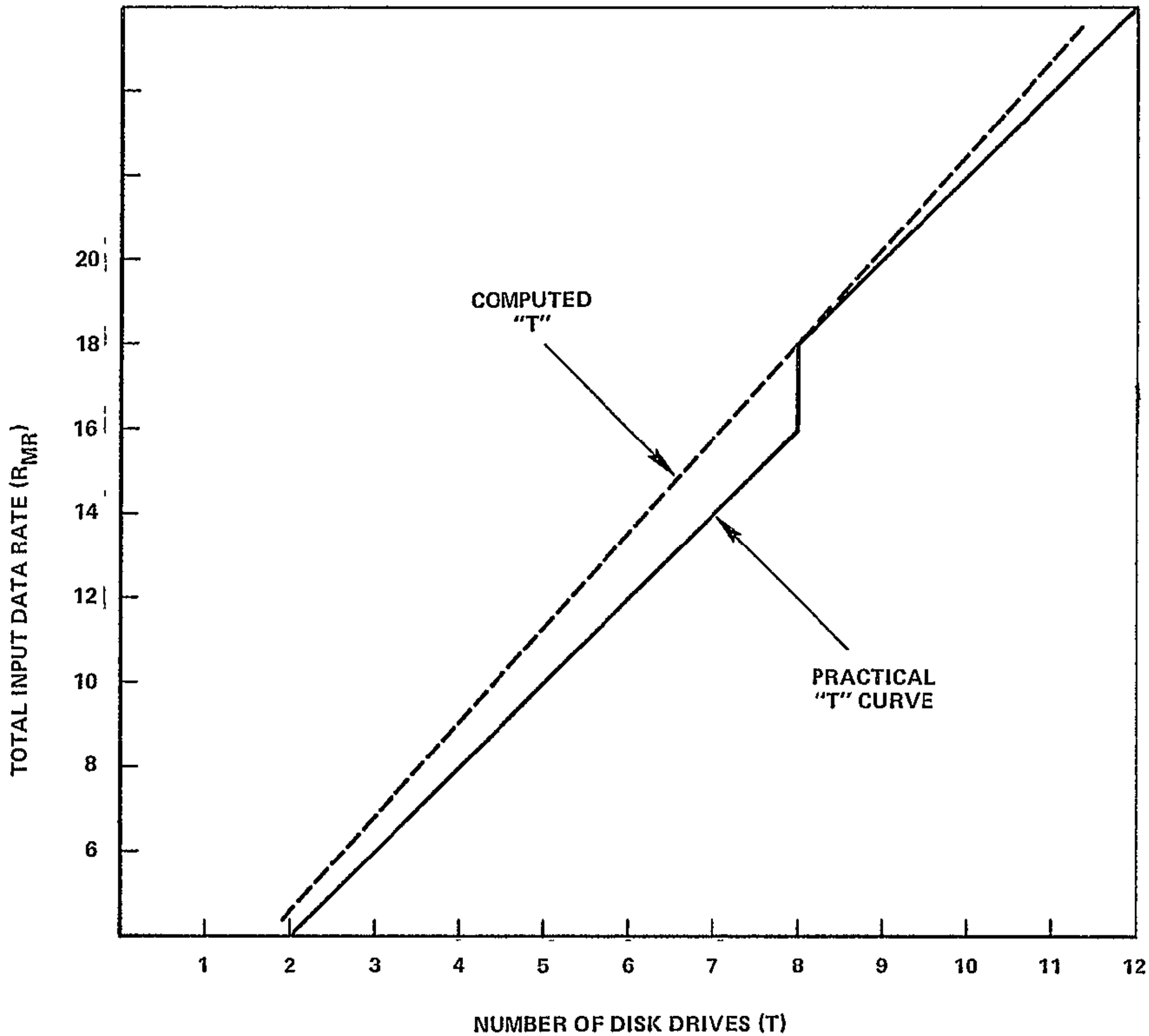


FIGURE 6-20. COMPUTED AND PRACTICAL ESTIMATES OF DISK DRIVE

computed value of T is 3.56, thus requiring T to be rounded up to 4. Attention is drawn to the point when R_{MR} equals 16 or 18 Mb/s. Due to rounding up at 16 Mb/s., one automatically obtains the capability to handle 18 Mb/s.

These values are translated in dollar amounts in Figure 6-21. For an absolute minimum system curve, ABCDE could be considered. It uses the minimum number of controllers and disk drives. It appears worthwhile to consider using two controllers, especially when the 16 Mb/s. operating point is approached. This cost-curve is FCDE, as shown in Figure 6-21.

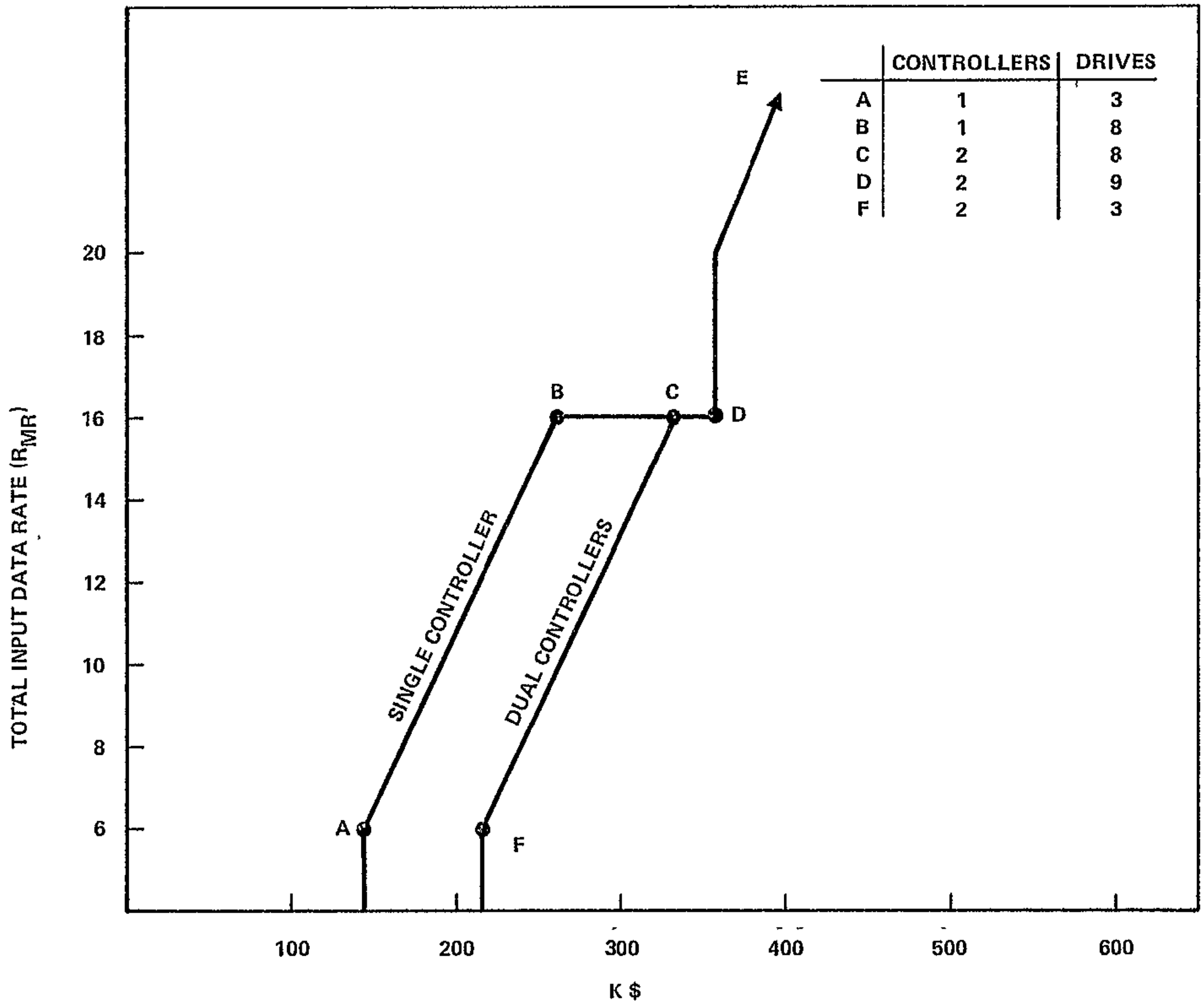


FIGURE 6-21. STAGING DISK COSTS

6.2.4 Peripheral Pool (Output)

Three sets of output peripherals are required:

- Dual density magnetic tape recorders (1600/6250 bpi)
- High density tape recorders
- 56 Kb/s. communication equipment

The cost and performance of these devices were presented earlier in Table 4-8. Because of given output product distributions, it is probable that during significant portions of time, only 1600 bpi tapes would be produced. This implies an I/O rate limited to 2.56 Mb/s.

For a facility to sustain any constant I/O rate, pairs of tape transports are required. Figure 6-22 illustrates the cost curves for all magnetic tape transports as a function of data rates that can be supported. Table 6-8 tabulates the costs and data rates that can be supported with 1600 bpi transports.

The cost curves for 56 Kb/s. communication devices are not shown because they would not be discernable in Figure 6-22. At (approximately) $3,000 per communication line, even ten units would only represent $30,000.

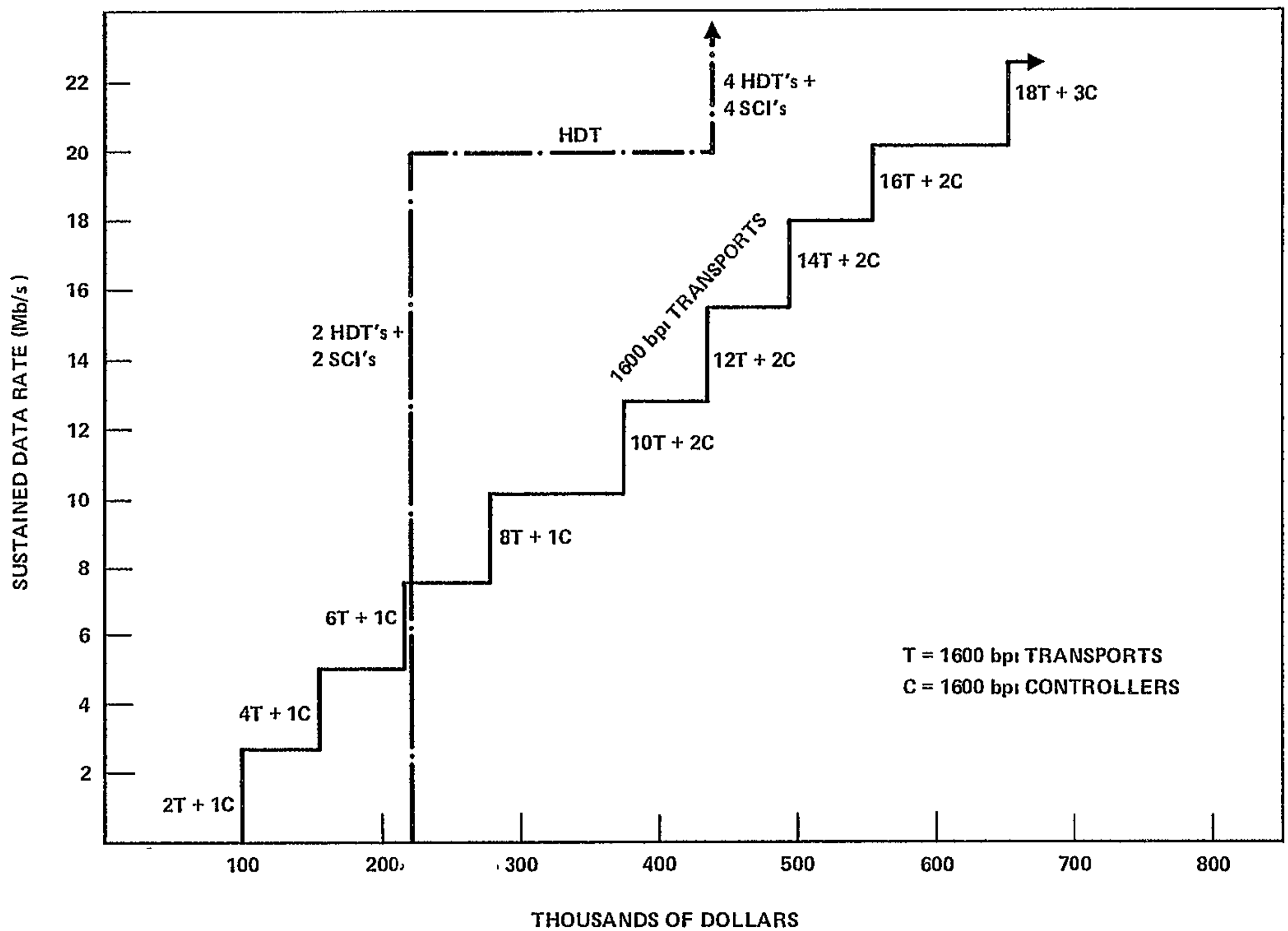


FIGURE 6-22. PERIPHERAL COST CURVES

TABLE 6-8. CONTROLLERS AND TAPE TRANSPORTS

No. of Controllers	No. of 1600 bpi Drives	Costs ($ 100K)	Data Rate (Mb/s.)
1	2	.986	2.56
1	4	1.58	5.12
1	6	2.18	7.68
1	8	2.78	10.24
2	10	3.77	12.84
2	12	4.37	15.36
2	14	4.97	17.92
2	16	5.57	20.40
3	18	6.56	23.04

6.2.5 Resource Monitor (RM) Requirements

The Resource Monitor performs the following functions:

1. Accepts input scenario data
2. Accepts input maps of TLM
3. Performs scheduling for all resources
   - Work Assemblers
   - Storage
   - Output Processor
   - Output Switch
4. Allocates and monitors resources to maintain schedules
5. Collects and stores input accounting data
6. Collects and stores output accounting data
7. Logs hardcopy of all accounting data
8. Prints all necessary forms for transmittal
9. Provides a query capability for system status

Figure 6-23 shows a generic RM. A detailed analysis of its functions follows

1) Accepts input scenario data

This data is provided as tape input and is defined a priori. It can be provided on an orbit-by-orbit basis, or it can describe a series of orbits. Basically the data contained on the tape are·

- The experiments which will be on for the scenario
- The DCS lines to which they will be connected
- The start and stop times of the experiments
- The ancillary data to be used by the experiments

2) Accepts input maps of TLM

This data is again provided as tape input and is defined a priori. It should be provided for the overall mission and updated in the event of a real-time TLM format change. The data should contain:

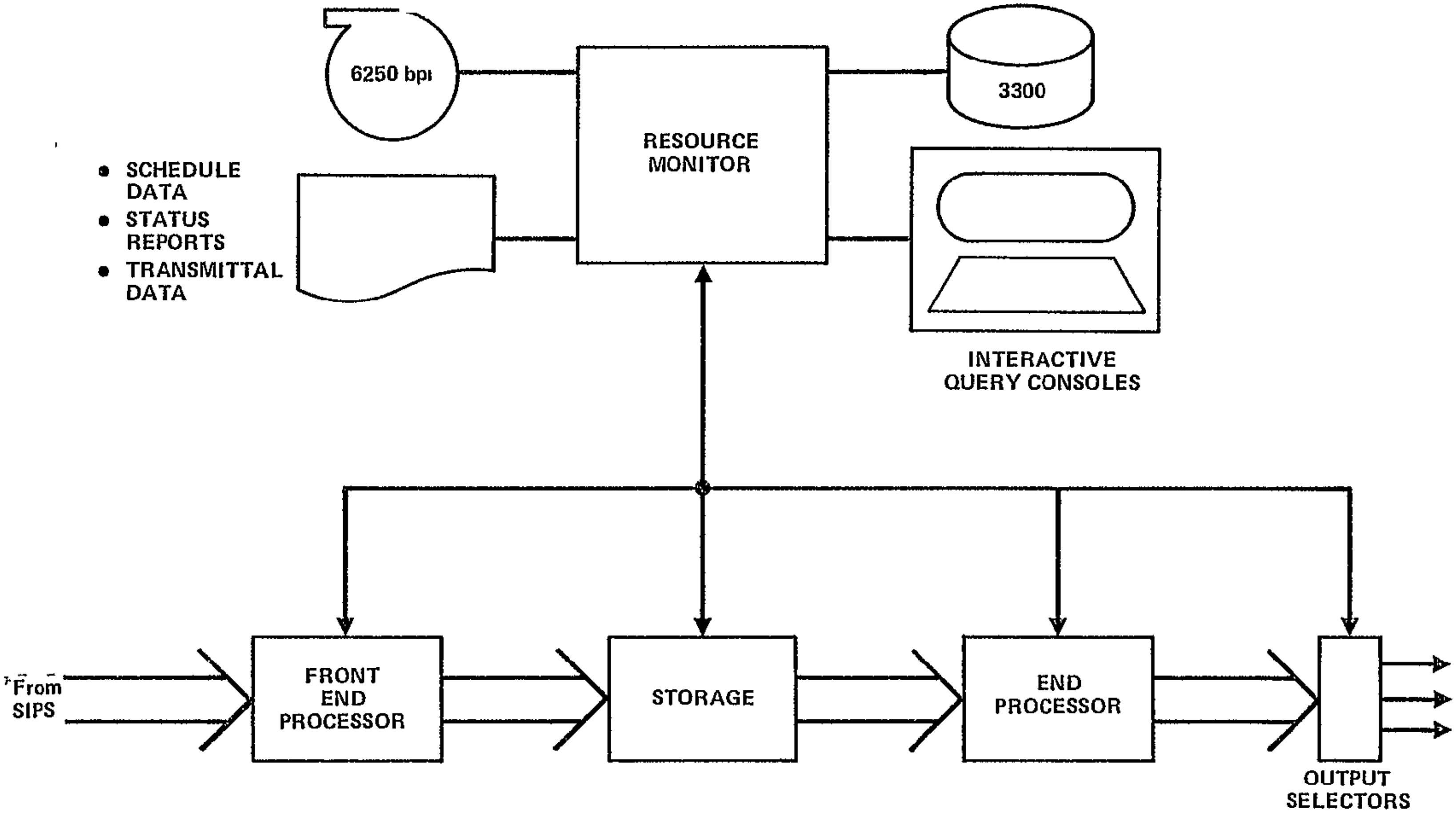


FIGURE 6-23. GENERIC RESOURCE MONITOR

- A description of the experiment TLM frame format, for all experiments.
- A description of the TLM formats for all other data.

NOTE: These data should be byte-oriented.

3) Performs scheduling for all resources

Using the two inputs just described, the RM performs the necessary algorithms to allocate units of work to each of the resources within the SOPS and to ensure that the use of resources is maximized and that a smooth workflow takes place. This is performed for the specific scenario input. The RM typically allocates buffers, storage and output devices.

4) Allocates and monitors resources

Once a resource is allocated, it must be continuously monitored to ensure that the resource is performing correctly. This is accomplished by handshaking with the various portions of the system. Typically this involves the following functions:

- Allocate a Work Assembler to a DCS line
- Allocate a storage unit to the work assembler
- Allocate an output processor to this data, and define the work to be done, e.g., what experiments to segregate, what ancillary data to compile etc.
- Allocate output processor media by experiment
- Obtain an indication of full buffers within the time expected
- Obtain an indication of Work Assembler work units complete.
- Obtain an indication of output processing completed, and o/p media written
- Record and flag any failures of work incomplete within expected time (watch dog)

5) Collects and stores input accounting data

As the input data is collected in the work assembler, it will gather information concerning the nature of the data. This information will be returned to the RM for storage and is used to track the resource performance. This data includes:

- The GMT for each frame
- The experiment ID for each frame
- The number of bytes collected per frame
- The number and position of missing or known incomplete frames
- The number of detected errors in each frame
- The number of frames collected per unit time
- The total number of frames collected per scenario

6) <u>Collects and stores output accounting data</u>

As the data is processed in the output processor and passed to the output media, the output processor collects information, which is then passed to the RM. This data includes:

- Start and stop times in GMT
- Number of frames processed for unit time
- Total number of frames processed for an experiment
- Number and position of overlapped frames found
- Number and position of filled frames
- Time validation errors
- Number of tapes written by experiment
- Amount of data transmitted over links per unit time

7) <u>Logs hardcopy of all accounting data</u>

All of the above data are made available in hardcopy.

System performance data is also hardcopied.

8) <u>Prints all necessary forms</u>

Using the above data, any forms that must be transmitted on tape to the experiment can be printed automatically.

9) <u>Provides a query capability</u>

All the data that is retained with the system should be made available interactively, via alphanumeric keyboard displays.

6.2.5.1 Configuring the RM

The resource monitor performs three major functions

- Schedules resources
- Monitors resource performance
- Collects and displays accounting data

Thus, the RM can be illustrated functionally in Figure 6-24. Each of the three functions is shown as a separate box.

Figure 6-24 shows a schedule processor whose function is to allocate resources for the various scenarios. It uses the input data provided. The resources allocated are then communicated to the schedule monitors whose function is to track the performance of the resources and to relay accounting data to the data collection processor. The schedule processor also stores its telemetry format data on the disc for use by the collection processor.

The collection processor maintains the accounting data, prints hard copy, and provides interactive query capability. There are defined j schedule monitors. The number of these required is a function of resources monitored, the type of machine used, and the actual amount of information to be fed through them.

It is necessary to compute the number and size of processors that would be required to perform the RM functions for each of the data flows defined for the main processing facility. Prior to this computation, the operations of the RM must be described.

6.2.5.2 RM Operations

The scenario of operations for the RM is defined in the following way. The scheduling of resources is performed statically. The data is provided to the monitor "off line", and resources and operations are scheduled before the operations begin. Figure 6-25 shows the order in which the data in input, and Table 6-9 shows the types of data used and the expected output products. This indicates that the system is not dynamically reconfigured but is mainly configured prior to mission start. It is within only the slacker processing times that a new scenario is introduced.

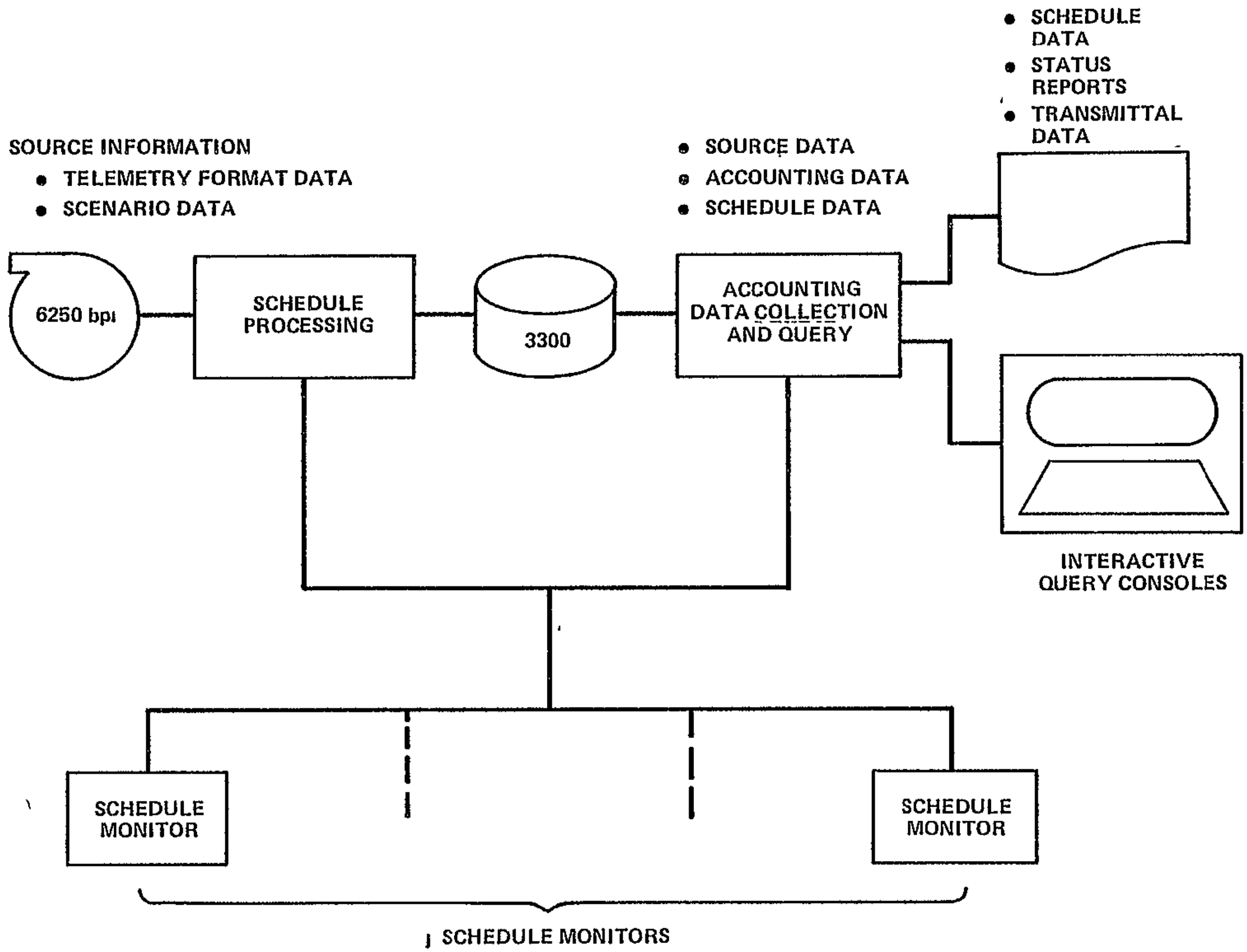


FIGURE 6-24. RM CONFIGURATION

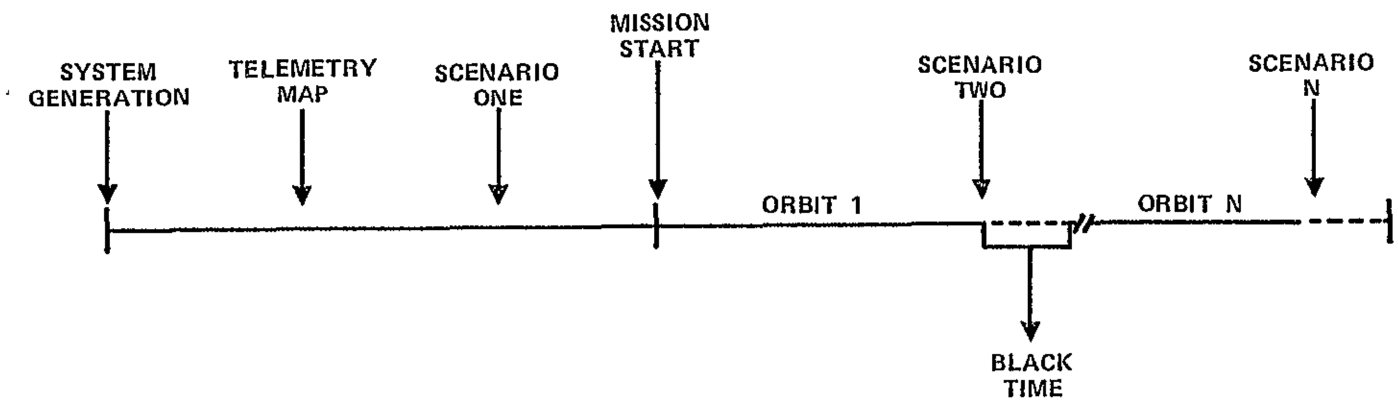


FIGURE 6-25. TIMELINE FOR INPUT DATA TO RESOURCE MONITOR, FOR USE IN SCHEDULING

TABLE 6-9. WORK ACCOMPLISHED AT RESOURCE MONITOR CONFIGURATION STEPS

INPUT DATA TYPE	DATA CONTENTS	OUTPUT DATA
SYSTEM	Describes and Quantifies all Resources: • Computers • Disks • Tapes • Buffer Sizes, etc.	Listing of System Components with assigned labels. (Addresses, etc.)
TELEMENTRY MAP	Describes the contents of all experiment and TLM formats	
SCENARIO DATA	Describes the experiments and other data which will be on and collected for the desired orbit, orbits, or other period of time	In combination with the system data & TLM Map produces a schedule list in hard copy, showing: • Assignment of tapes to experiments • Expected time of tape completion in chronological order • Work orders to operators and assignments • Transmittal orders for completed tapes • Data trace checkpoints Non Hardcopy • TLM Maps to Resources • Assignment & Interconnection of system components

A scenario is defined as the description of an orbits' worth of data. This is consistent with the SOPS facility scenarios previously described. However, such a definition is not mandatory. A scenario could be described as a number of orbits, or as a time interval. The RM functions would remain unchanged, only the parameter keys would differ, and that difference would have no impact upon system operation.

6.2.5.3 Sizing the RM

The RM must be capable of performing its functions for both of the data flows being considered. The heaviest workload imposed upon the RM is maintaining resources and collecting accounting data. As previously explained, this is the only real-time function undertaken. Thus, emphasis is placed upon this function.

To facilitate a discussion of both data flows, the SOPS can be considered as two parts, a front-end, and a back-end processor. (This is consistent with the previous diagrams). Because both processors are considered to perform the same type of work, a single set of computations will suffice for both. Computations will therefore be performed only for the front-end processor work. A multiplying factor of 2 will translate the results into terms appropriate to the back-end.

In order to establish a base line set of parameters, sizing is performed based on a variable number of bytes transferred per buffer, with a variable number of operations being performed on each byte.

Thus, it is possible to derive utilization factors based on various data rates. All that is required then is to pick an operating point for processor utilization given an input rate.

At the same time, the volume of accounting data required to be stored on-line and archived, is computed for a chosen operating point. (A change of operating point requires only a simple recomputation of volume, and a decision concerning the cost-effectiveness of the storage media required to maintain this volume). The computations follow.

For each buffer accounting, data is collected. We will collect N bytes of data.

$$\text{Buffer rate} = \frac{R_i}{8B} \text{ buffers per sec}$$

where R_i = input rate in MB/s

B = buffer size in bytes

8 = number of bits in a byte

Therefore, rate of collection of data $= \frac{NR_i}{8B}$ bytes/sec. Now let us perform P operations on each byte. Therefore, we have $\frac{PNR}{8B}$ operations/sec.

The capability of a machine with 0.7 vs cycle time at an average of 3 cycles/operation is 2.1 vs per operation or 4.76×10^5 operations per second.

The utilization factor of a machine is described as

$$U = 100 \times \frac{\text{Number of operations/sec to be performed}}{\text{capability in ops/sec}} \ \% .$$

So that in this case we have

$$U = 100 \times \frac{\frac{PNR_i}{8B}}{4.76 \times 10^5} \ \%$$

$$= \frac{100\ PNR_i}{8B \times 4.76 \times 10^5} \ \%$$

$$= \frac{2.63 \times 10^{-5}\ PNR_i}{B} \ \%$$

Now the buffer size (B) is fixed at about 10 Kbytes

$$U = \frac{2.63 \times 10^{-5}}{10 \times 10^3} PNR_i \ \%$$

$$= 2.63 \times 10^{-9}\ PNR_i \ \%$$

We will now compute U for various combinations of parameters, thus

P (number of operations)$_{/byte}$ = 1, 5, 10, 20
N (number of bytes)$_{/buffer}$ = 1, 2, 4, 8
R_I (input rate) = 8, 12, 20 Mb/s.

The following values are computed.

TABLE 6-10. RM UTILIZATION

N	P	U (% utilization)		
Bytes	Ops	8 Mb/s	12 Mb/s	20 Mb/s
1	1	2.1×10^{-2}	3.16×10^{-2}	5.26×10^{-2}
	5	1.05×10^{-1}	1.58×10^{-1}	2.63×10^{-1}
	10	2.1×10^{-1}	3.16×10^{-1}	5.26×10^{-1}
	20	4.2×10^{-1}	6.31×10^{-1}	1.05
2	1	4.21×10^{-2}	6.31×10^{-2}	1.05×10^{-1}
	5	2.1×10^{-1}	3.16×10^{-1}	5.26×10^{-1}
	10	4.21×10^{-1}	6.31×10^{-1}	1.05
	20	8.42×10^{-1}	1.26	2.1
4	1	8.42×10^{-2}	1.26×10^{-1}	2.10×10^{-1}
	5	4.21×10^{-1}	6.31×10^{-1}	1.05
	10	8.42×10^{-1}	1.26	2.10
	20	1.68	2.52	4.21
8	1	1.68×10^{-1}	2.52×10^{-1}	4.21×10^{-1}
	5	8.42×10^{-1}	1.26	2.10
	10	1.68	2.52	4.21
	20	3.37	5.05	8.42

These values are plotted in Figures 6- through 6- for the various R_i's with both P and N as parameters.

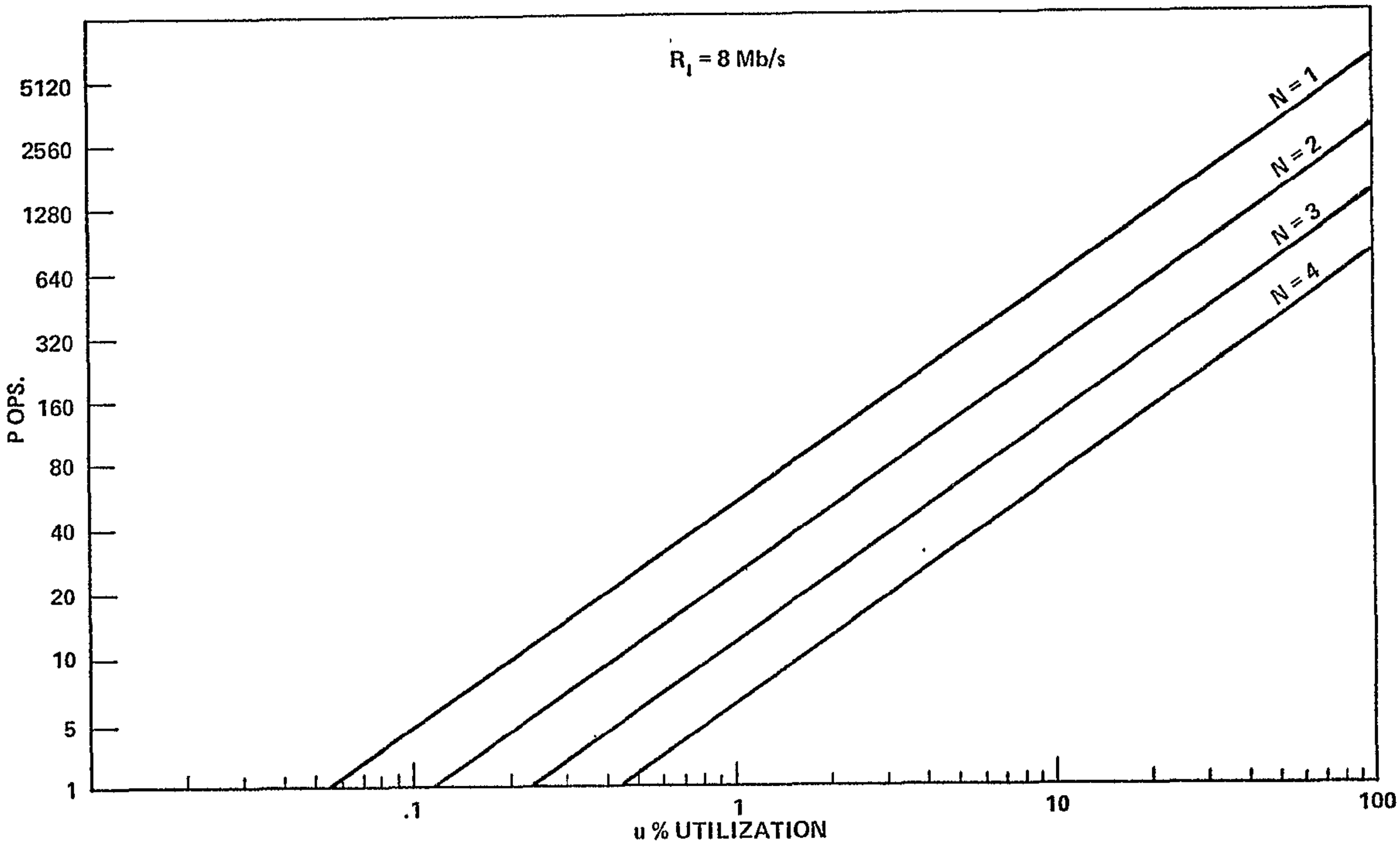


FIGURE 6-26. RESOURCE MONITOR UTILIZATION AT 8 Mb/s WITH P CONSTANT

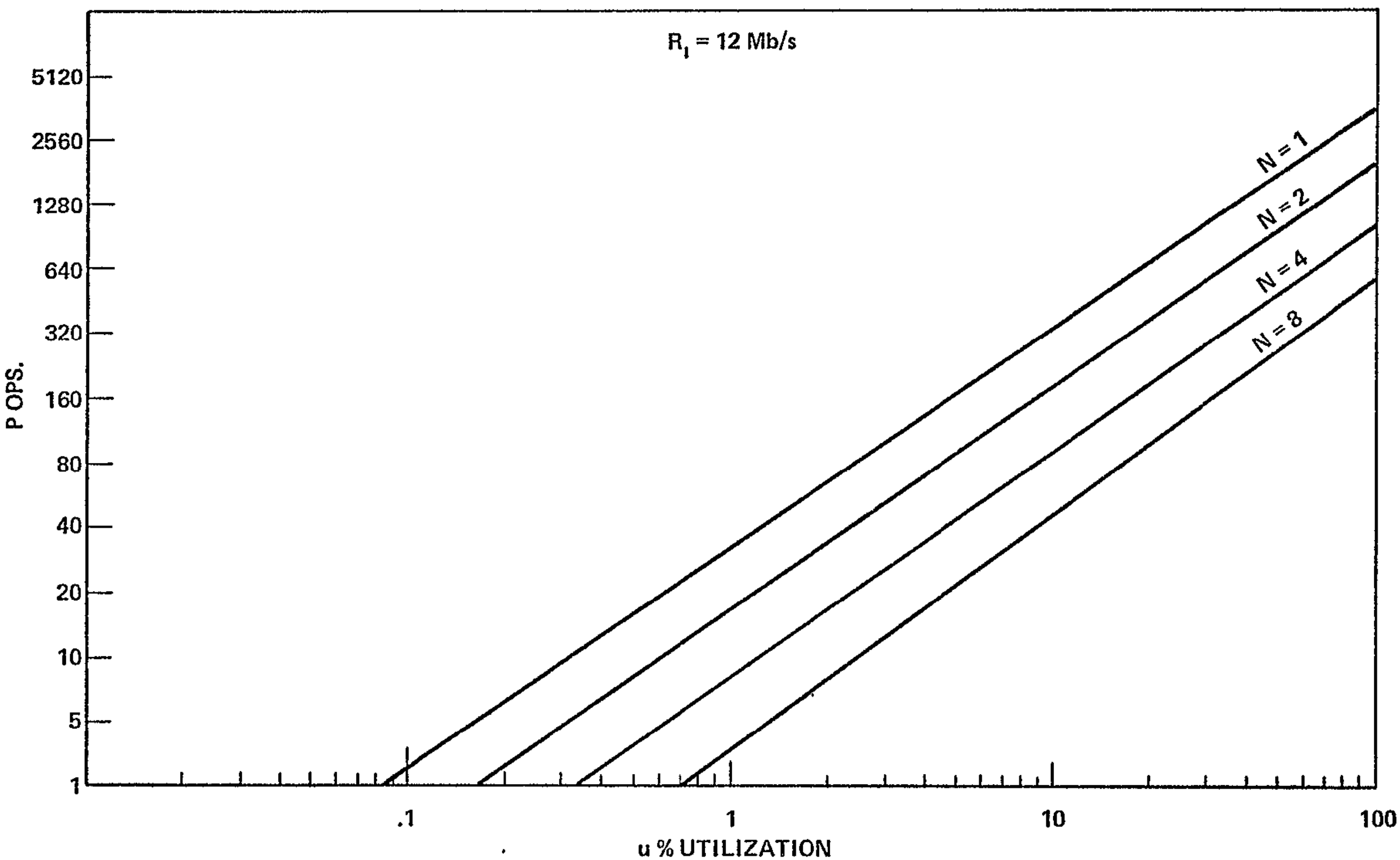


FIGURE 6-27. RESOURCE MONITOR UTILIZATION AT 12 Mb/s WITH P CONSTANT

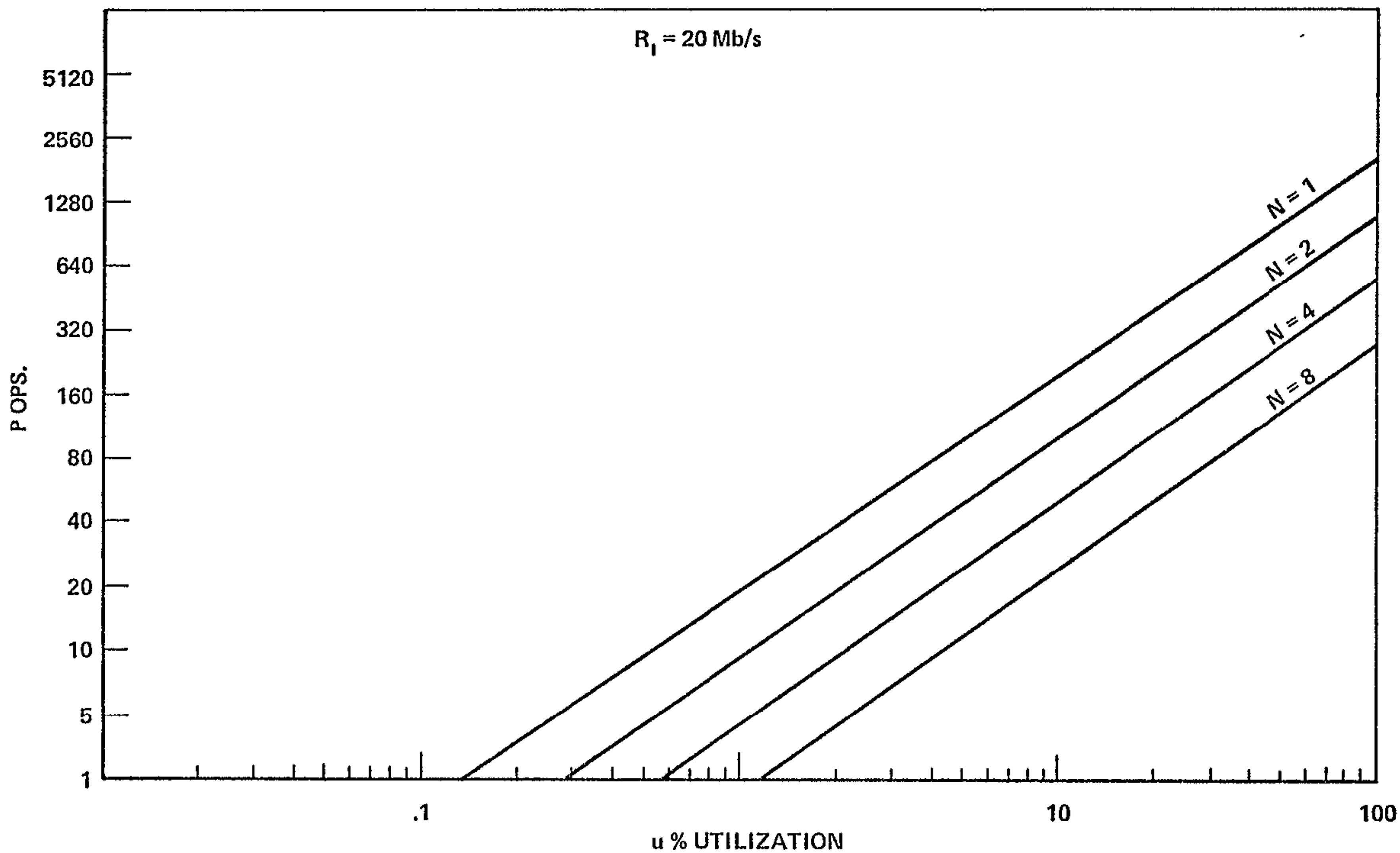


FIGURE 6-28. RESOURCE MONITOR UTILIZATION AT 20 Mb/s WITH P CONSTANT

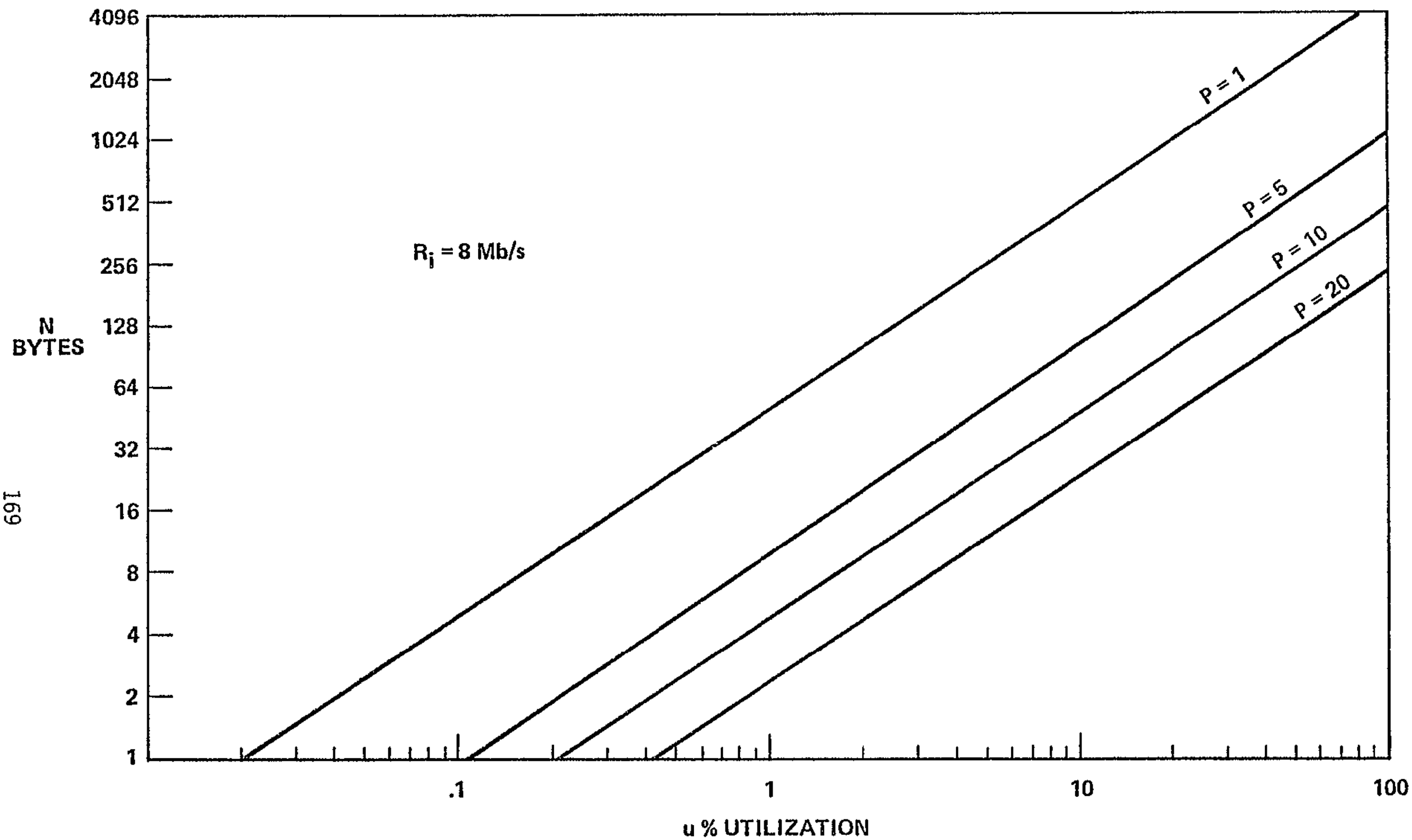


FIGURE 6-29. RESOURCE MONITOR UTILIZATION AT 8 Mb/s WITH N CONSTANT

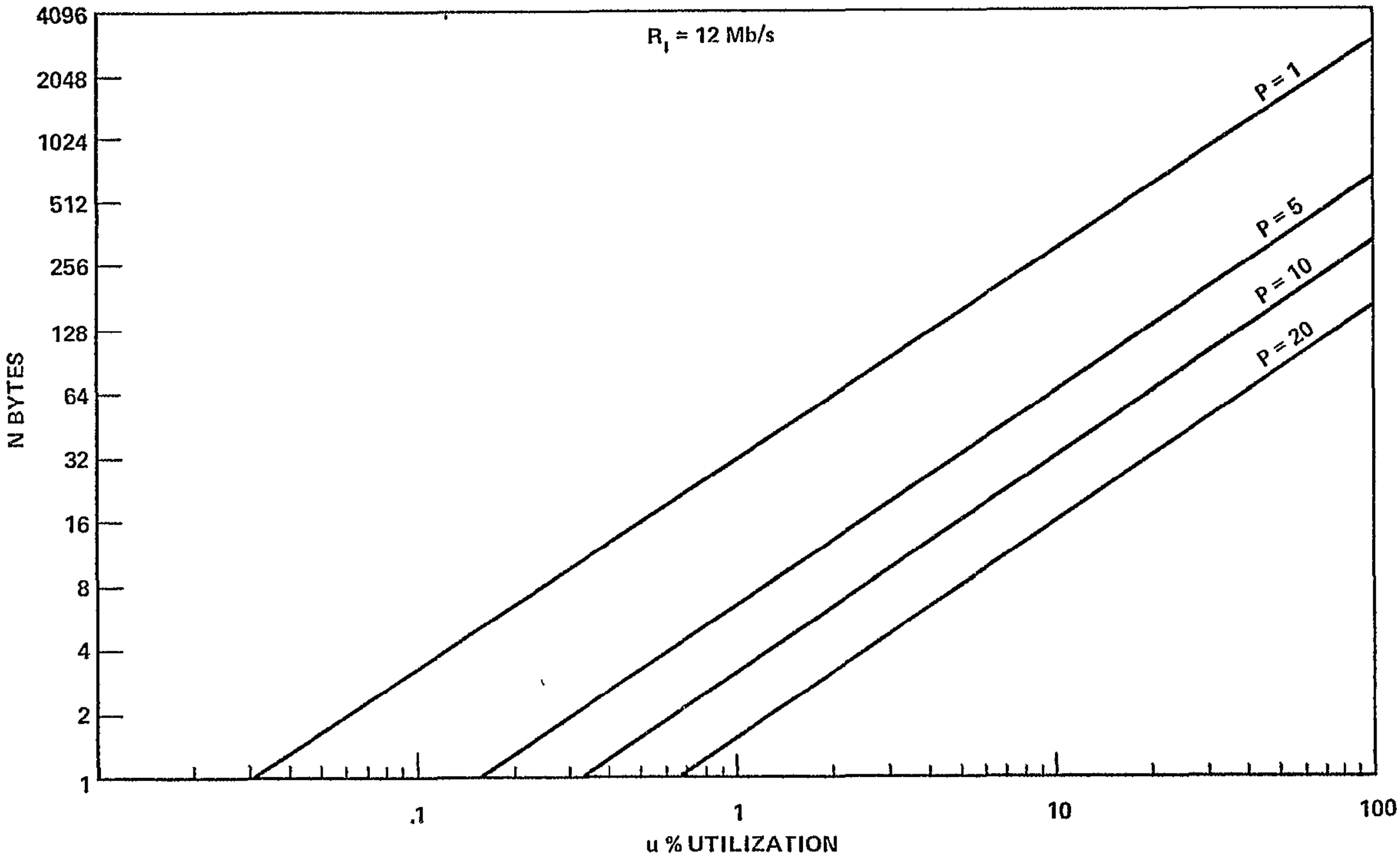


FIGURE 6-30. RESOURCE MONITOR UTILIZATION AT 12 Mb/s WITH N CONSTANT

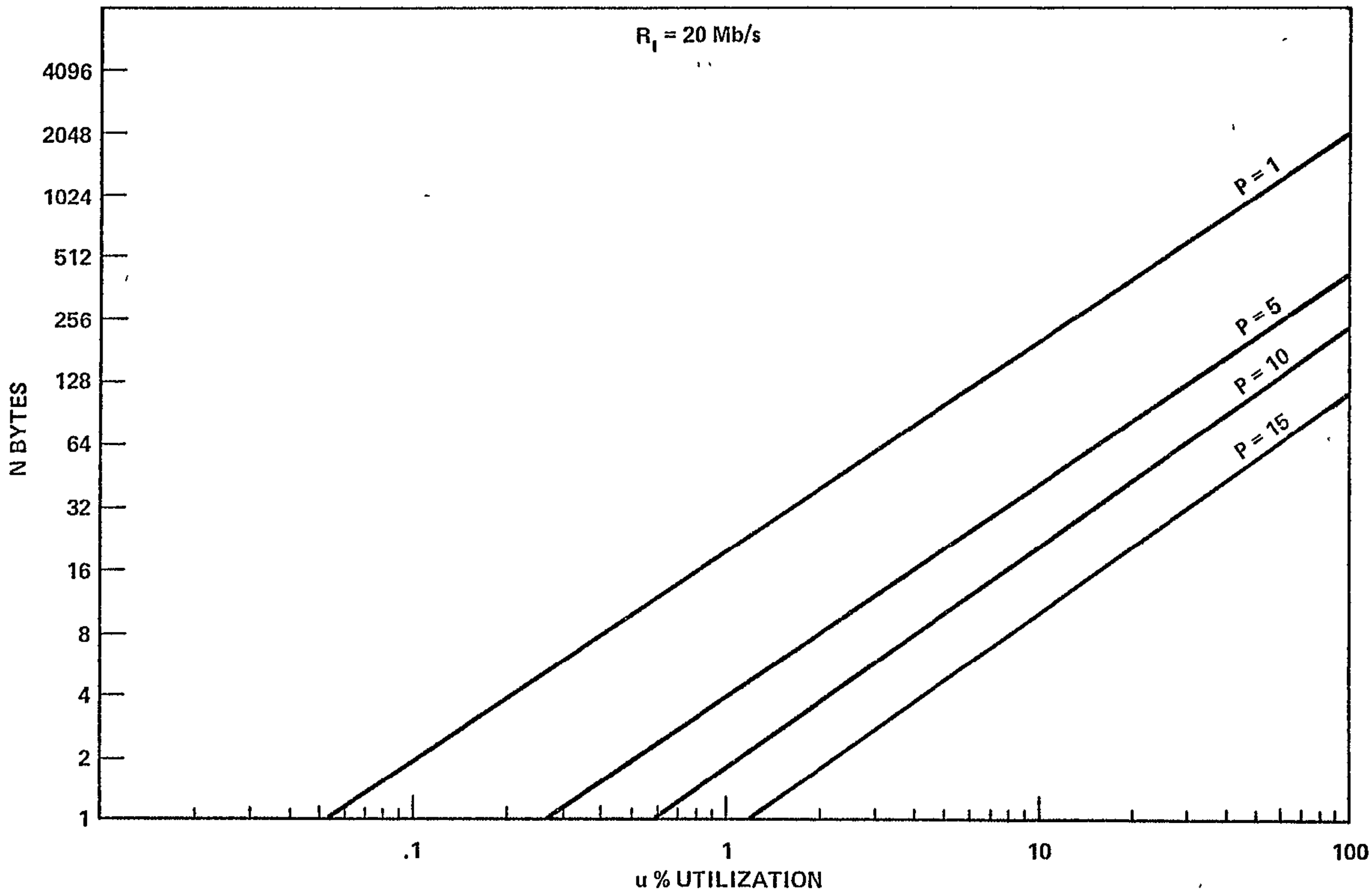


FIGURE 6-31. RESOURCE MONITOR UTILIZATION AT 20 Mb/s WITH N CONSTANT

These curves make it apparent that for either low byte rate or low operations, a single processor is capable of performing both input and output accounting functions.

If, for example, the input data rate to the front-end processor was 8 Mb/s and we wished to collect 8 bytes per buffer and perform 20 operations per byte, then the utilization would be 3%. And if the back-end processor rate were 20 Mb/s and we collect 8 bytes with 40 operations, the utilization is 10.5% for a total of 13.5%. Thus, from Figure 6-24, j reduces to one, which leaves sufficient computing capability to handle the other functions within the same machine.

In the above example, we collected a total of 16 bytes/buffer so that the volume of data collected is:

$$v = \# \text{ buffers/mission} \times \text{Nbytes/buffer}$$

$$= 6.25 \times 10^7 \times 8 \text{ bytes}$$

$$= 10^9 \text{ bytes}$$

Number of bytes collected or per orbit $= 6.25 \times 10^5 \times 8$ bytes

$= 5 \times 10^6$ bytes

Now, if a 3330 disc is used for on-line storage, then we can maintain $\frac{200 \times 10^6}{5 \times 10^6}$ orbits on 40 orbits and to retain this data on 6250 bpi tapes, we will require:

$$\frac{10^9 \text{ bytes}}{1.5 \times 10^8 \text{ bytes}} \text{ tapes/mission}$$

$$= \underline{6.6 \text{ tapes}}$$

The use of a single processor although possible, does have one major disadvantage: single point failure, which can be catastrophic to the facility. It is useful, therefore, to perform same computation directed towards improving processor processor utilization, and providing backup.

If there are two identical processors, one for input accounting, and one for output accounting and if the same buffer size is used in both cases, then a redundant configuration can be arranged so that if one processor fails, the other could do both jobs. To achieve this, we will set the utilization at 50%. This can be achieved by varying two parameters: work done per byte (P) and the number of bytes extracted (N). Ultimately, the amount of data collected is reflected in the amount of storage require to retain accounting data.

Therefore, let us use the P parameter curves, extract the various values and N's involved, and then compute data volumes. The N values are rounded to the closest multiple of bytes.

P Ops	N = Number of bytes for 50% operation		
	8 Mb/s	12 Mb/s	20 Mb/s
1	2048	1536	1024
5	512	384	256
10	256	196	128
20	128	96	64

Now it is given that the mission volume $= 5 \times 10^{12}$ bits

$= 6.25 \times 10^{11}$ bytes/mission

$\cong 6.25 \times 10^{9}$ bytes/orbit

Now the buffer size is given as 10×10^{3} bytes. Therefore, the number

$$\text{of bytes collected per mission} = \frac{6.25 \times 10^{11} \text{ bytes/mission}}{10 \times 10^{3} \text{ bytes/buffer}}$$

$= 6.25 \times 10^{7}$ buffers/mission

or 6.25×10^{5} buffers/mission

Now the number of bytes collected per mission = N x number of buffers/mission or N x number of bytes/orbit.

The values of N from Table 6-10 are now substituted, and the results obtaines are tabulted in Tables 6-11 and 6-12. We will now consider the number of bytes collected per mission in relation to the total number of bytes per mission as a ratio, i.e., number of bytes/mission divided by the number of bytes called per mission. These results are plotted in Figure 6-32.

TABLE 6-11. NUMBER OF BYTES COLLECTED

P OPS	9 Mb/s PER MISSION	12 Mb/s PER MISSION	20 Mb/s PER MISSION
1	1.28×10^{11}	9.6×10^{10}	6.4×10^{10}
5	3.2×10^{10}	2.4×10^{10}	1.6×10^{10}
10	1.6×10^{10}	1.2×10^{10}	8×10^{9}
20	8×10^{9}	6×10^{9}	4×10^{9}

TABLE 6-12. RATIO OF MISSION BYTES

P OPS	RATIO		
	8 Mb/s	12 Mb/s	20 Mb/s
5	19.53	26.04	39.06
10	39.06	52.08	73.08
20	78.13	104.17	156.25

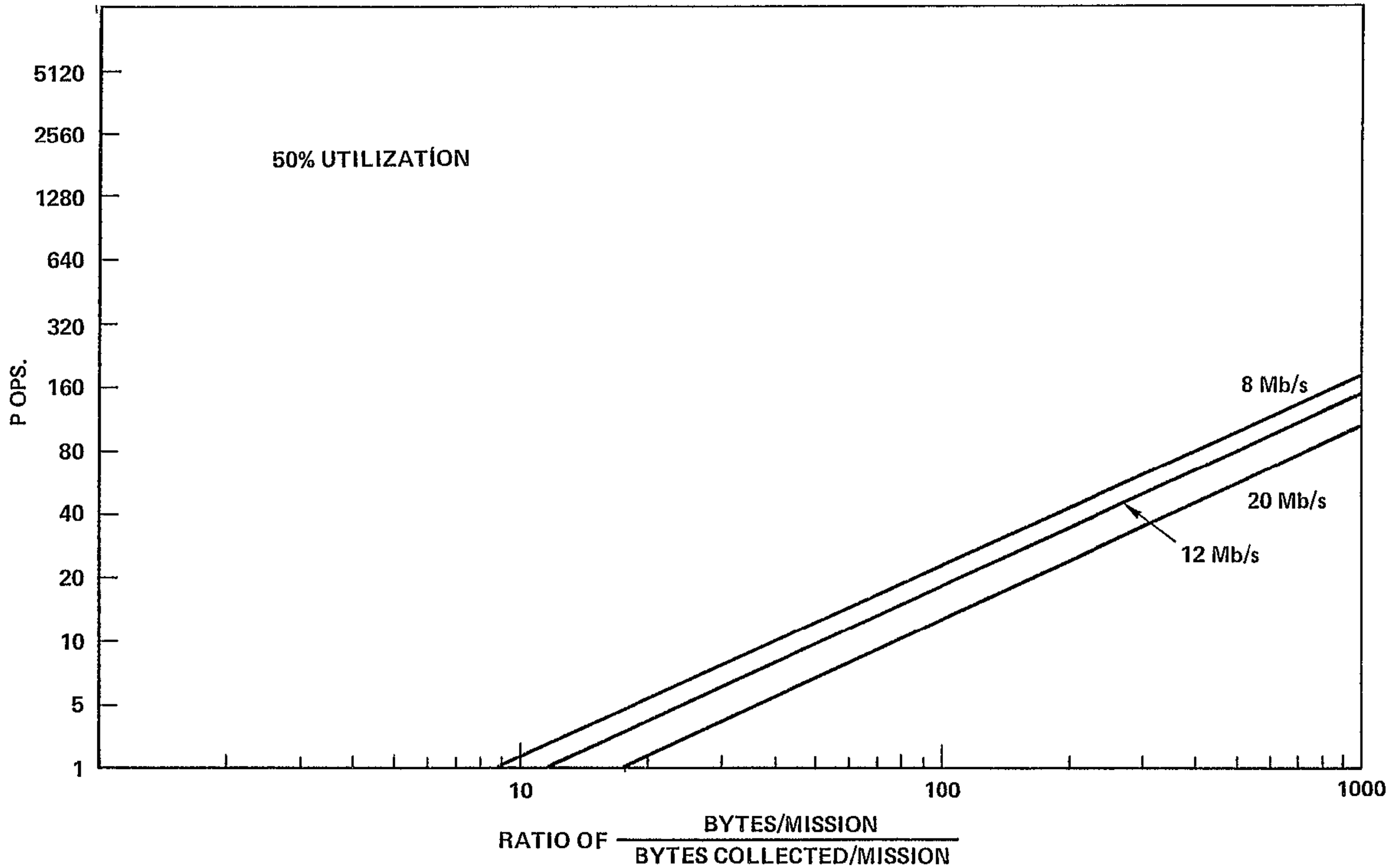


FIGURE 6-32. MISSION BYTE RATIO

Let us suppose now that we choose a ratio of 500:1 (i.e., for every 500 data bytes, there is one accounting byte for both input and output). To calculate the data values only for input, we have:

bytes collected per mission

$$= \frac{6.25 \times 10^{11}}{500}$$

$$= 1.25 \times 10^{9} \text{ bytes/mission}$$

$$= 1.25 \times 10^{7} \text{ bytes/orbit} = 12.5\text{M bytes/orbit}$$

Now the capacity of a 3330 disk is 200×10^6 bytes, and on one drive, we can collect·

$$\frac{200 \times 10^6}{12.5 \times 10^6} \text{ orbits of data}$$

$$= 16 \text{ orbits worth of data}$$

And for scenario #3, we require to retain only 3 orbits worth on line.

Now if all of the data is archived on 6250 bpi tape, then we require for a capacity of 1.2×10^9 bits = 1.5×10^8 bytes.

$$\frac{1.25 \times 10^9}{1.5 \times 10^8} \text{ tapes/mission}$$

$$= 8.3 \text{ reels}$$

say, 9 reels, which is a reasonable number.

And if we now also consider output accounting, then, for the same operating point, we simply double the number of tapes and halve the number of orbits or amount of data that are retained on-line. The result of 18 tapes and 8 orbits is still within the scenario requirements.

Referring to Figure 6-32, at a 500:1 ratio, we now discover that at 20 Mb/s we can perform 80 operations per byte and at 8 Mb/s we can perform about 140 operations per byte

Thus, full on-line redundancy can be obtained with the configuration of Figure 6-33, which illustrates a four computer system.

The schedule computer and accounting computer could be collapsed into one, leaving full monitor redundancy, while possibly degrading either schedule or data accounting functions or both.

Comparative costs for the three configurations are shown in Table 6-13.

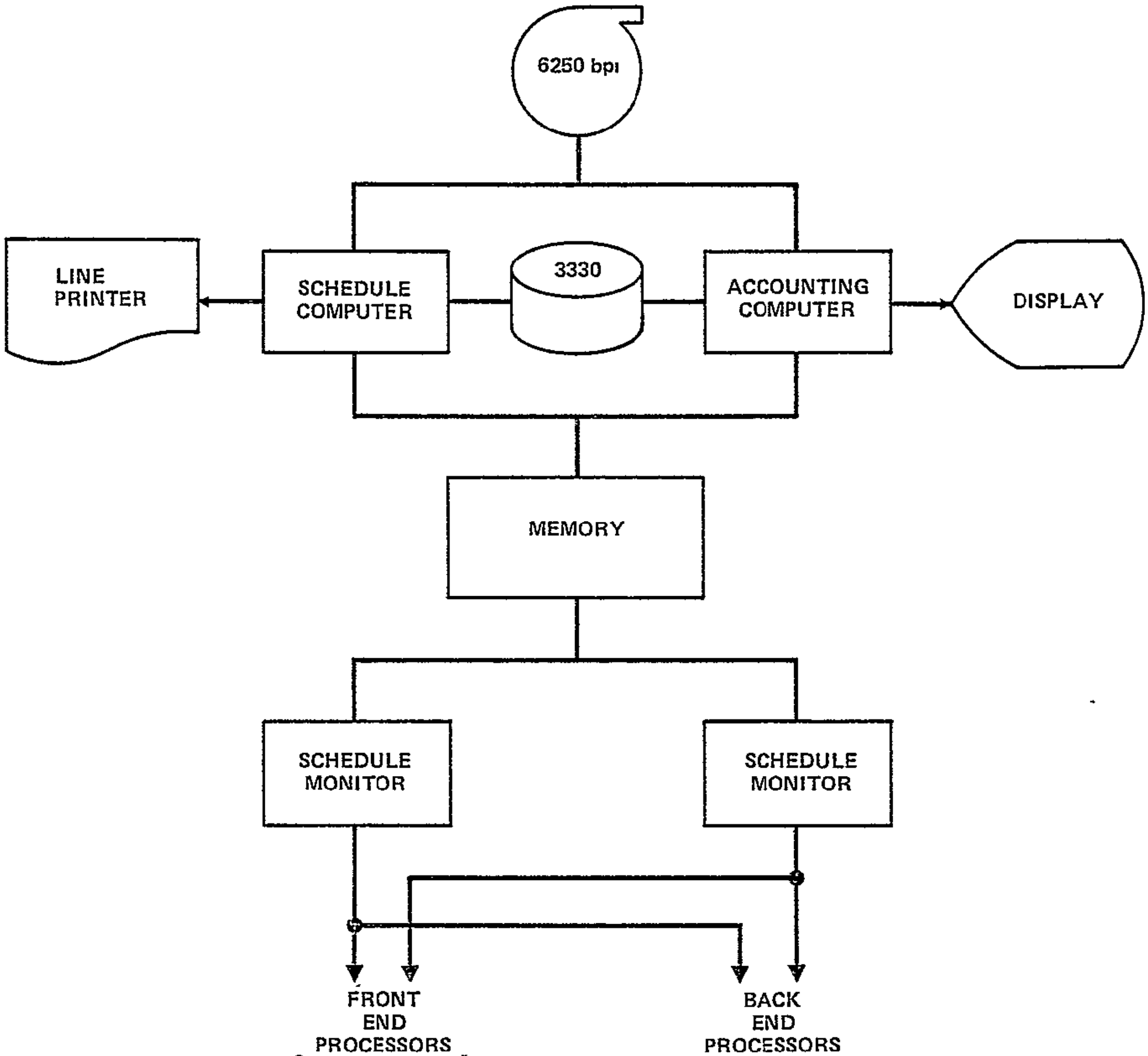


FIGURE 6-33. FULLY REDUNDANT RM CONFIGURATION

TABLE 6-13. COMPARATIVE COSTS OF THREE RESOURCE MONITORS

ITEM	SINGLE COMPUTER	PARTIALLY REDUNDANT (3 COMPUTERS)	FULLY REDUNDANT (4 COMPUTERS)
Computers at $46K each	$46K	$138K	$184K
Core Memory At 10% of a Single CPU	4.6K	4.6K	4.6K
6250 bpi Tape and Controller	68.6K	68.6K	68.6K
3330 Disc and Controller	95.5K	95.5K	95.5K
Line Printer and Controller	10K	10K	10K
Display Terminal	5K	5K	5K
TOTAL	$229.7	$321.7K	$367.7K
% DIFFERENTIAL	0	+ 40%	+ 70%

6.3 ARCHITECTURE NUMBER 2

Architecture number 2 is illustrated in Figure 6-34. This architecture fully supports data flow number 2 (as previously illustrated in Figure 6-2). A brief system utilization walkthrough is presented below.

Spacelab and GMT data enter the system via multiple SIPS output lines. It is assumed that all data on these lines are commutated (viz., lines 1 through 18). The incoming data enters a Work Assembler (WA), where data is decommutated and conveniently large experiment buffers are built. Additionally, ancillary data are extracted from the appropriate data lines. When the appropriate Mass Storage Unit is available, a large experiment buffer load of data is written out. This process continues to roughly correspond to the time of one orbit (approximately 100 minutes). During this interval, precise information concerning the actual decommutation of experimenter data is collected and sent to the Resource Monitor (RM). This data collection and temporary buffering of experiment data continues in units of "orbits" until the end of the mission.

At some chosen point in time (i.e., corresponding to either the 2nd or 3rd orbit), the output processing of data begins. The output subsystems receive scheduling information from the Resource Monitor so that any required data editing may be completed, the emphemeris and attitude data reformatted and written, the ancillary data merged, and the data products finally formatted and written. Peripherals, as required, are selected from a pool (as shown in detail in Figure 6-5), and are assigned to any of the "K" subsystems (as shown in Figure 6-6).

6.3.1 Work Assembler

The first major assembly of equipment in the architecture is the Work Assembler (WA). It is illustrated in Figure 6-35. As shown, it has 19 primary inputs, 18 data input lines (a one-to-one correspondence with the 18 SIPS output lines), and one GMT line from the SIPS. Associated with each SIPS data input line is an interrupt line which notifies the WA of incomplete data frames, error situations, end of data frames, etc.

In this architecture, the WA functions as in the previous architecture,

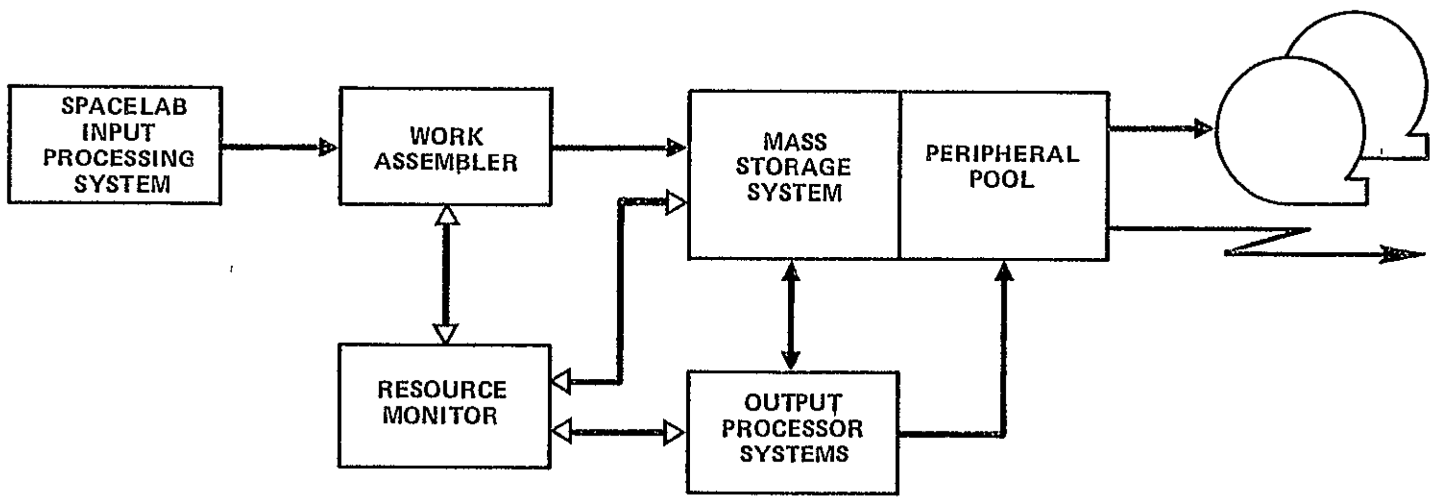


FIGURE 6-34. ARCHITECTURE NO. 2

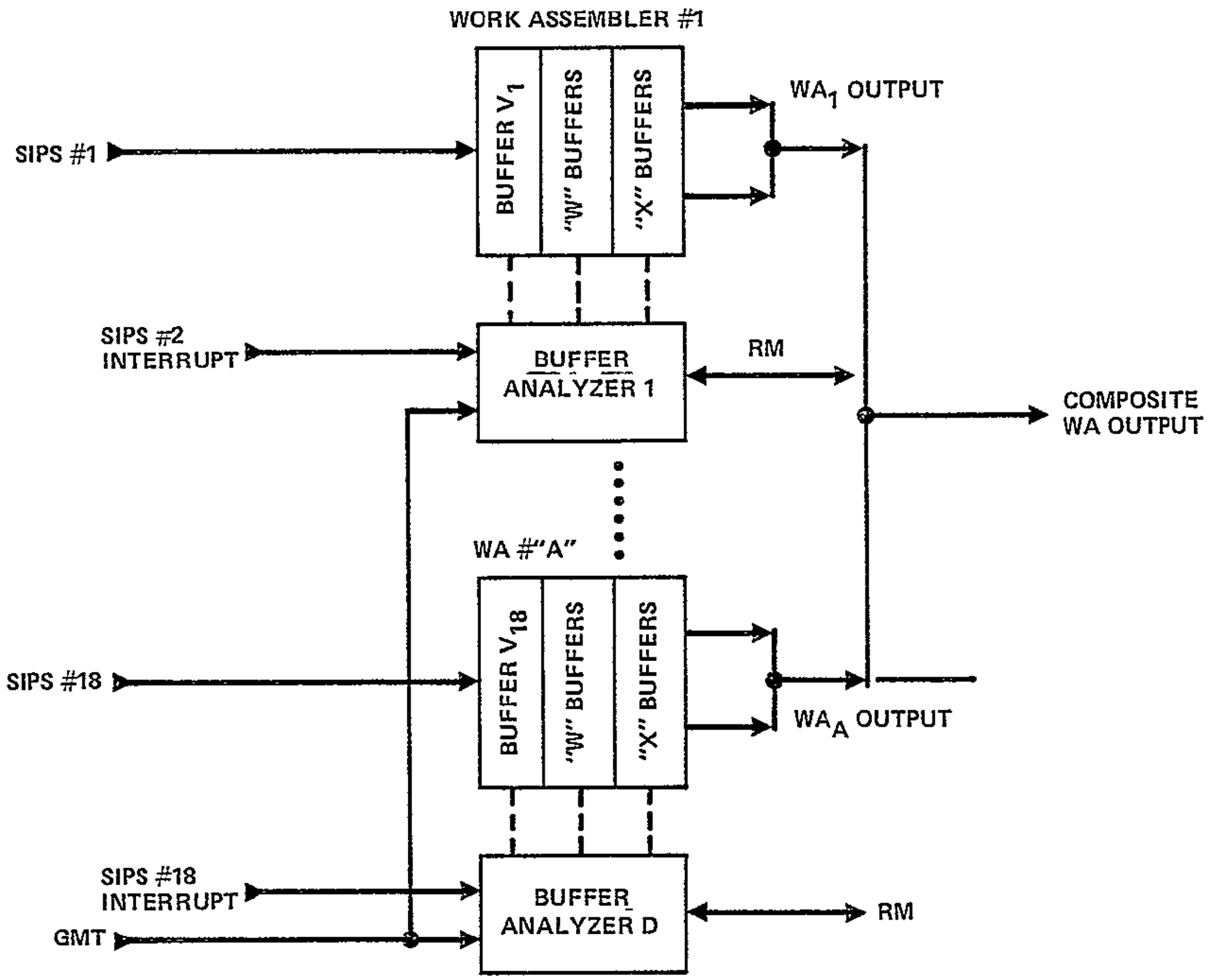


FIGURE 6-35. GENERAL BLOCK DIAGRAM FOR WORK ASSEMBLER SUBUNITS

i.e., it smoothes the input data stream so that large units of work can be conveniently stored on an interim MSS. At the center of this scheme is a three-tier set of buffers (V, W, and X). A logical layout of these buffers is provided in Figure 6-36. For SIPS line number 1, for example, assume that incoming data is commutated (i.e., multiple experiments are interleaved) and that "a" types of major frames of data are possible. The data stream enters the WA via the V_1 buffer. The associated Buffer Analyzer (BA) looks for information identifying the type of major frame, what experiments are inside the major frame, what the GMT time tag is, etc. The length of this "V" buffer is at a minimum, 4 minor frames (since the first four minor frames of any major frame contain these data). Once the BA determines or confirms one type of the major frame, the major frame is then shunted to a W (1 through "a") buffer. This "W" buffer is at least one major frame in length (a maximum of 4096 x 256 = 1.05 x 10^6 bits). If, for example, the major frame is a type "a" major frame, then the data contained in it is exclusively experiment "C" (see Figure 6-36). If, on the other hand, the major frame is a type "2" (as illustrated in Figure 6-36), then data elements belonging to experiments 2, 4, and 5 would then be shifted to output buffers X_1, X_2 and X_5. This is basically how the three tier set of buffers decommutates the incoming data stream. Output buffers X_1 through X_d (d = 48 in this study) fill up and when each fills, the BA and the RM are notified that a large group of decommutated data is ready to be written onto a MSS. (It may be possible to do away with the V buffers and absorb its functions into W. As will be shown, X buffers account for only 1.4% of the total buffers.) As the WA collects data, it will transfer the data to subsequent portions of the system when larger groupings are advantageous.

In Figure 6-36, an individual WA consists of V, W, and X buffers and an associated Buffer Analyzer (which may be either a dedicated CPU, dedicated microprocessor, or a shared CPU). Each WA subunit should be identical so that any system reconfiguration can take place with the fewest number of problems. The BA receives data from and transmits it to the the Resource Monitor. This data exchange consists of "data maps" transmitted to the BA, quality information, and error messages transmitted to RM, etc.

In order to size the entire WA system, quantities have to be estimated:

i = The number of incoming "V" buffers
j = The number of bytes in each V buffer
k = The number of W buffers

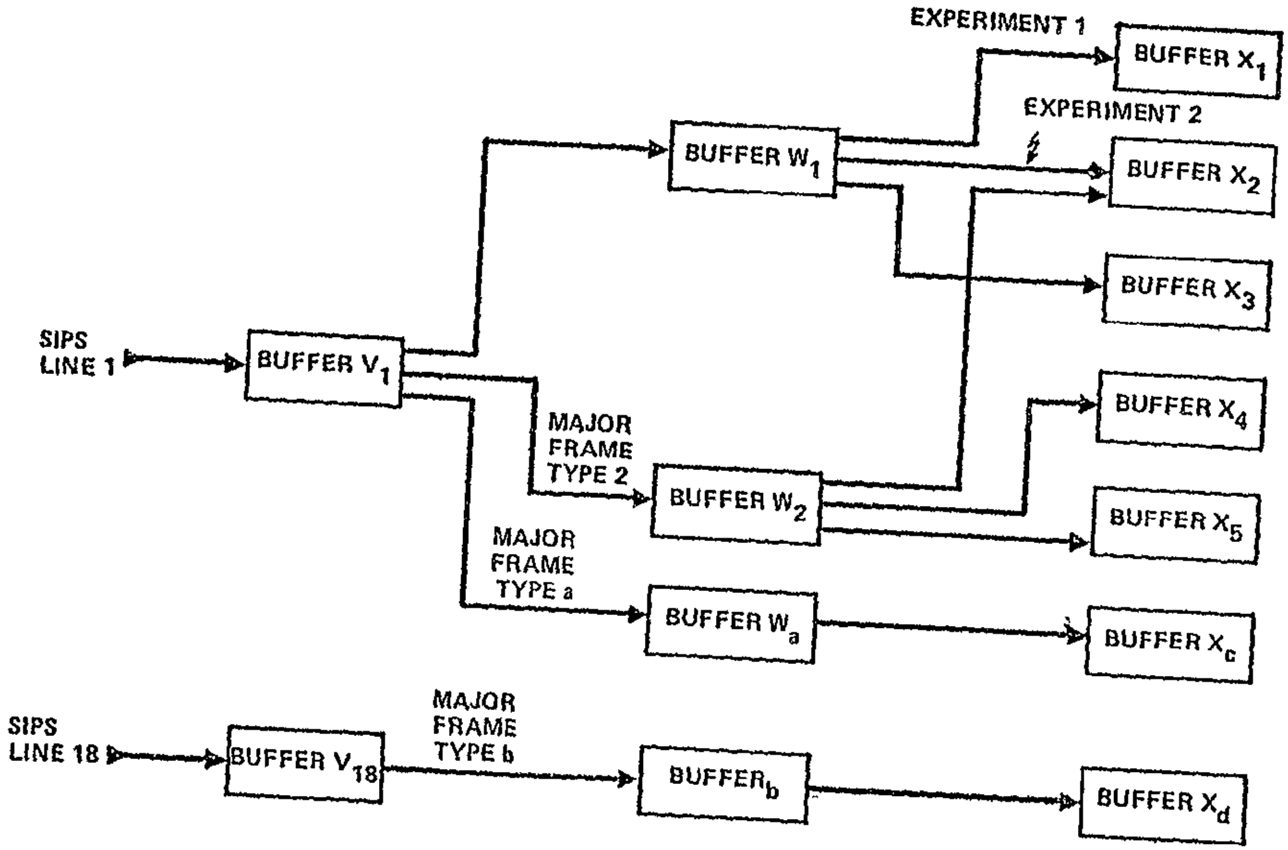


FIGURE 6-36. LOGICAL LAYOUT OF A BUFFER HIERARCHY IN THE WORK ASSEMBLER

l = The number of bytes in each W buffer

m = The number of X buffers

n = The number of bytes in each X buffer

Based on given materials, it appears that "i" has to be set to at least 18. One cannot assume that certain lines are going to be inactive during an orbit at this point in time. Operational modes may change, and the system must be capable of supporting the full DCS output.

The number of bytes in each V buffer (j) can be estimated as follows. Each input line should be at least "double-buffered" to allow the BA enough time to make a proper determination of frame type. If it takes a minimum of four minor frames to obtain input statistics, it would be wise to hold at least five minor frames. To accomodate any size major frame, each "V" buffer would be (4096 bits/minor frame x 5 = 20,480 bits = 2,560 bytes). Therefore, a pair of equal-sized V buffers would equal 5120 bytes.

To size the number (k) of W buffers, it appears that k is at least 18. The upper limit of k is unknown because it is not known how many types of major frames will be present. To circumvent this situation, W buffer could be double buffers of the maximum size, and then "k" and "l" could be easily computed. The quantity "k" would be (2 x 18) 36 and "l" is simply (4096 bits/major frame x 256 minor frames/major frame) 1.05×10^6 bits or 1.31×10^5 bytes each.

As shown in Section 6.2.1, it would be best to set the last buffers (X) to approximately some small multiple of a disk track. Depending on which disk is chosen, the sizes would be between 13 and 10k bytes. For consistency, let the number of X buffers (m) be 48 (corresponding to 48 separate experiment buffers), plus 3 (one for ephemeris, one for attitude, and one for miscellaneous ancillary data), for a total of 51. As stated earlier, the number of bytes for each X buffer should be set to 32,768 bytes.

Thus, the total buffer size in the WA is:

$$(i \times j) + (k \times l) + (m + n)$$

Substituting previously determined values, then the above expression is:

$(18 \times 5120) + (36 \times 1.31 \times 10^5) + (51 \times 32{,}768)$ bytes

$= (9.22 \times 10^4) + (4.72 \times 10^6) + (1.67 \times 10^6)$

$= 6.48 \times 10^6$ bytes

$= 5.18 \times 10^7$ bits

At 0.1 cents/bit ($\$10^{-3}$/bit), this buffer would cost \$51,834. If 4096 bit RAMs at about \$6.50 each were used, then the 12,655 units would be required at a cost of \$82,257.

The ratio of work to be done versus system capability can be expressed analytically as "u" of the BA used in the WA. This relationship is identical to derivation as discussed in Section 6.2.1.

$$u = \frac{\left(\frac{r_i}{s_{mf}} \times j\right) + \left(\frac{r_i}{s_{MF}} \times k\right)}{\frac{1}{f \times c}} \times 100$$

Where:

u = computer utilization (%)

r_i = input data in Mb/s.

s_{mf} = size of a minor frame in bits

s_{MF} = size of a major frame in bits

j = total number of lines of code executed for each minor frame of data

k = total number of lines of code executed for each major frame of data

f = multiplicative factor (to convert cycle time to instruction time)

c = cycle time in seconds of candidate CPU

And: $s_{MF} = n(s_{mf})$

Where: n = integer number of minor frames per major frame

For ease of data manipulation, the expression for u reduces to:

$$u = \frac{100 \cdot c \cdot f \cdot r_i}{s_{mf}} \left(j + \frac{k}{n}\right)$$

Evaluation of the expression:

$$u = \frac{100.c.f.r_1}{s_{mf}} \left(j + \frac{k}{n} \right)$$

where

c = .7 us

f = 3

j = 225 operations per minor frame

k = 150 operations per major frame

and

r_1 (Mb/s)	s_{mf} (bits)	n	u (%)
8	512	10	788.6
8	512	50	749.0
8	512	100	744.0
8	512	256	741.0
8	1024	10	394.3
8	1024	50	374.5
8	1024	100	372.0
8	1024	256	370 5
8	2048	10	167 7
8	2048	50	159.2
8	2048	100	158.2
8	2048	256	157.6
8	4096	10	98.6
8	4096	50	93.6
8	4096	100	93.0
8	4096	256	92.6
12	512	10	1182.9
12	512	50	1123.4
12	512	100	1116.0
12	512	256	1111.5
12	1024	10	581.4
12	1024	50	561.7
12	1024	100	558.0
12	1024	256	555.7

r_1 (Mb/s)	s_{mf} (bits)	n	u (%)
12	2048	10	295.7
12	2048	50	280.9
12	2048	100	279.0
12	2048	256	277.9
12	4096	10	147.9
12	4096	50	140.4
12	4096	100	139.5
12	4096	256	138 9
20	512	10	1971.9
20	512	50	1872.4
20	512	100	1860.0
20	512	256	1852.6
20	1024	10	985.7
20	1024	50	936.2
20	1024	100	930.0
20	1024	256	926.2
20	2048	10	492.9
20	2048	50	468.1
20	2048	100	465.0
20	2048	256	463.1
20	4096	10	246.4
20	4096	50	234.1
20	4096	100	232.5
20	4096	256	231.6

TABLE 6-14. BUFFER ANALYZER UTILIZATION FACTOR

Since the nature of the input data stream is not narrowly defined as yet, it would be advisable to examine u with different factors varied. The above compact expression, obviously, is very sensitive to certain combinations of driving factors. The objective is to determine the worst case which drives up the system utilization. The factors which are relatively fixed are "c" at .7 us (from the minicomputer characterization section), "f" at 3 (to very closely approximate load and store operations), "j" at 225 (best known approximation: 50 for input data accounting, 50 for quality checking, 50 for decommutation, and 75 for time validation), and "k" at 150 (best known approximation: 100 for input data accounting, and 50 for quality checking).

The expression for "u" can be simplified (just for the previous case) to:

$$u = \frac{(100)\ (.7 \times 10^{-6})\ (3)\ (r_i)}{s_{mf}} \left(225 + \frac{150}{n}\right) = 4.73 \times 10^{-2}\ \frac{r_i}{s_{mf}} \left(1+\frac{0.67}{m}\right)$$

Before searching for the worst case, u should be evaluated to establish a baseline operating point.

Typical values are as follows.

s_{mf} = 4096, 2048, 1024, 512 bits

r_i = 8, 12, 20 Mb/s

n = 256, 100, 50, 10

Table 6-14 provides a range of values for "u" as a function of s_{mf}, r_i, and n

As can be seen from the table (Table 6-14), as the input data rate goes up, the number of processors to handle the work goes up, and as the buffer size (the minor frame size) goes up, the amount of work to be done goes down. Additionally, the number of minor frames to a major frame has relatively little effect on changing the magnitude of utilization factor (i.e., it takes the form of .67/n). Table 6-14 is presented graphically in Figure 6-37.

To summarize, the WA can be defined in terms of hardware and capital

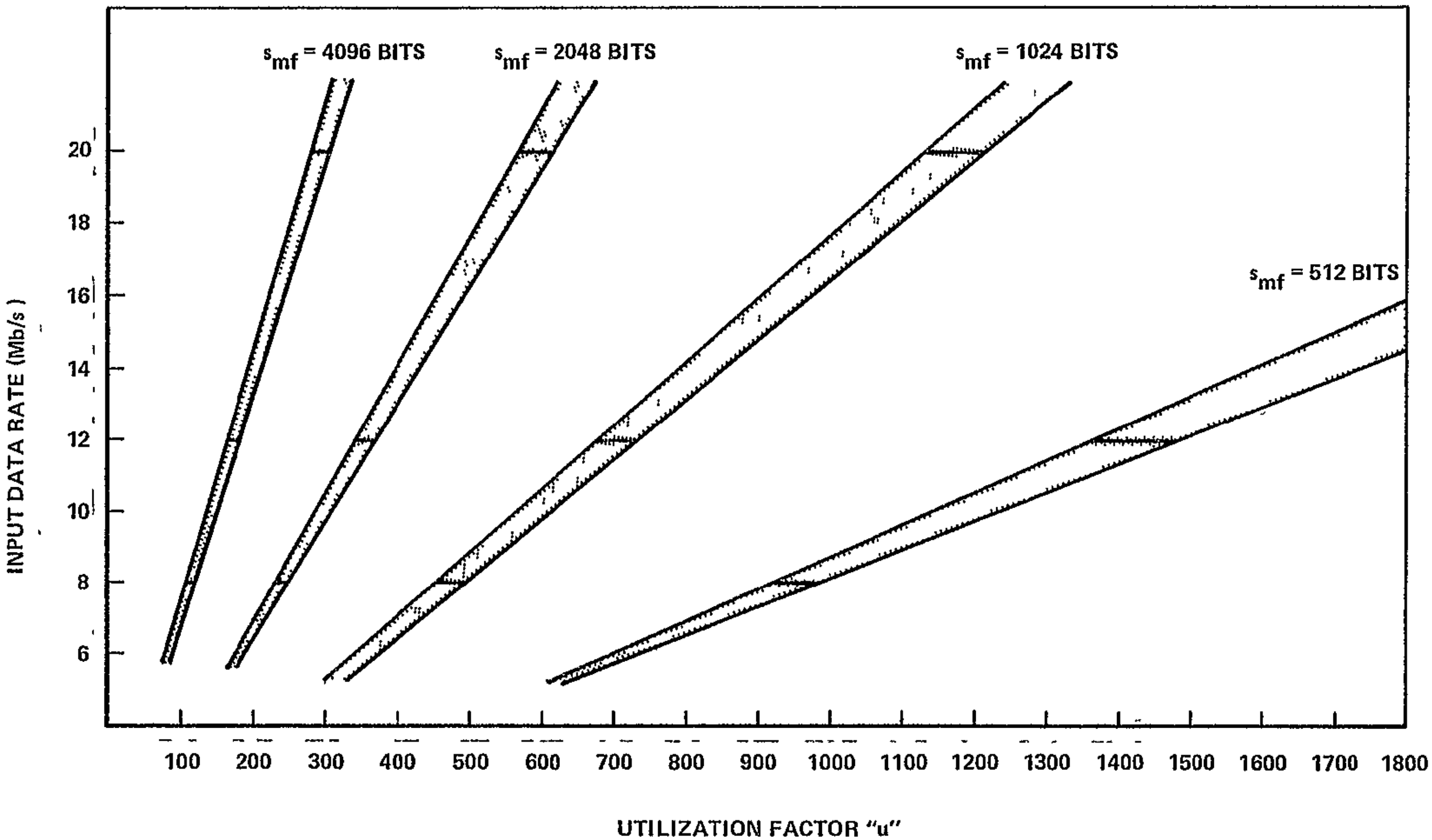


FIGURE 6-37. WA UTILIZATION

expenditure as shown in Table 6-15. Using the information in Tables 6-14 and 6-15, an illustration showing the projected system (WA only) costs is presented in Figure 6-38 as a function of input data rates. A detailed WA is presented in Figure 6-39.

Work Assembler Attribute:	Parameter	Units	Projected Cost ($)
Number of Identical WA Subunits	A	18	Not Applicable
Number of Buffer Analyzers	D	1 to 18	$46K ea.[1]
Total Buffer Costs[2]	Not Applicable	Not Applicable	$52K to $83K[3]
Misc. Hardware	Not Applicable	1	$20,000
Total System Cost	Not Applicable	1	100K + (D) ($46K)[4]

NOTES:

1. Average price for minicomputer surveyed

2. 6.48×10^6 bytes/system = 5.18×10^7 bits/system

3. At .1 cents/bit (=$.001 bit = $\$10^{-3}$/bit): $5.18 \times 10^7 \times 10^{-3}$ = $51,834. If 4096 bit RAM ICs were used at $6.50 each, then ($5.18 \times 10^7/4096$ =) 12,655 x $6.50 = $82,257

4. Total buffer costs (approximately) + Misc. Hardware ($20K) = $100K

TABLE 6-15. DETAILED WORK ASSEMBLER COSTS

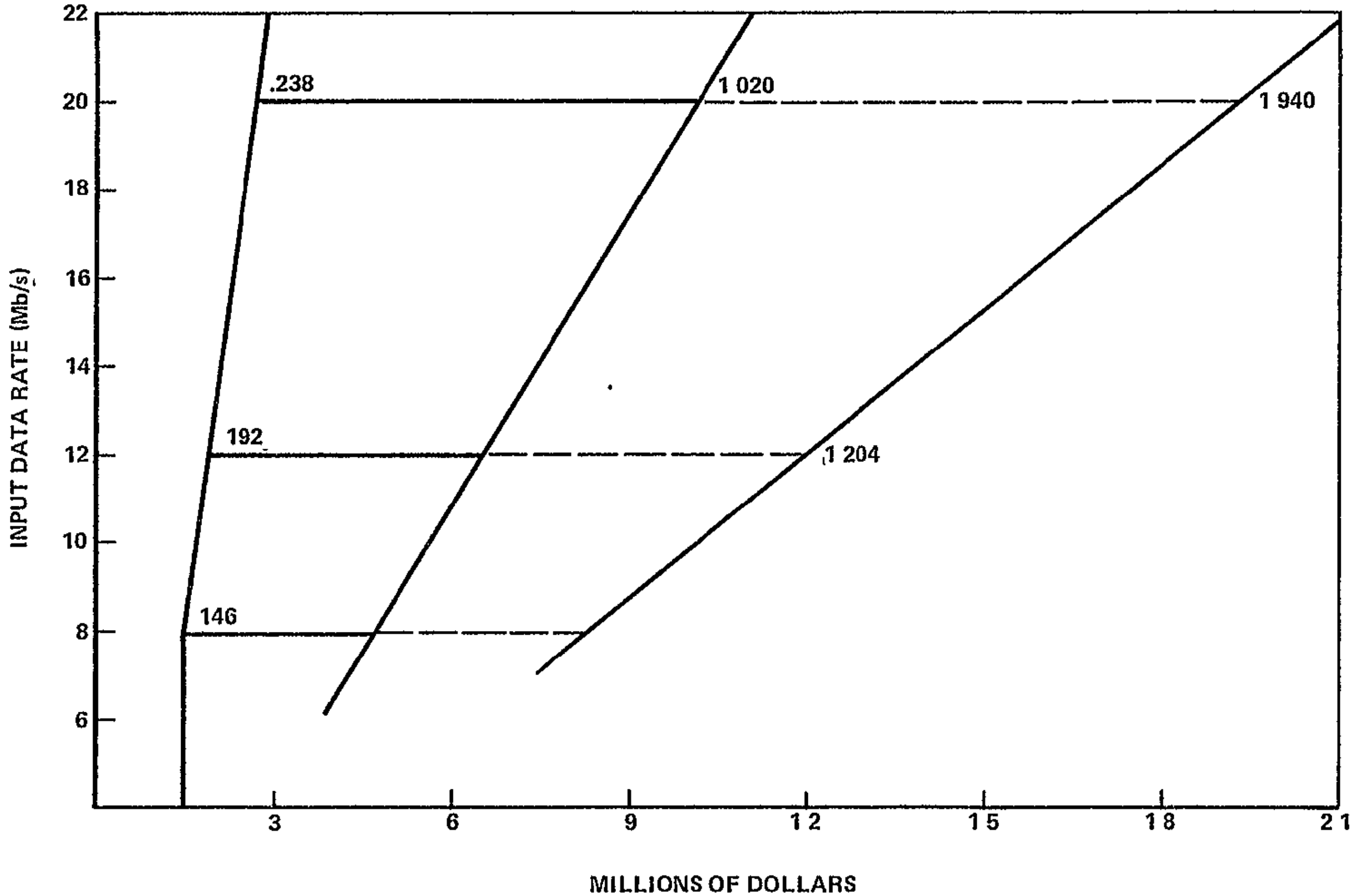


FIGURE 6-38. WORK ASSEMBLER COSTS

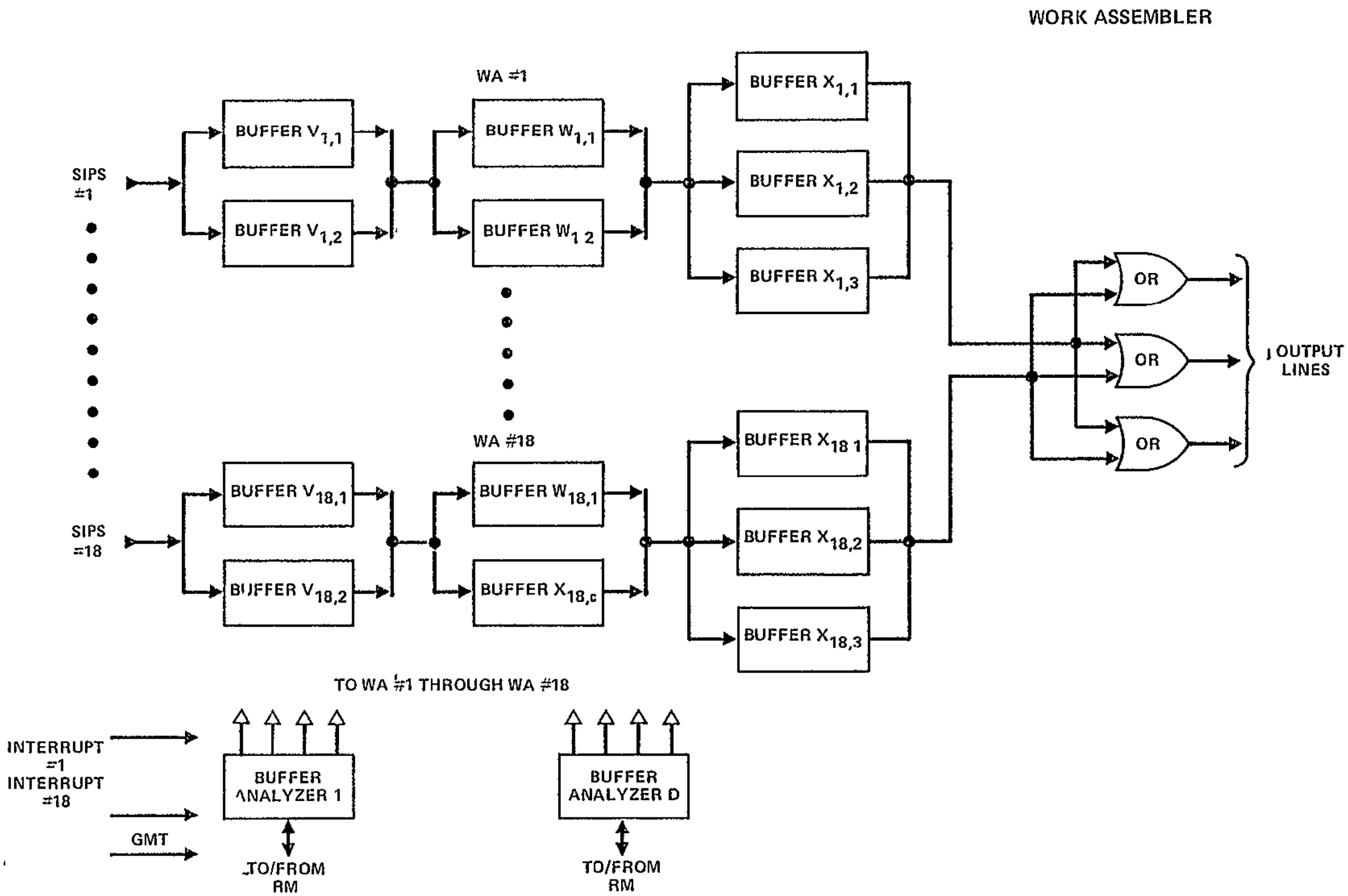


FIGURE 6-39. DETAILED WORK ASSEMBLER

6.3.2 MSS Considerations

The next step is to consider what possibilities exist for the MSS. If 3330 type disks were used in the SOPS, the most convenient scheme would be to collect "orbit" groups of data. If there are 5×10^{12} bits/mission and approximately 100 orbits/mission, then there will be approximately 5×10^{10} bits/orbit, or 0.63×10^{10} bytes/orbit. Since a 3300 disc unit holds about 83.0 $\times 10^{6}$ bytes, the quotient of $(0.63 \times 10^{10}$ bytes/orbit)/(83.9 $\times 10^{6}$ bytes/unit) yields 75.09 disk units/orbit. This, for obvious reasons, rules out 3330 type discs. However, if one were to use 167.8×10^{6} byte removable disk packs, then 37.54 disc packs per 100 minutes would be needed. Thus, large disk units are not yet impractical.

The next option uses HDTs as the MSS. Since an orbit's worth of data is approximately 5×10^{10} bits, and since a reel of HDT can hold approximately 1.4×10^{10} bits, the product $(5 \times 10^{10}$ bits/orbit)/$(1.4 \times 10^{10}$ bits/reel) yields 3.57 reels of HDT per average orbit. This option becomes more attractive when one considers that the HDT can handle a data rate of up to 20 Mb/s.

To determine the best way to handle bursts of high-rate data, assume a worst case burst at 50 Mb/s for 10 minutes. This hypothetical worst case burst represents $(50 \times 10^{6} \times 60 \times 10)$ 3×10^{10} bits of high rate per orbit! This could represent up to (3/5) 60% or an orbit data group. To transfer this volume of data (originally entering the DCS at 50 Mb/s), a slow-down of only (20 Mb/s)/(50 Mb/s) 1 to 2.5 is required to capture it from the SIPS tape recorder. Thus, if the biggest burst of 10 minutes occurs, 25 minutes of SIPS playback time is required. Since an orbit's worth of data will occur during the 70 to 80% of the projected 100 minute interval, a SIPS lull period of between 20 and 30 minutes per orbit could easily be utilized for recording the high rate data for better use, and any unprocessed data could be easily deferred until the next lull.

Operationally, it would be advantageous to keep the high rate data on separate reels of HDT $(3 \times 10^{10}$ bits/orbit)/1.4×10^{10} bits/reel) = 2.14

reels/orbit) so that during deferred output processing, this data base can be merged.

Two parameters (viz., G and H) and the resulting costs have to be derived before comparing HDTRs to devices like the Terabit system. The two parameters are (G) how many MSS units are required and (H) how many bytes of storage are in each unit?

For the recording HDTRs, it appears that G = 3 Two units should be on-line all of the time, and a third unit should serve as a spare on-line unit. The data rates would be no problem since each HDTR could handle up to 20 Mb/s. H would be equal to 1.4×10^{10} bits, as previously discussed. (It was shown earlier that 2 HDTRs plus 1 spare HDTR are required for playback. Thus, the total number of HDTRs would equal 5 (G = 5)).

When considering a device such as the Terabit system, the primary limiting factor restricting its easy utilization is its input data rate - at best 9.6 Mb/s (instantaneous), and realistically 5 6 Mb/s. If the average incoming data rate were 9 Mb/s, at least two units would have to be connected to the WA. Operationally, this would not be any problem, because the WA output is easily switched. Since the Terabit system uses tapes that hold 46.8×10^9 bits, then one orbit's worth of data would be held on (5×10^{10} bits/orbit)/(46.8×10^9 bits/reel), 1.07 reels. (This is clearly an advantage over HDTs.) Therefore, one would have to have 2 units plus one spare on-line for recording. (The HDTRs would be required to have 2 additional output units plus 1 spare - thus, a total of 5 units.) The tradeoff between the HDTs and a Terabit appears to be straightforward. For the price of just 1 Terabit system (approximately $1.5M), one could obtain at least 13 HDTR's plus 13 bidirectional SCI (13 x (70 + 40)K = $1.43M). A proposed intermediate MSS could contain five (5) HDTRs plus five (5) SCI's (5 x (70 + 40) = $550K) It is also recommended that a small disk (the size of which has not been determined) to be present to facilitate quick-look and future POCC requirements. However, it may be unlikely that many submitted SOPS designs would incorporate HDT or Terabit because few designers have a good familiarity with them.

The next step in examining candidate MSS centers is the use of 6250 bpi tapes. At least 3 drives would be required for recording incoming data, because 2 would be needed to maintain a 10 Mb/s input data rate operationally (viz., a pingpong mode of operation). Four drives would represent a 20 Mb/s capability, and would greatly simplify tape operations. Since each 6250 bpi reel can hold approximately 1.2 x 10^9 bits/reel, and since a hundred minute orbit represents about 5 x 10^{10} bits, then approximately 41.7 reels (5 x 10^{10}/1.2 x 10^9) would be filled. This medium is an attractive possibility because the quantity of tapes required is not too high. 41.7 reels every 100 minutes would, on the average, be one reel every 2.4 minutes.)

As far as costs go, four 6250 bpi drives (at $30K each) represent about $120,000 together with a single controller (at $38.6K), which only costs $158,600. 6250 bpi drives are clearly more cost-effective than HDTRs ($158.6K for 4 drives versus $330K for 3 HDTRs).

To fit into the overall architecture which was illustrated earlier, a separate set of 6250 bpi drives would be required to output the intermediate archived data. These drives would have to be independent of the first four drives so that scheduling of resources can be accomplished. Thus, the full configuration proposed for the MSS is illustrated in Figure 6-40.

As illustrated, the MSS consists of 2 pairs (total of 4) 6250 bpi drives that ping-pong operationally for the record mode. A spare unit is used as a "wild card" in both the record and playback portions of the MSS. The playback portion of the MSS is identical to record layout. A disk (of undetermined size) links the input and output portions of the MSS to facilitate quick-look capabilities.

Figure 6-41 illustrates the cost-curve for the basic hardware that was illustrated in Figure 6-39 (less the small disk). As a bare minimum, configuration of drives (2 in, 2 out, and one spare) can sustain a continuous rate up to 10 Mb/s. (10 Mb/s in and 10 Mb/s out). As shown, the next addition (two pairs of drives) brings a step to the cost-curve.

As a conclusion to the MSS discussions, the subject of an automatic

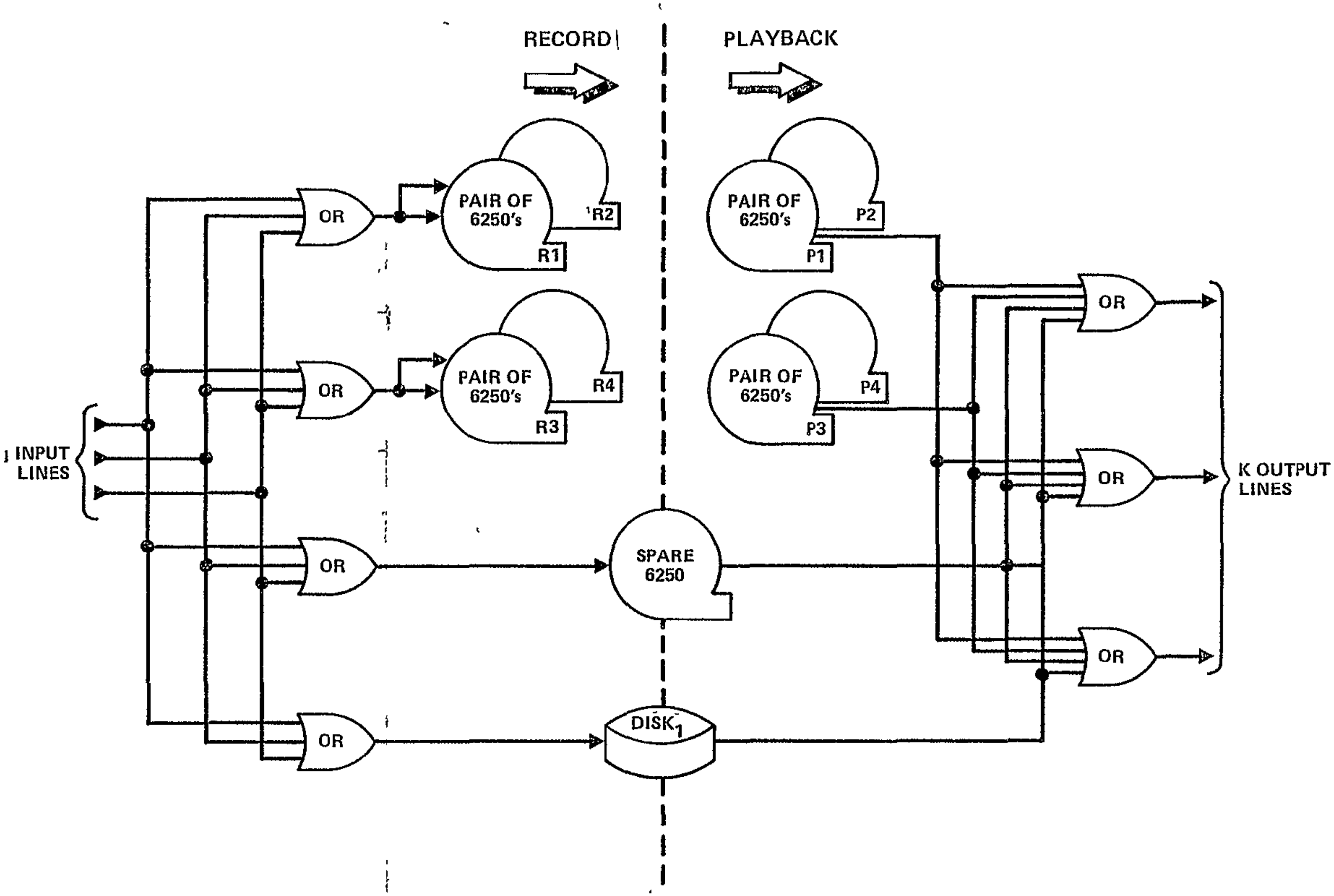


FIGURE 6-40. INTERMEDIATE MSS

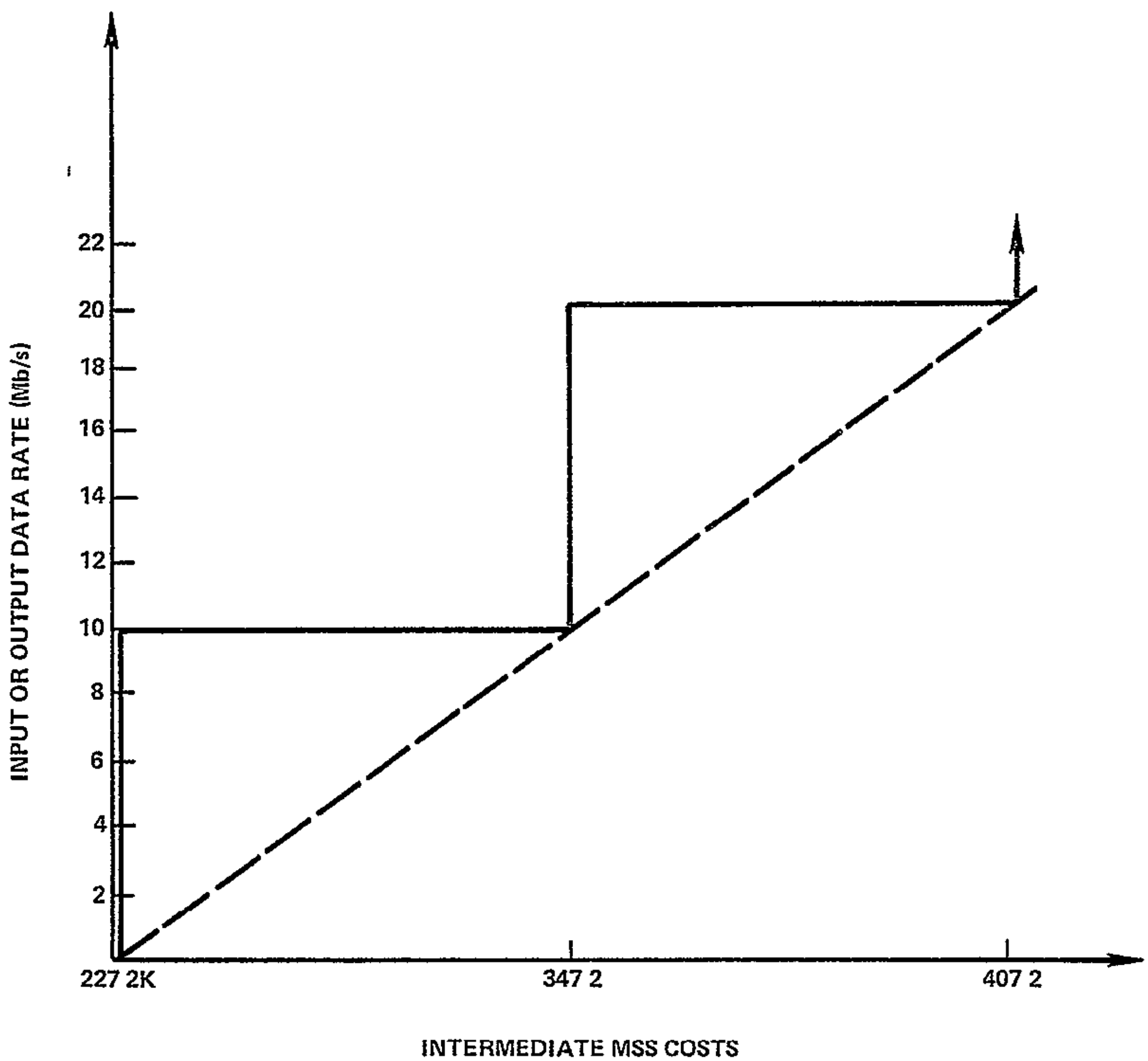


FIGURE 6-41. INTERMEDIATE MSS COST CURVE

tape handling system (such as Calcomp's ATL) will be discussed briefly. Before the trade-offs between operators and automatic tape handling are considered, it should be stressed that systems such as the ATL require a rather sophisticated computer manager (in the ATL, either an IBM 360 or 370, or an emulation). The choice of devices such as these must be considered only if an overwelming advantage can be found. Figure 6-41 shows four curves, starting from the bottom of the figure:

- The cost of one full-time operator and a 10% a year raise over 5 years
- The cost of ten part-time operators and a 10% a year raise over 5 years
- The cost of ten full-time operators and a 10% a year raise over 5 years
- A preferred ATL configuration (2 controllers and slots for 8 drives)

Figure 6-42 clearly shows that it is profitable (economically) to use such a device.

6.3.3 Output Processor

At this point in the processing system we have the following:

- Blocks of experiment data (decommutated) on approximately 42 reels of 6250 bpi tape
- Uniform work units (same size)
- A precise (byte-by-byte) map of all experiment (and ancillary) data
- Quality control information that may have come in at some time after reception and intermediate storage of experiment data
- High-rate bursts of data (both overlapped data that was recorded and transmitted later, and high bit rate experiment data) blocked into uniform work units.

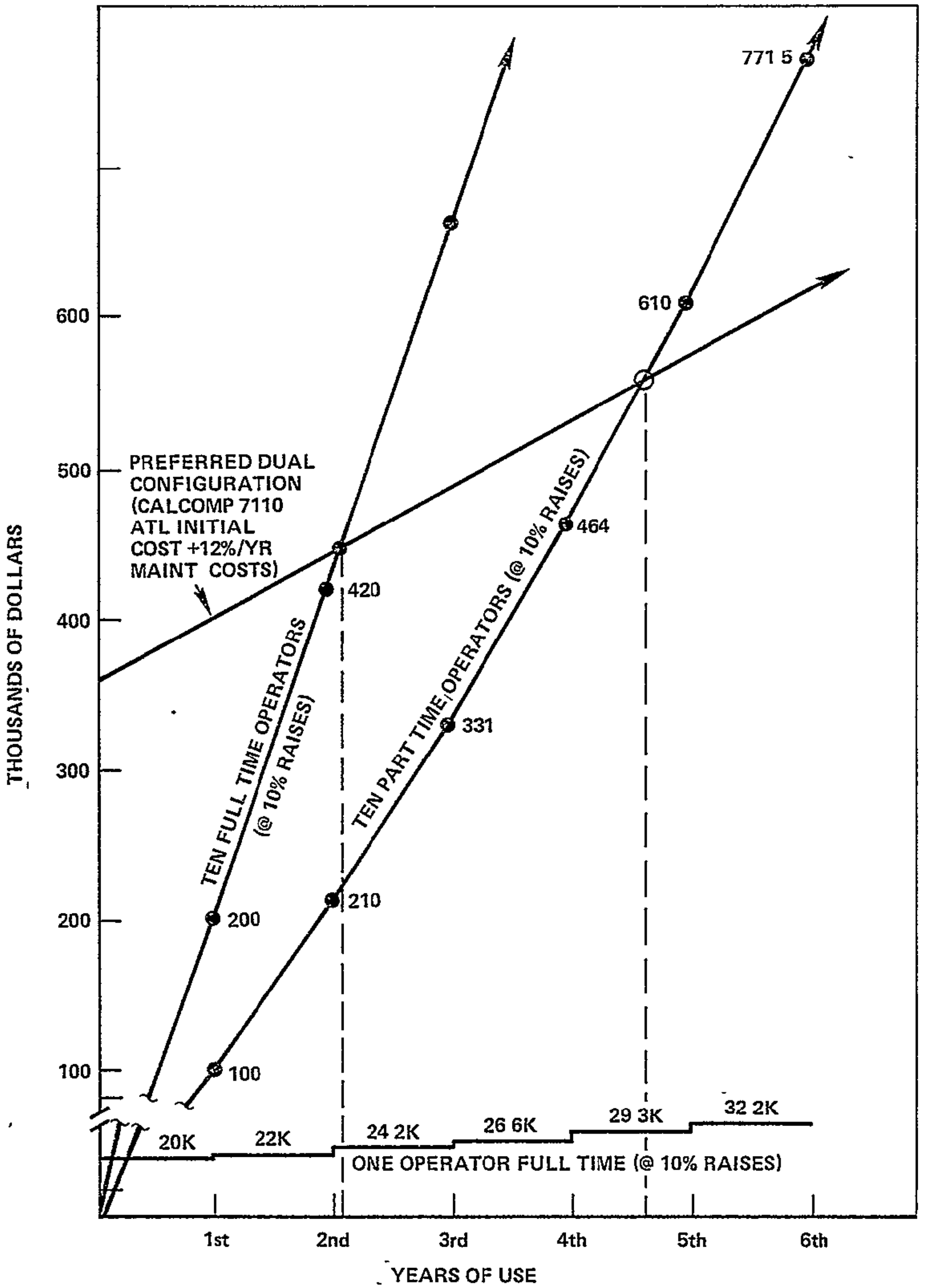


FIGURE 6-42. CUMULATIVE COSTS FOR AN ATL VERSUS OPERATORS

The preceding allows for a simple and straightforward output processor configuration as illustrated in Figure 6-43. As shown, it is highly modular, flexible, and resistant to single-point failure. A general data walkthrough is presented in the following paragraphs. Detailed design considerations follow that.

Blocks (or work units) of decommutated experiment data are transferred from the 6250 bpi transports (units 1 through G) to waiting memories (units 1 through L) via a DMA channel. The entire work unit is buffered, and these blocks are linked to other blocks to form larger blocks. As soon as a conveniently large experiment data file is assembled, the experiment file is then sent to a staging disk. When a significant amount of experiment data is built up on the staging disk, an output data product is written. The CPU acts strictly as a data manager in the task of linking data blocks. If missing data is not input to the system, fill data is substituted.

To set broad operational limits, it shall be assumed that 5×10^{12} bits/mission are to be processed. With approximately 100 orbits/mission, then 5×10^{10} bits/mission is derived. If this data were to go through the facility (viz., the output processor) in about 100 minutes (100 minutes/orbit), then the statistical data rate would be $(5 \times 10^{10}$ bits/orbit)/(100 x 60 sec/orbit) = 8.33Mb/s. It would therefore be prudent to design to at least 16 Mb/s (or 20 Mb/s) to allow for adequate operator rest periods, repairs, etc.

<u>Detailed Data Flow</u>

A set of 6250 bpi tapes containing a set of experiment data are selected and mounted for playback. The quantities of tapes containing an experiment's data could be between 1 and 42 reels. Ordinarily, most reels contain the regular low and medium-rate experiment data. The regular data, for example, would be played back on transport #1 and the high-rate burst data on transport #G. The RM would set up the playback of high-rate data so that its data would be placed in the approximate GMT time slot so that the removal of overlapping data and chronological ordering functions could be easily performed. This is illustrated in Figure 6-44. The intent at this point is to line up work units for linkage processing so that a minimum amount of data handling is required.

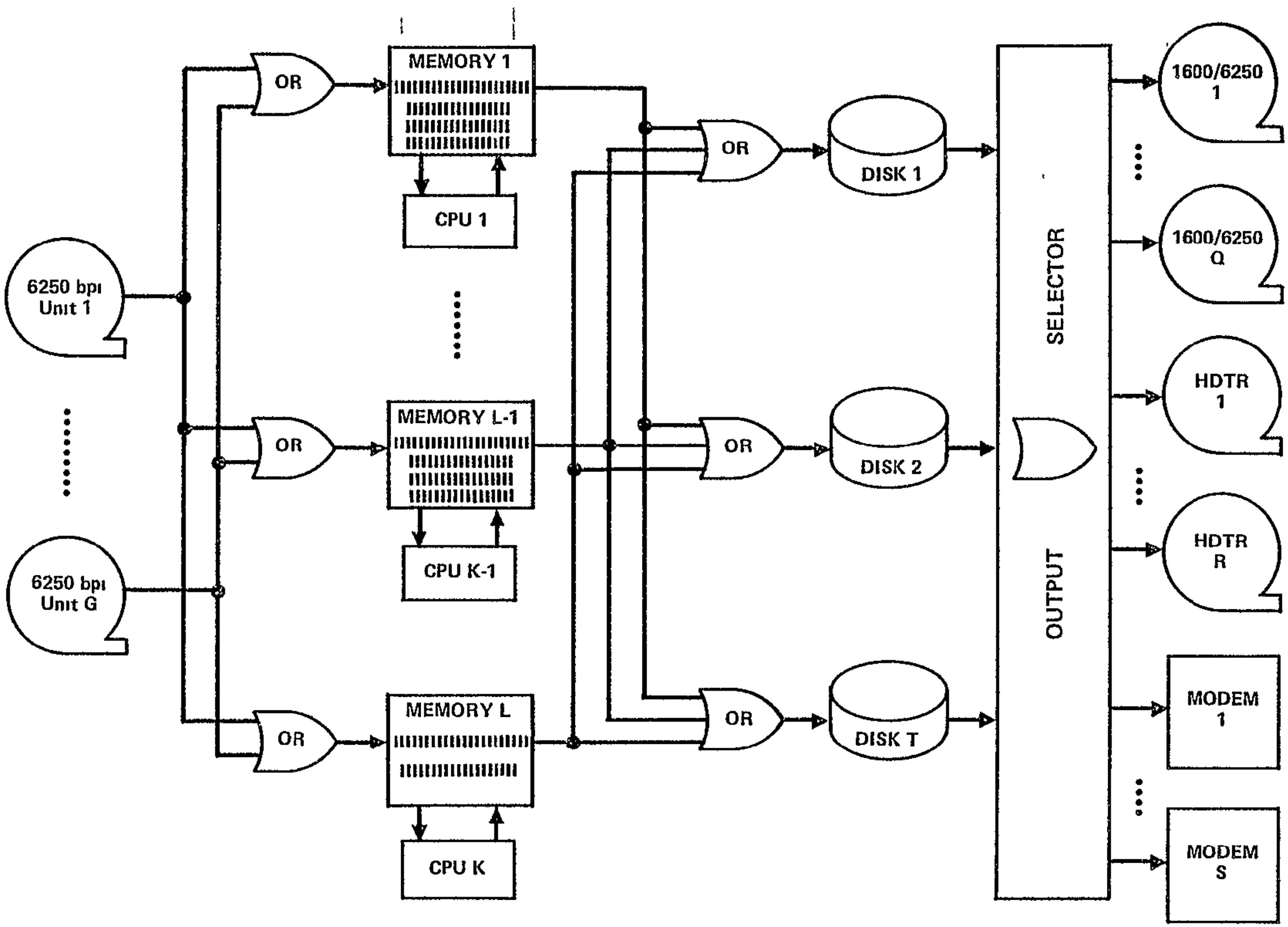


FIGURE 6-43. OUTPUT PROCESSOR BLOCK DIAGRAM

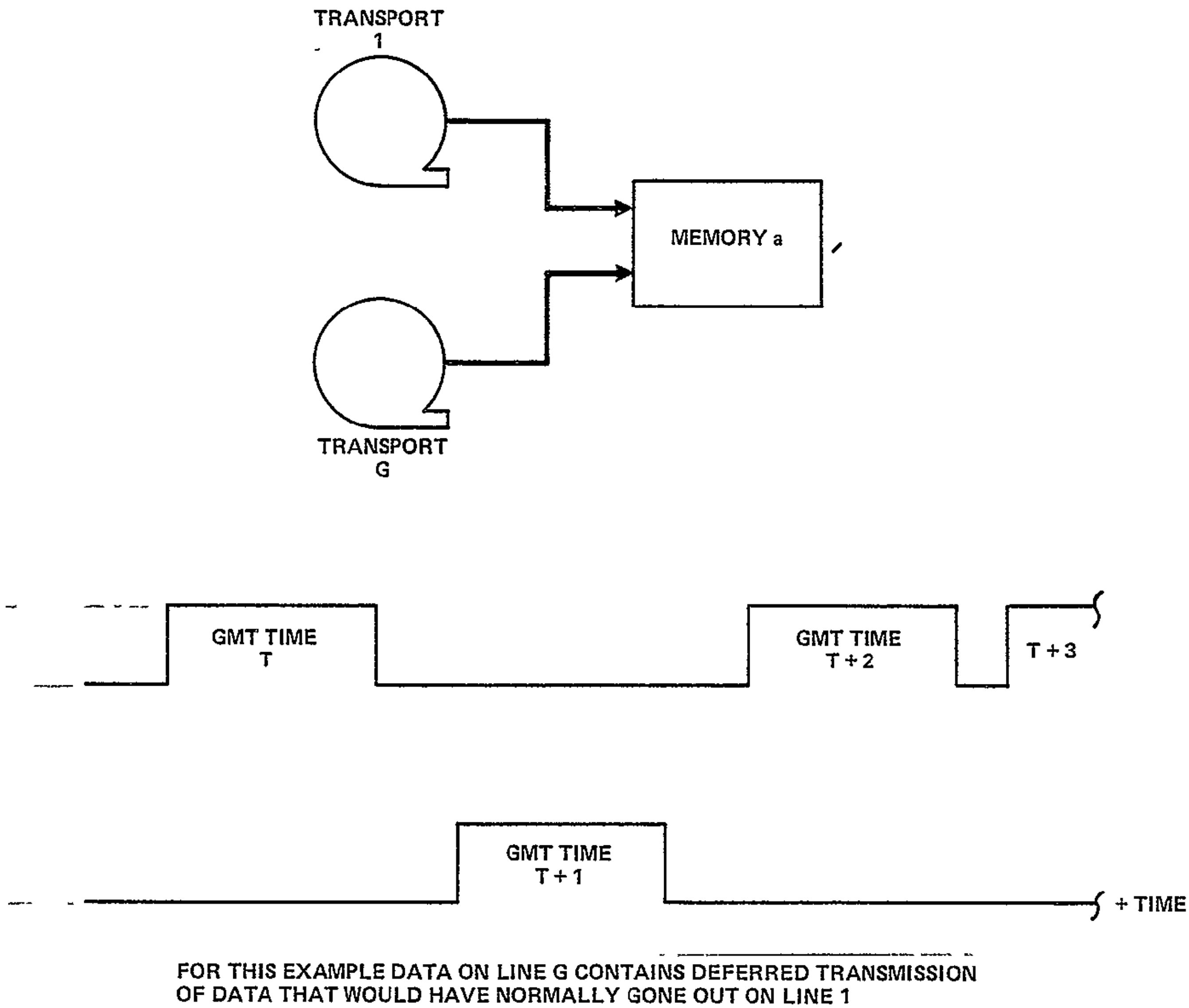


FIGURE 6-44. PLAYBACK OF BURST DATA FROM 6250 bpi TRANSPORTS

The next step is to examine the attributes and functions of the "L" memories as shown in Figure 6-43. Assuming these memories are linked to the "K" CPU's (K does not necessarily equal L), the maximum DMA Rate (as selected from Table 4-7) is (2.5 M words/sec. x 16 bits/word =) 40 Mb/s. It should be pointed out that this value is a computed average and many minicomputers (for example) could be faster. In general, the DMA rates can be expressed as:

$$R_{DMA} = R_{IN} + R_{OUT} + R_{OVERHEAD}$$

where:

R_{DMA} = DMA channel rate ($\sim$ 40 Mb/s)

R_{IN} = Input channel rate ($\sim$ 20 Mb/s)

R_{OUT} = Output channel rate ($\sim$ 20 Mb/s)

It has been found in past experiences that $R_{OVERHEAD}$ can amount to 10% of R_{DMA} in most good memory systems. Thus, for a steady state situation, $R_{IN} = R_{OUT} \cong 18$ Mb/s. This appears to be entirely acceptable.

The output processors CPU (1 through k) as illustrated in Figure 6- shall perform the following operations on data within the previously discussed memories:

- Output data accounting
- Quality checking
- Overlap removal
- Data fill
- Merging ancillary data
- Data store

It would now be appropriate to consider the same type of computational unit which was utilized in the Work Assembler, i.e., the average minicomputer as earlier specified in Table 4-7.

The work load for the output processor was specified in Table 4-11 and is summarized:

Function	Estimated lines of code executed per:			
	m.f.	M.F.	Orb. G.	Exp. File
Output data accounting	50	100	5000 x E	50,000
Quality check	50/200*	50/200*	500 x E	5,000
Data Store	0	0	5000 x E	10,000
Overlap Removal	0	0	20000 x E	0
Data fill	0	0	5000 x E	10,000
Merging ancillary data	0	0	5000 x E	0
Subtotals	100	150	40500 x E	75,000

* Second value for deviant conditions

Thus, one of the tools to determine the acceptability of the candidate computation unit is a determination of the system utilization (u) factor. This relationship can be expressed as:

$$u = \frac{\left(\frac{r_i}{s_{mf}} \times j\right) + \left(\frac{r_i}{s_{MF}} \times k\right) + \left(\frac{r_i}{s_{OG}} \times l\right) + \left(\frac{r_i}{s_{EF}} \times m\right)}{\frac{1}{f \times c}} \times 100$$

Where:

u = computer utilization (%)

r_i = input data in Mb/s

j = total number of lines of code executed for each minor frame of data

l = total number of lines of code executed for each orbit group

m = total number of lines of code executed for each experiment file

k = total number of lines of code executed for each major frame of data

f = multiplicative factor (to convert cycle time to instruction time)

c = cycle time in seconds of candidate CPU

s_{mf} = size of a minor frame in bits

s_{MF} = size of a major frame in bits

s_{OG} = size of an orbit group in bits
s_{EF} = size of an experiment file in bits

And: $s_{MF} = n\left(s_{mf}\right)$

Where: n = integer number of minor frames per major frame

For ease of data manipulation, the expression for u reduces to

$$u = 100 \cdot c \cdot f \cdot r_i \left[\frac{1}{s_{mf}}\left(J + \frac{k}{n}\right) + \frac{1}{s_{OG}} + \frac{m}{s_{EF}}\right]$$

Since the nature of the input data stream is not narrowly defined as yet, it would be advisable to examine "u" with different factors being varied. The above compact expression is very sensitive to certain combinations of driving factors. The objective is to determine the worst case which drives up the system utilization. The factors which are relatively fixed are "c" at .7 us (from the minicomputer characterization section), "f" at 3 (to very closely approximate load and store operations), "J" at 100 (best known approximation), and "K" at 150 (best known approximation), "l" at 40,500 x E (best known approximation), and "m" at 75,000 x E (best known approximation).

The expression for "u" can be simplified (just for the previous case) to:

$$u = (100)\ (.7 \times 10^{-6})\ (3)\ r_i \left[\frac{1}{s_{mf}}\left(100 + \frac{150}{n}\right) + \frac{40500 \times 48}{5 \times 10^{10}} + \frac{75000 \times 48}{\left(5 \times 10^{12}\right)/48}\right]$$

$$= (2.1 \times 10^{-4})\ r_i \left[\frac{100}{s_{mf}}\left(1 + \frac{15}{n}\right) + 7.34 \times 10^{-5}\right]$$

Before searching for the worst case, u should be evaluated to establish a baseline operating point. Typical values are as follows:

s_{mf} = 4096, 2048, 1024, 512 bits

r_i = 8, 12, 20 Mb/s

n = 256, 100, 50, 10

Table 6-16 and Figure 6-45 illustrates these findings. Table 6-17 summarizes the projected cost and Figure 6-46 illustrates the cost curves.

r_i	s_{mf}	n	u
8	512	10	377
8	512	50	338
8	512	100	333
8	512	256	330
8	1024	10	189
8	1024	50	169
8	1024	100	167
8	1024	256	165
8	2048	10	94
8	2048	10	84
8	2048	100	83
8	2048	256	83
8	4096	10	47
8	4096	50	42
8	4096	100	42
8	4096	256	42
12	512	10	566
12	512	50	507
12	512	100	500
12	512	256	495
12	1024	10	283
12	1024	50	253
12	1024	100	250
12	1024	256	250
12	2048	10	142
12	2048	50	127
12	2048	100	125
12	2048	256	124
12	4096	10	71
12	4096	50	63
12	4096	100	62
12	4096	256	62

r_1	s_{mf}	n	u
20	512	10	943
20	512	50	845
20	512	100	833
20	512	256	825
20	1024	10	472
20	1024	50	422
20	1024	100	416
20	1024	256	413
20	2048	10	236
20	2048	50	211
20	2048	100	208
20	2048	256	206
20	4096	10	118
20	4096	50	106
20	4096	100	104
20	4096	256	103

TABLE 6-16. OUTPUT PROCESSOR UTILIZATION FACTOR

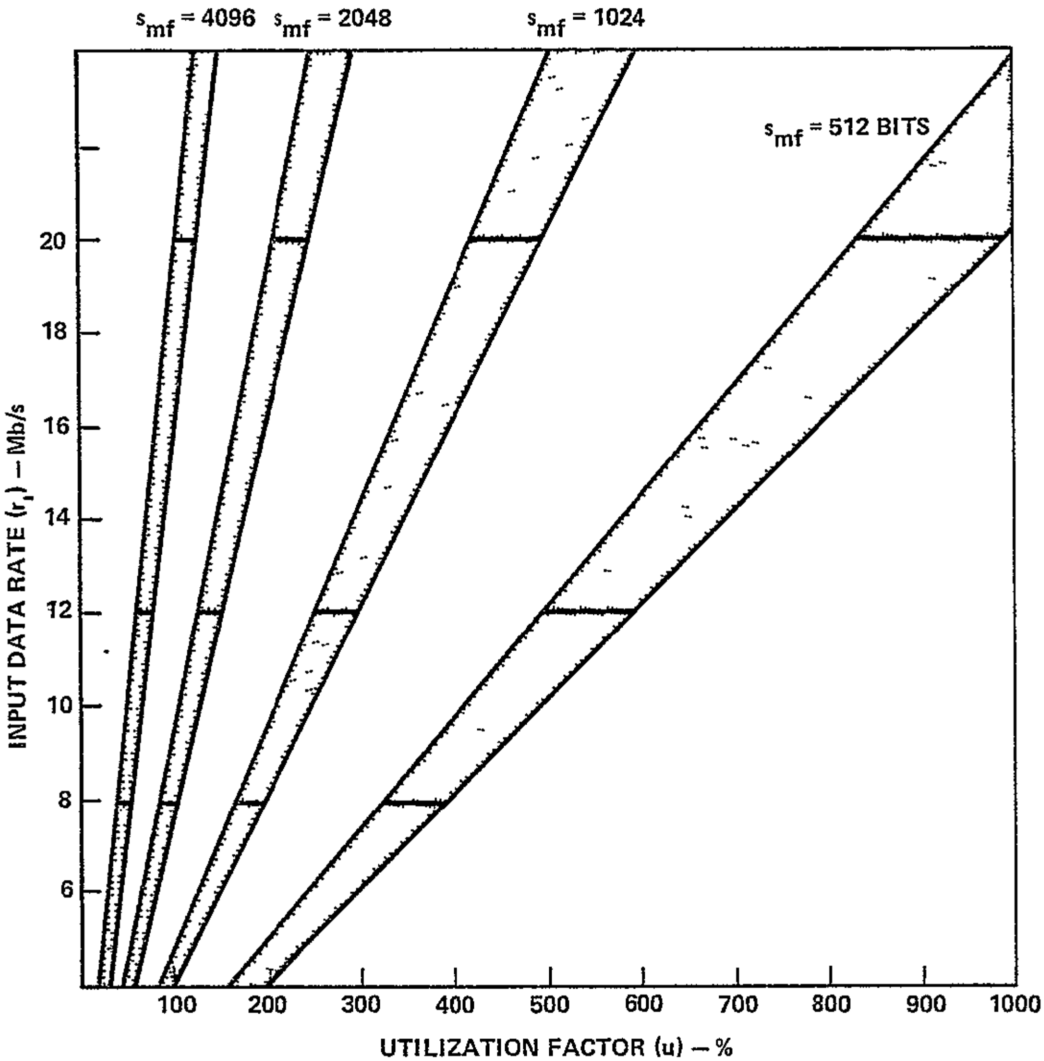


FIGURE 6-45. OUTPUT PROCESSOR UTILIZATION FACTOR

ATTRIBUTE	PARAMETER	UNITS	PROJECTED COSTS ($)
Total Memories[1]	L	1 to 20	---
Number of Bytes in Each Memory[2]	M	52	---
Total Buffer or Memory Costs[3]	(L X M)	(52) (L)	(I) 46,000
Number of output Processors	K	1 to 20	46,000 ea.
Misc. Hardware[4]	-	1	$20,000
Total System Costs	-	1	20,000 + K(1.1) (46,000)

NOTES:

1. It is assumed L = K; i.e., one memory to each
2. 4 buffers @ 13K = 52K bytes
3. This cost would be core costs associated with each CPU. It will be assumed that this core cost is about (an additional) 10% of a CPU cost.
4. Projected cost; standard interface electronics.

TABLE 6-17. OP PROJECTED COSTS

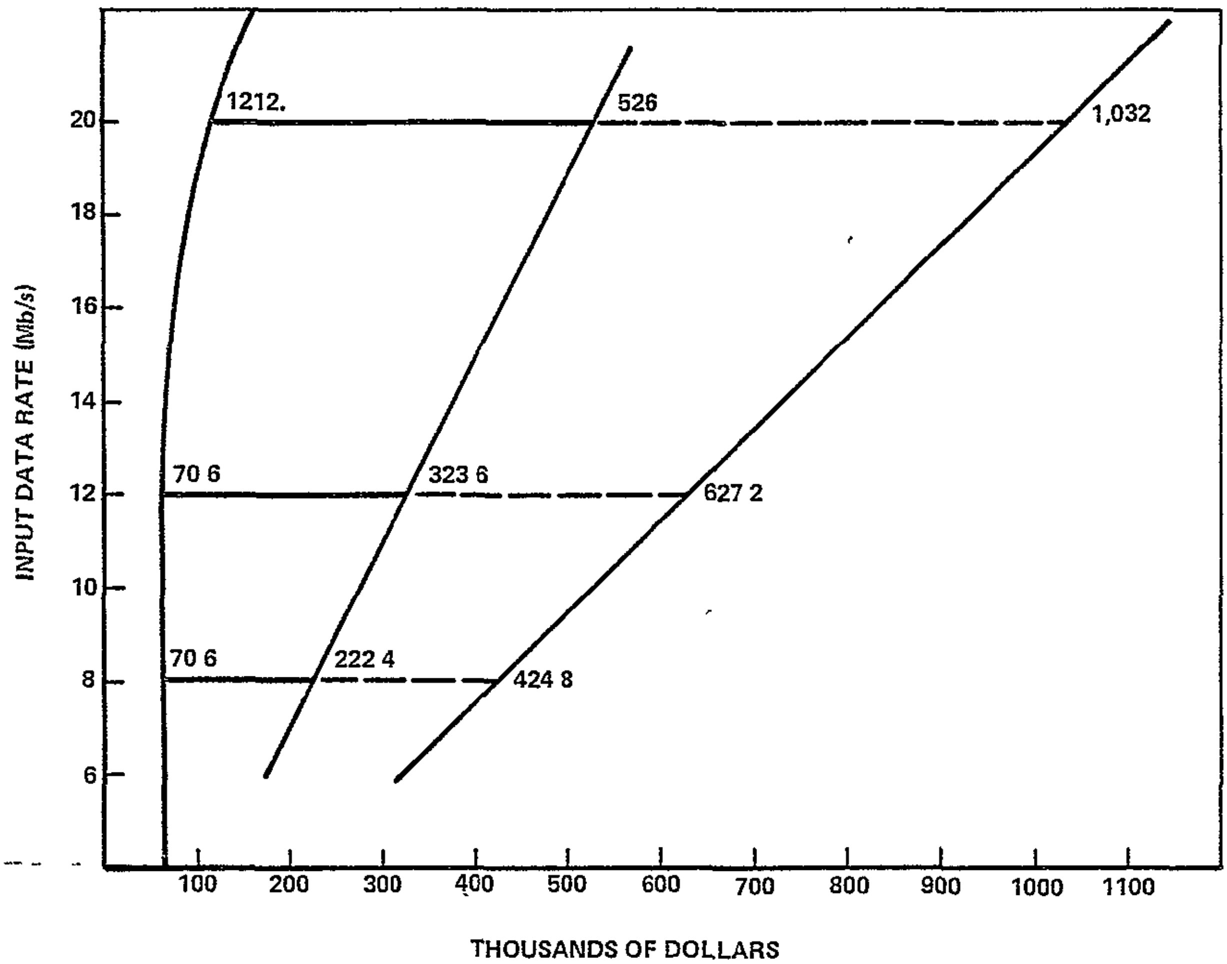


FIGURE 6-46. OUTPUT PROCESSOR COST CURVES

6.3.4 Peripheral Pool

Same as 6.2.4

6.3.5 Resource Monitor

Same as 6 2.5

7.0 SUMMARY OF ADVANTAGES AND DISADVANTAGES

This section of the study enumerates the significant advantages and disadvantages of each of the proposed architectures. These advantages and disadvantages are not necessarily diametrically opposed to one another.

Architecture Number 1:

	Advantages	Disadvantages
Work Assembler	• Errors in decommutation map will not destroy integrity of data base. • A very effective data rate smoothing effect is performed. • A minimal amount of data analysis and data manipulation is performed.	• Possible problem when one channel is greater than 8 Mb/s (up to 16 Mb/s)
Mass Storage System	• HDTRs can easily keep up with data stream. • A minimum amount of reels of tape are processed.	• Sequential blocks of data are hard to locate for playback. • Bit error rate for HDT is higher than desirable.
Output Processors	• Considerable confidence can be placed on the output data processing because late incoming status data can be easily incorporated.	• Output processors may be susceptible to uneven work assignments because captured data is not grouped together. • Staging of data from MSS to output processor could be hampered by small number of source tapes. • Data Decommutation map has to be passed again to Output Processor.

Architecture Number 2

	Advantages	Disadvantages
Work Assembler	• No significant advantages were identified.	• Mistakes (due to faulty decommutation data or otherwise) could be very hard to recover.
Mass Storage System	• 6250 bpi tape drives are amendable to Calcomp ATL adoptation. • Large number (~45) of tape reels simplify output data processing.	• Cost of an additional ATL computer could offset the cost advantage of an ATL.
Output Processors	• There is minimal amount of data handling and manipulation. • Design can easily handle decommutation if required in error-recovery mode of operation.	• No serious disadvantages were identified.

8.0 RANKING OF ARCHITECTURES

In addition to the advantages and disadvantages as tabulated in Section 7, there are two additional ranking criteria:

- Point ratings of each architecture
- Total system costs

Table 8-1 provides a function-by-function rating of each architecture. Both architectures were designed to earn the highest possible rating; and the points assigned to each architecture proved to be quite similar. The normalized total point scores reveal, therefore, that the two architectures are equivalent in terms of function. The projected cost differentials tell a different story.

System costs can be projected in terms of two (system) operating points. A "full up" system would be best sized to handle up to 8 Mb/s for the Work Assembler and first half of the Mass Storage System; and 12 Mb/s for the second half of the Mass Storage System and the Output processors. A low-high cost for each system block is provided in Table 9-2. The low-high costs are based on 100% and 50% confidence factors used in sizing the software portions (specifically the "estimated lines of code executed" as tabulated in Table 4-11) of the system. Table 8-2 indicates that Architecture 2 is less costly.

TABLE 8-1. RATINGS OF ARCHITECTURES

SECTION 2 PAR. NO.	BRIEF STATEMENT OF SPECIFICATION	ASSIGNED WEIGHT (1-10)	RATINGS ARCHITECTURE 1	RATINGS ARCHITECTURE 2
2.0	• Modularity	8	10	10
	• Expandability	8	6	10
2.1.1.1	• Data Characterization	9	8 Output Processors Work Load is more complicated than Arch. 2.	10
	• Experiment Mix Profile	9	8 "	10
2.1.1.2	• Tapes	10	10	10
	• Communications	7	10	10
	• Data Volumes	10	10	10
2.1.1.3	• Throughput	10	10	10
2.1.2.1	• Update Input Accounting	10	6 Accounting is kept on Recording basis instead of file	6 Same as Architecture #1
2.1.2.2	• Update Output Accounting	10	7 System data flow does not reflect the full data	7 Same as Architecture #1
2.1.2.3	• Quality Check	10	10 Accountability	10
2.1.2.4	• Receive and Sort TLM • Receive and Sort Ephemeris and Attitude	10 10	8 Technique of data storage makes difficult retrieval for output processing	8 Decommutation of Data on-the-fly is potentially riskly if error in given info. is not immediately passed onto to SOPS
	• E & A Data	10	8 "	8 "

TABLE 8-1. RATINGS OF ARCHITECTURES, (CONT'D.)

SECTION 2 PAR. NO.	BRIEF STATEMENT OF SPECIFICATION	ASSIGNED WEIGHT (1-10)	RATINGS	
			ARCHITECTURE 1	ARCHITECTURE 2
2.1.2.5	• Merge Ancillary	10	8	10
2.1.2.6	• Creating and accessing files	10	6 Cumbersome way of storing data for access by the output processor	6 Same as Architecture #1
	• Allocate, log, and record	10	7 Too much interaction with RM	7
2.1.2.7.1	• Time Validation	5	10	10
2.1.2.7.2	• Remove overlapped data	10	8 Overlapped data may be on same HDT	10
2.1.2.8	• Coordinate Transformation	8	10	10
	• Ancillary data	8	8	9
2.1.2.9	• Interpolate attitude	5	10	10
	• Coordinate transformation	8	10	10
	• Ancillary Attitude computations	8	10	10
2.1.3	• Modularity	8	10	10
	• Capacity	10	10	9
	• Error Rates	10	6 HDT error rate to high	10
	• Technology	9	8	10
	• Media	7	10	10
	• Maintainability	9	8 HDT set up difficulties	10

TABLE 8-1. RATINGS OF ARCHITECTURES, (CONT'D.)

SECTION 2 PAR. NO.	BRIEF STATEMENT OF SPECIFICATION	ASSIGNED WEIGHT (1-10)	RATINGS	
			ARCHITECTURE 1	ARCHITECTURE 2
2.1.3, cont'd	• Availability	8	8 Both architectures have only one data bus shown which will effect running in a degraded mode, if a bus failure occurs	8
	• Interface	8	10	10
	• Persistance	8	10	10
	• Self-test	8	9	9
	• Transfer rate	10	10	9
	• Transferability	10	9	10
2.1.4	• Convert to experiment format	10	10	10
	• Write to tape	10	10	10
2.1.5	• Transmission Rate	10	10	10
	• Switched Circuit	10	10	10
	• Packet Switched	10	10	10
2.1.6	• Operations	9	8	8
	• Personnel	9	8	8
	• Reliability and Availability	9	9	10
	• Maintenance Support	9	10	10
2.2.1	• Quick Look	3	5 Too difficult to access data from HDTs.	9

TABLE 8-1. RATINGS OF ARCHITECTURES, (CONT'D.)

SECTION 2 PAR. NO.	BRIEF STATEMENT OF SPECIFICATION	ASSIGNED WEIGHT (1-10)	RATINGS	
			ARCHITECTURE 1	ARCHITECTURE 2
2.2.2	• Process data for GSFC POCC	3	5 Data will not be available for quicklook	9
	• Retrieve data	3	6 processing, because of HDT still storing	8
	• Format data	3	10 input data.	10
	• Transfer data to POCC	3	7	10
TOTAL POINTS			3660	3880
MAXIMUM POINTS		419 x 10	4190	4190
NORMALIZE POINT SCORES			8735	.9260

TABLE 8-2. PROJECTED SYSTEM COSTS (HARDWARE ONLY)

SOPS Subsystems	Architecture Costs For: (100 K $) 1 Low	1 High	2 Low	2 High	Approx. Cost Distribution (%)
Work Assemblers	204	388	468	836	25
Mass Storage System[1]	330	330	347	347	15
Output Processors	765	1,470	324	627	20
Output Staging Devices	210	290	210	290	10
Output Peripheral Pool[2]	600	600	600	600	20
Resource Monitor	228	322	228	322	10
TOTALS:	2,337	3,400	2,177	3,022	100

1. MSS for Architecture 1 consists of HDTRs, Architecture 2 uses 6250 bpi drive <u>without</u> the CALcomp ATL.
2. 56 Kb/s modem costs not included.

APPENDIX A

LIST OF ACRONYMS AND ABBREVIATIONS

LIST OF ACRONYMS AND ABBREVIATIONS

BA	Buffer Analyzer
bpi	bits per inch
CCT	Computer Compatible Tape
DBM	Data Base Management
DMA	Direct Memory Access
E/A	Ephemeris and Additude
ESA	European Space Agency
FS	Frame Synchronizer
GEI	Geocentric Equatorial Inertial
GMT	Greenwich Mean Time
GSFC	Goddard Space Flight Center
GSTDN	Ground Spaceflight Tracking and Data Network
HDT	High Density Tape
HDTR	High Density Tape Recorder
IC	Itegrated Circuit
IPD	Information Processing Division
ips	inches per second
JSC	Johnson Space Center
Kb/s	Kilobits per second
Mb/s	Megabits per second
MCC	Mission Control Center
MSS	Mass Storage System
O&A	Orbit & Attitude
OP	Output Processor
POCC	Payload Operations Control Center
QC	Quality Control
RAM	Random Access Memory
RM	Resource Monitor
SCI	Serial Controller Interface
SDPF	Spacelab Data Processing Facility

LIST OF ACRONYMS AND ABBREVIATIONS, (CONT'D.)

SEI	Solar Ecliptic Inertial
SIPS	Spacelab Input Processing System
SOPS	Spacelab Output Processing System
TDRS	Tracking and Data Relay Satellite
TLM	Telemetry
WA	Work Assembler

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