NASA-CR-192408

Title of Grant: Performance Evaluation of Platform Data Management System Under Various Degrees of Protocol Implementation.

Granting Agency: National Aeronautics and Space Administration.

Technical Officer: Mr. Ed. Rothe
Goddard Space Flight Center
Greenbelt, Md.
Code 421

Type of Report: Final Report.

Principal Investigator: Dr. Mohammed Arozullah.

Period of This Report: October 1,1989 to November 30,1990

Grant Number: NAG 5-1285.

Grantee Institution: The Catholic University of America
Washington, D.C. 20064

IN-82-CR
p. 78

N93-20161
Unclas
G3/82 0147944

(NASA-CR-192408) PERFORMANCE EVALUATION OF PLATFORM DATA MANAGEMENT SYSTEM UNDER VARIOUS DEGREES OF PROTOCOL IMPLEMENTATION Final Report, 1 Oct. 1989 - 30 Nov. 1990 (Catholic Univ. of America) 78 p

SUMMARY

This report presents an analysis of the performance of 1553 BUS used as the Housekeeping (H/K), Payload Engineering (P/L Eng), or Payload (P/L) Science bus of the Command and Data Handling (C&DH) subsystem of the Data Management System (DMS).

The performance is evaluated by calculating the delays encountered by messages by developing and using a queue theoretic models of the H/K, P/L Engineering and Science buses implemented with the 1553 BUS.

For the Housekeeping and Payload Engineering buses the delay values are calculated under a slotted allocation scheme suggested by General Electric (GE) Company and also under an unslotted allocation scheme. In the GE slotted allocation scheme every subsystem is assigned a fixed 2.5 ms long slot for transmission/reception irrespective of whether the subsystem has data for transmission/reception. In the unslotted allocation scheme presented here there is no pre-assignment of slots and a subsystem is allowed access to the channel for only the length of time needed for transmission/reception of actual accumulated data. Worst case and average delay for individual subsystems and overall average delays are presented for the slotted allocation scheme. For the unslotted scheme average delays are presented for the various subsystems under a number of loading conditions. Also overall average delays are presented for these loading conditions. Results are presented in table forms for easy perusal. Tables summarizing and comparing these delays are also presented.

For the Payload Science bus the delay values are calculated by developing and using a polling model that can collect data from a set of instruments (known lowrate instruments) by polling these instruments number of times per cycle that is proportional to their data generation rates. The delay values are evaluated for a number of cases that include various degrees of retry and bus controller transmissions in addition to the actual data generated by the terminals. The results are summarized in a tabular form for easy comparison.

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1. INTRODUCTION

The Platform Data Management System (DMS) collects Housekeeping (H/K), Payload (P/L) Engineering, and Payload Science data from various subsystems and payloads on the platform for transmission to the ground through the downlink via TDRSS. The DMS also distributes command data received from the ground to various subsystems and payloads. In addition, DMS distributes timing and safemode data.

The function of collection and distribution of various types of data is performed by the Command and Data Handling (C&DH) subsystem of DMS. The C&DH subsystem uses for this purpose, a number of data buses namely, Housekeeping, Payload Engineering, Payload Science, Time and Safemode buses, as shown in Figure 1. Out of these buses, the H/K, P/L Engineering, and P/L Science buses are planned to be implemented by using MIL-STD 1553 Bus. These buses and various subsystems connected to them are shown individually in Figures 2, 3, 4, and 5.

Most of the period covered by this report was spent in developing a queue theoretic model of the 1553 Bus as used in the DMS. The aim is to use this model to test the performance and suitability of the 1553 Bus to the DMS under a number of alternative design senarios.

2. THE 1553 BUS

A considerable amount of time was spent in studying and understanding the principle of operation and protocols used in this bus. Reference [1] which describes the operation of the 1553 Bus was extensively studied and used for this purpose.

Summary of Characteristics of 1553 Bus

Hardware: 1553B Data Bus
Specs:

Transmission rate/Clock speed :	1,000,000 bits per sec/1 MHz
Operation :	Asynchronous, Half Duplex
Coding :	Manchester Biphase Coding
Each word :	20 bits (3 synchronization bits + 16 data bits + one parity bit)
Types of words :	Command, Status and Data
Word transmission time :	20 microsec
Maximum # of terminals (RTs) :	30

3. PLATFORM DATA MANAGEMENT SYSTEM (DMS)

Some time was spent in studying and understanding the operation of the Command and Data Handling (C&DH) functions and services of the DMS.

Reference documents [2] and [3] were studied and used for this purpose. The following information was extracted from these documents.

i. Types of Bus Traffic

a. Housekeeping Bus Traffic
   Scheduled Bus Cycles
   - Command Distribution/Memory Loads
   - Housekeeping Telemetry Collection
   - Subsystem Inter-ORU Traffic
   - GPS R/P Data
   - Time Update Messages

b. P/L Engineering Bus
   Scheduled Bus Cycles
   - P/L Cmd/Tlm/Memory Loads
   - Plate H/K Cmd/Tlm
   - Ancillary Data Distribution
   - P/L-to-P/L Messages
   - Time Update Messages

c. P/L Science Bus
   Polled Operation
   - LR Instrument Science Packets
   - Ancillary Data Packets
   - Platform Engineering Tlm Packets

ii. Bus Traffic Allocations and Bus Cycles as Proposed by GE.

a. Housekeeping Bus Traffic Allocations are shown in Table 1.
b. Typical Bus Cycles are shown in Tabe 2.
c. Housekeeping Bus Timings are shown in Table 3.
d. P/L Engineering Bus Traffic Allocations are shown in Table 4.

iii. Data Bus Traffic Requirements of the C&DH Subsystem of DMS

Tables 5A and 5B show the traffic requirements for the H/K, P/L Engineering, and P/L Science buses.

4. PERFORMANCE EVALUATION

4.1 Introduction

The foregoing information was used to evaluate the performance of the H/K, P/L Engineering and P/L Science buses using the 1553 BUS. Performance was evaluated in terms of the worst case delay and the average delay. For the H/K and P/L Engineering buses these delay values were calculated under slotted (cf. Tables 1 through 4) and unslotted allocation schemes. Under the slotted scheme each subsystem or instrument was assigned a specific slot whether it had data to transmit or not. Under the unslotted scheme, a subsystem or an instrument is assigned transmission channel only when it needs it and only for the length of time it needs it; additionally time can be allocated for the controller to transmit data once in every slot.

For the Payload Science bus the delay values are calculated by developing and using a polling model that can collect data from a set of instruments (known lowrate instruments) by polling these instruments number of times per cycle that is proportional to their data generation rates. The delay values are evaluated for a number of cases that include various degrees of retry and bus controller transmissions in addition to the actual data generated by the terminals.

The results are summarized in a tabular form for easy comparison.

4.2 Results of Delay Calculations

4.2.1 Delay Values for Housekeeping Bus

4.2.1.1 H/K Bus Traffic Allocation

The Traffic allocation on the H/K Bus is shown in Table 1. The following information is extracted from Table 1. It is assumed that all messages sent on the housekeeping bus are expected to be 32 words or fewer.

EPS - Electrical Power Subsystems. This group is polled every 20 ms, i.e., 50 times per second.
Number of terminals, and the data generation rate of these terminals is not known. It is assumed that no terminal generates more than 32 words/poll.

HKPG - Other Housekeeping Subsystems. This group is polled every 20 ms, i.e., 50 times per second.
Number of terminals, and the data generation rate at these terminals is not known. It is assumed that no terminal generates more than 32 words/poll.

GN&C - Guidance, Navigation & Control Subsystem. This group is polled every 10 ms. It consists of 18 seperate data points or sources (instruments or remote terminals).

The allocation of GN&C traffic is controlled through a 50 slot allocation cycle. Each slot potentially contains a thruster control command TC(2), active during propulsion maneuvers. Approximately 50% of available GN&C bandwidth is spare. Details of this allocation scheme is shown in Table 3.

CMD - Command Data Transfer. Data source is the PCP (Platform Control Processor), with data destinations: BDU, GPS R/P, HK BDUs and TFG. This group is polled every 10 ms.

TLM - Telemetry Data Transfer. It consists of maximum 32 word messages. This group is polled every 10 ms.

4.2.1.2 H/K Bus Data Generation Rates

In order to calculate the delays for various data sources it is necessary to calculate data generation rates of these sources. This information has been extracted from Tables 5A and 5B. Data generation rates of the aforementioned sources are tabulated in Table 6. Details of calculation of GN&C data generation and the number of retries is worked out and presented in Table 7.

Using Tables 5A, 5B, 6 and 7 data generation rates for these data sources have been calculated and are summarized below.

EPS	- max. 1600 words per second	50 slots of 2.5 ms
HKPG	- max. 1600 words per second	50 slots of 2.5 ms
GN&C	- 379 words per second	100 slots of 2.5 ms
CMD	- max. 6424 words per second	100 slots of 2.5 ms
TLM	- max. 3200 words per second	100 slots of 2.5 ms

4.2.1.3 Delay Calculation for the H/K Bus Under the Slotted Allocation Scheme Suggested by GE

In the slotted allocation scheme suggested by GE and shown in Table 1, every subsystem (EPS, HKPG, GN&C, CMD/MEMLOAD, & TLM) is assigned fixed slots of 2.5 ms duration for data transmission/reception irrespective of its need for the channel.

Table 8 gives the worst case and the average delays for the above mentioned subsystems. Table 9 shows the calculations for the average worst delay time for the same subsystems. Table 10 shows calculations for the overall average delay time.

In calculating the resuls shown in Tables 8, 9, and 10 it has been assumed that any data, arriving or being generated at a subsystem after a polling of that subsystem has started, has to wait until the next poll for that subsystem for transmission. It is also assumed that data are equally likely to arrive at any time between two subsequent poles. Thus the worst delay will be suffered by a data unit arriving right after the start of a poll. The least delay will be suffered by a data unit arriving just prior to a poll.

Average delays values are calculated by using a weighted averageing, the weights being the frequency of occurence of a particular subsystem in the slotted allocation scheme shown in Table 1.

4.2.1.4 Delay Calculation for H/K Bus Under Unslotted Scheme

Under the unslotted allocation scheme there is no preassignment of slots. Rather a data source is assigned a slot only if it needs to transmit or receive data. Further, a data source is given access to the channel just long enough to transmit its data. However, the sequence of data sources used in the slotted scheme is maintained in the unslotted scheme also.

It appears from the allocation frame in Table 1 for the H/K Bus, that for the slotted scheme some of the data sources are polled once in 5 frames whereas others are polled 5 times in a frame or 10 times in a frame. For the unslotted scheme it is desired that the same sequence of allocation be maintained. Thus to calculate delay for various data sources we have maintained the same polling cycle for them as in the slotted case, namely once every 5 frames, 5 times/frame and 10 times/frame. We have also calculated delay for each of these cases under the following loading conditions:

Case 1. Retries and transmission by the controller are included.
Case 2. Retries are included but transmission by the controller is excluded.
Case 3. Retries and transmission by the controller are excluded.

Table 11 shows delay values for five-frame long polling cycles (frames are as shown in Table 1). These delay values are applicable to any data source that is polled once in every five frames, e.g. HGA Pointing Commands (HGC) and HGA Position Samples (HGA) in GN&C.

Tables 12 and 13 show similar results for 1/5 frame and 1/10 frame polling cycles respectively for the above three conditions. Table 12 applies to EPS and HKPG. Table 13 applies to GN&C, CMD/MEMLOAD, and TLM.

4.2.1.4.1 Formulae Used For Delay Calculations

Delay values are calculated by using the following formule:

$$\text{Average delay } E(D) = (Tc/2)(1 - \rho/N) + (\rho \cdot s/2)(1 / (1 - \rho)) + (1 - \rho/N)s / 2 \quad \text{----------------} \; (1)$$

Where:

N = Number of polled terminals in a polling cycle

= Overall Utilization Factor
= Average data arrival rate/Average data service rate

$$Tc = \text{Average Scan Time} = L / (1 - \rho) \quad \text{----------------} \; (2)$$

L = Walk Time = (initial controller response time + poll time) + (number of polls - 1) X (controller inter message response time + poll time) -------(3)

Poll time = command word transmission time + status word transmission time + max RT response time = 20 + 20 + 10 = 50 microsec ---------------- (4)

s = transmission time for one word = 20 microsec

With Poll time = 50 microsec.
Walk Time L = (100 + 50) + (number of polls - 1) X (200 + 50) microsec

It is seen that for small utilization factor
the average delay E(D) = Tc / 2 ----------------- (5)

4.2.1.5 Summary of delay Calculations For H/K Bus

The results of delay calculations under slotted and unslotted allocation schemes are summarized in Table 14.

4.2.2 Delay Results For The P/L Engineering Bus

4.2.2.1 P/L Eng. Bus Traffic Allocations

ANCIL DATA: Ancillary Data consists of maximum 32 words/message/poll. This group is polled every 100 ms.

P/L MSG : These are P/L to P/L messages. These messages are polled every 50 ms i.e. 20 times per second. Generation rates are not known. However, it is assumed that these messages are not more than 32 words/message/poll.

CMD/MEMLOAD: Command Data Transfer. Data source is the Platform Control Processor (PCP) and data destination is BDU's and P/L's. This group is polled every 10 ms.

P/L TLM: P/L Eng. Telemetry Data Transfer. It consists of maximum 32 words/message/poll. This group is polled every 20 ms.

H/K TLM: Plate H/K Telemetry Data Transfer. It consists of maximum 32 words/message/poll. This group is polled every 20 ms.
H/K TLM + P/L TLM <= 50 Kbps.

HKPG: P/L Plate Housekeeping. This group is polled every 20 ms, i.e., 50 Times per second. Number of terminals, and the generations rate at these terminals are not known. Assumed one terminal with a data rate of 32 words/message/poll.

Maximum length of all messages sent on the P/L Eng. Bus are expected to be 32 words per poll.

4.2.2.2 P/L Eng. Bus Data Generation Rates

In order to calculate the delay values for various data sources, it is necessary to calculate the data generation rates of these sources. The following information has been extracted from Tables 5-A and 5-B and is summerized below:

SOURCE OF DATA	MAXIMUM DATA RATES (words/second)	AVERAGE DATA RATES (words/second)
ANCIL DATA	320	160
P/L MSG	640	320
CMD/MEMLOAD	3860	1930
TLM (H/K + P/L)	3200	1600
HKPG	1600	800

Total average data generation rate = 4810 words/sec
1553 Bus average service rate = 50,000 words/sec

In this case the rate of data genaration is less than the rate of transmission.

$$\text{Utilization Factor } \rho = \frac{\text{Average rate of data generation}}{\text{Average rate of data transmission}}$$

$$= 4810/50,000 = 0.0962 < 1.$$

Thus the system (1553 Bus used as P/L Eng. Bus) is stable and the delays and queue sizes should not be very long. Detailed calculations follow.

4.2.2.3 Delay Calculations For The P/L Eng. Bus Under Slotted Allocations Scheme Suggested by GE.

In the slotted allocation scheme every data source (ANCIL DATA, P/L MSG, CMD/MEMLOAD, P/L and H/K TLM, and HKPG) is assigned fixed slots of 2.5 ms duration for data transmission /reception irrespective of its need for the channel.

Table 15 gives the worst case and the average delays for the above mentioned data sources. Table 16 shows the calculations for the overall average worst delay time for the same data sources. Table 17 shows the calculations for the overall average delay time.

In calculating the results shown in Tables 15, 16, and 17 it has been assumed that any data, arriving or being generated at a subsystem after a polling of that subsystem has started, has to wait until the next poll for that subsystem for transmission. It is also assumed that data are equally likely to arrive at any time between two subsequent poles. Thus the worst delay will be suffered by a data unit arriving right after the start of a poll. The least delay will be suffered by a data unit arriving just prior to a poll. Average delay values are calculated by using a weighted averaging,the weights being the frequency of occurence of a particular subsystem in the slotted allocation scheme shown in Table 4.

4.2.2.4 Delay Calculation For P/L Eng. Bus Under Unslotted Scheme.

Under the unslotted allocation scheme there is no preassignment of slots. Rather a data source is assigned a slot only if it needs to transmit or receive data. Further, a data source is given an access to the channel just long enough to transmit its data. However, the sequence of data sources used in the slotted scheme (Table 4) is maintained in the unslotted scheme also.

It appears from the allocation table 4 for the P/L Engineering Bus that for the slotted scheme some of the data soureces are polled once in 100 ms, whereas others are polled once in 10 ms, 20 ms or 50 ms. For the unslotted scheme it is desired that the same sequence of allocation be maintained. Thus to calculate delays for various data sources we have maintained the same polling cycle for them as in the slotted case. We have also calculated delays for each of these cases under the following loading conditions:

Case 1 : Retries and Controller Transmission are included.
Case 2 : Controller Transmission is excluded
Case 3 : Retries and Controller Transmission are excluded.
Case 4 : 50% Controller Transmission and 50% Retries are Excluded.
Case 5 : Retries are Excluded.
Case 6 : 50% Controller is Excluded.
Case 7 : 50% Retries are Excluded.
Case 8 : Controller Transmission and 50% Retries are Excluded.
Case 9 : Retries and 50% Controller Transmission are Excluded.

Tables 18, 19, 20, and 21 show the calculations for the average delay for P/L Eng. Bus without slotting for CMD/MEMLOAD and TLM; HKPG; P/L MSG; and ANCIL DATA respectively.

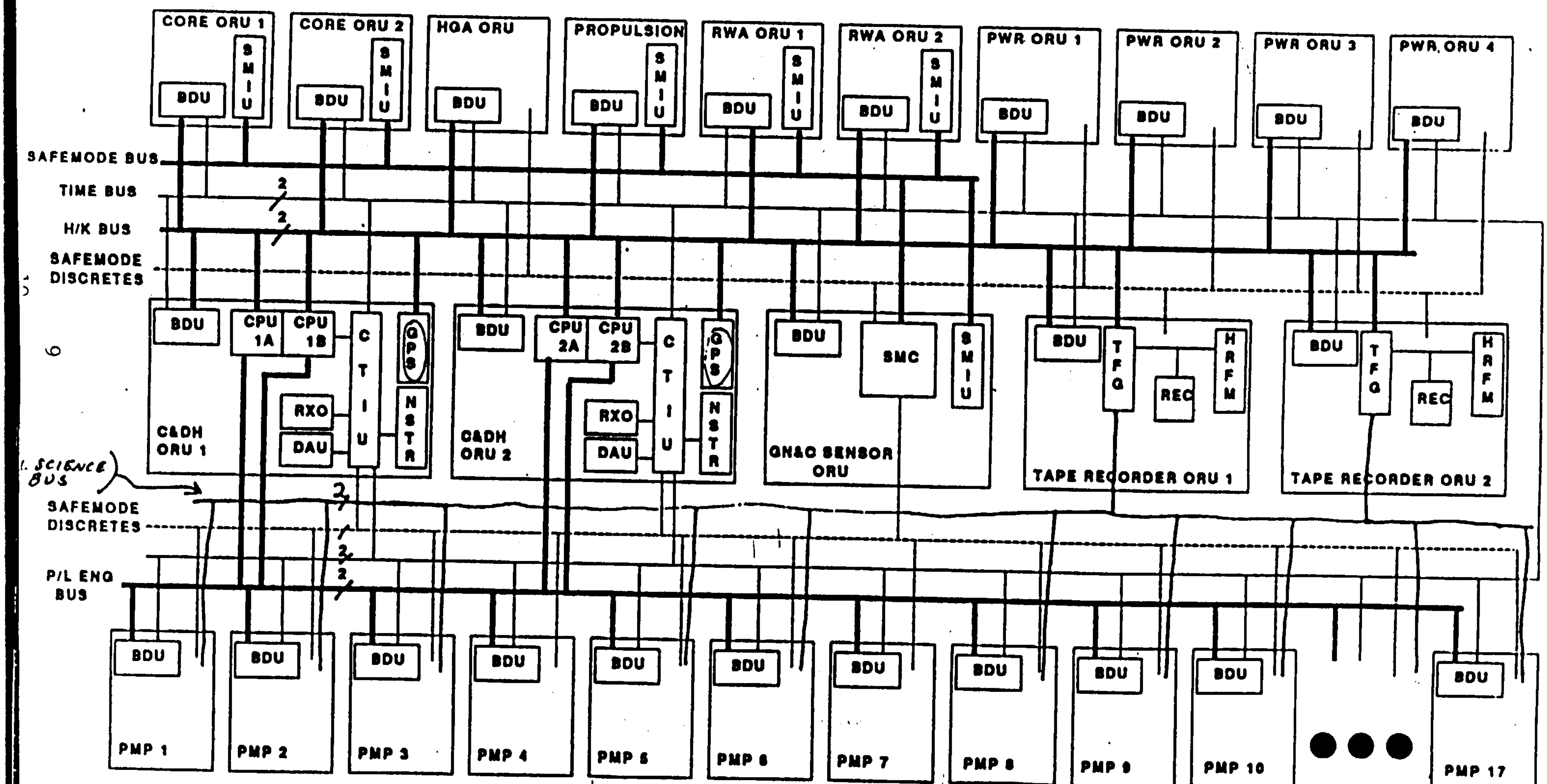
Tables 22, 23, 24, 25, 26, 27, 28, 29, and 30 show the caculations for the overall average delay for P/L Eng. Bus for the nine cases mentioned above respectively. The delay values are calculated by using the equations (1), (2), (3), (4), and (5) in section 4.2.1.4.

4.2.2.5 Summary of Delay Calculations For P/L Eng. Bus.

The delay values for the P/L Eng. Bus under the slotted and unslotted allocation schemes are summarized in Table 31.

C&DH H/K Bus Topology

Eos-A Platform



LEGEND

BDU: Bus Data Unit
CPU: Central Processing Unit
CTIU: Cmd/Tim I/F Unit
DAU: Decryption/Authentication Unit
GPS: GPS Rcvr/Processor
HRFM: High Rate Frame Mux
NSTR: NASA Std Tape Recorder
PMP: Payload Mounting Plate
REC: Tape Recorder
RXO: Redundant Crystal Osc.
SMC: Safe Mode Controller
SMIU: Safe Mode I/F Unit
TFG: Transfer Frame Generator

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FIGURE 2. HOUSEKEEPING BUS TOPOLOGY

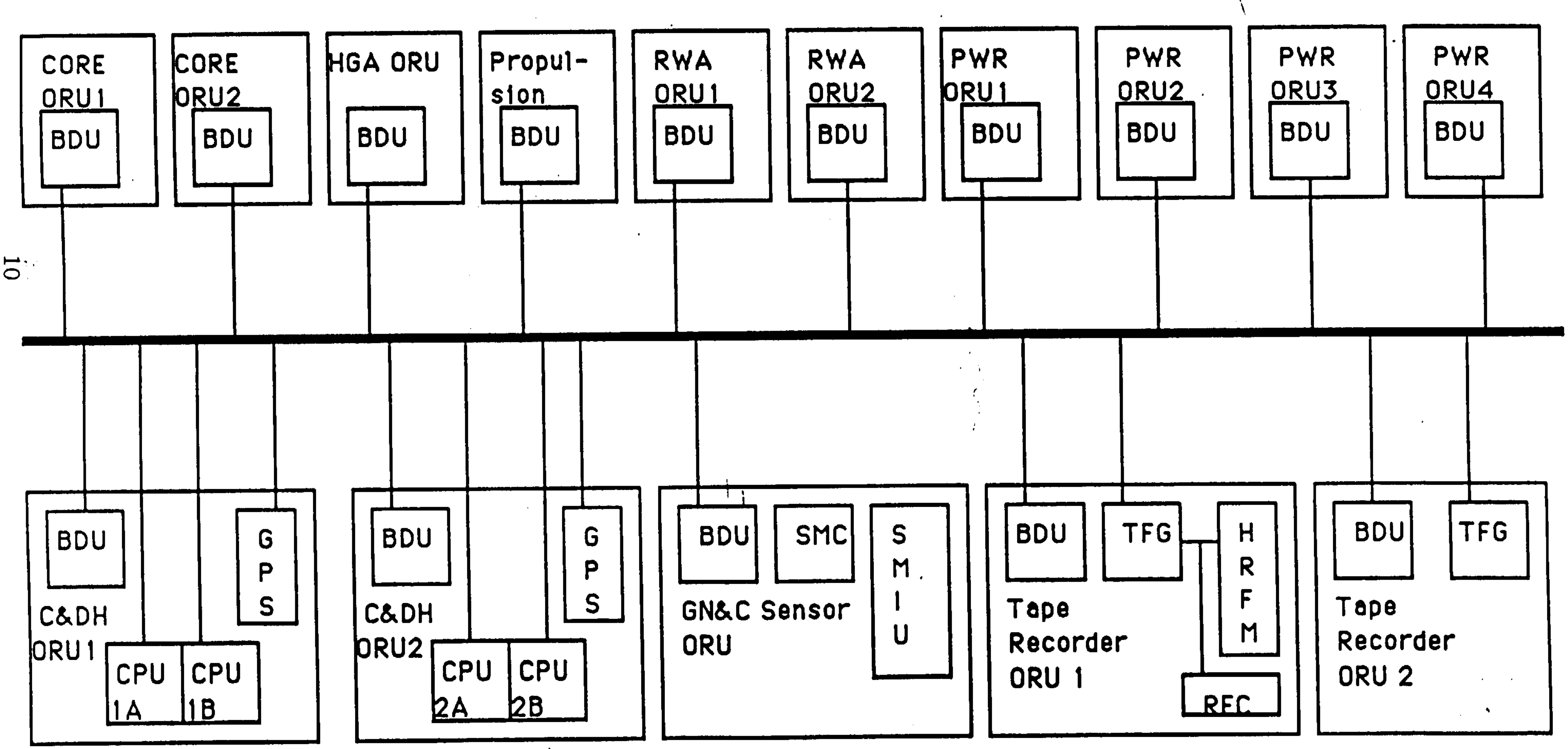

FIGURE 3. P/L ENGINEERING BUS TOPOLOGY

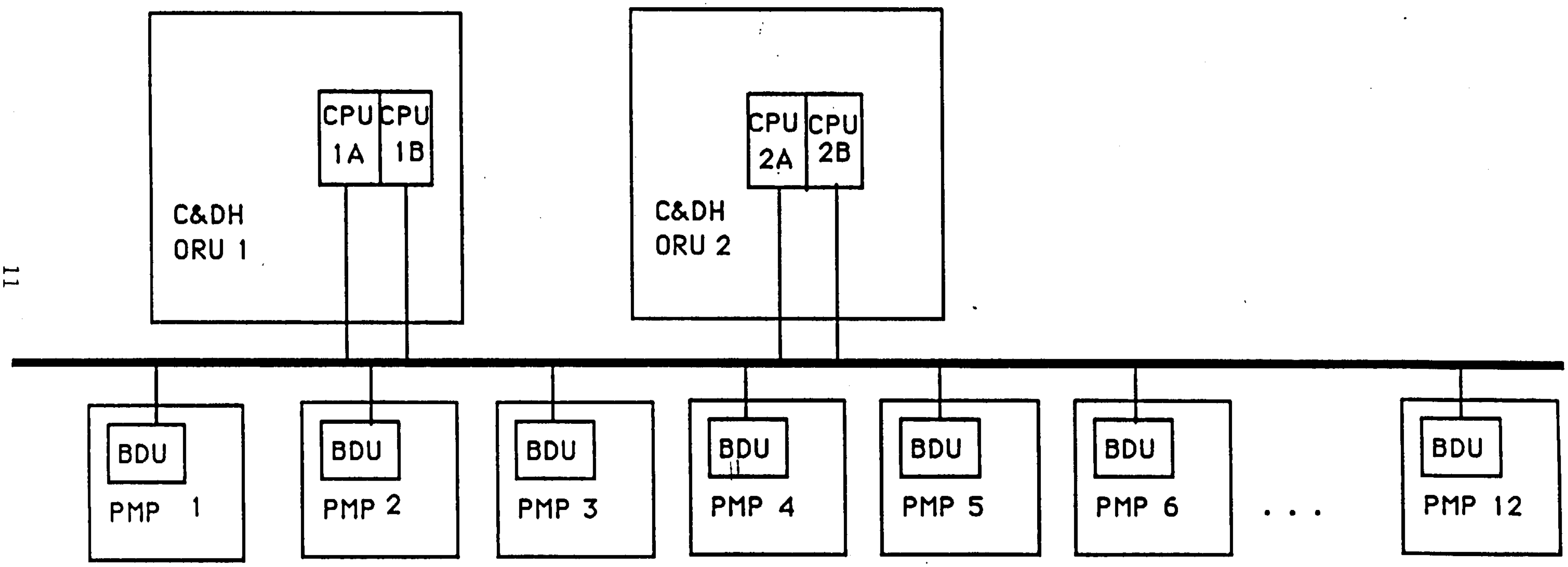

FIGURE 4. P/L SCIENCE BUS TOPOLOGY

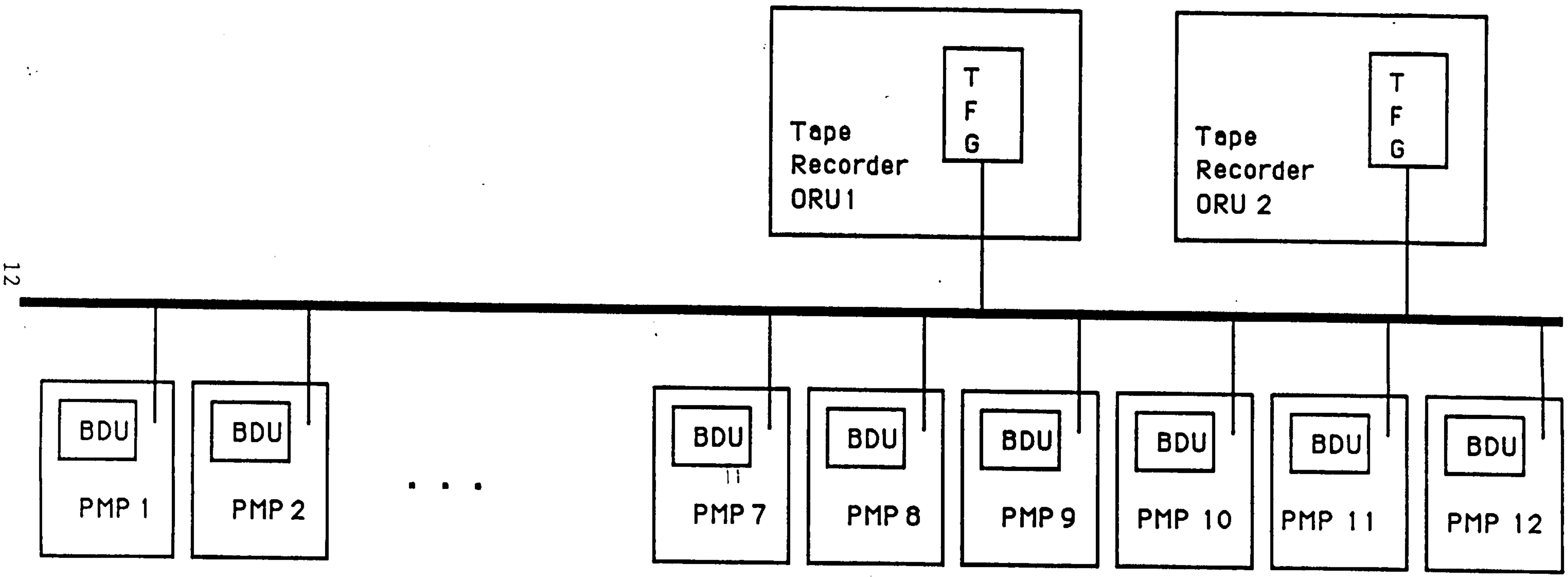

FIGURE 5 SAFEMODE BUS TOPOLOGY

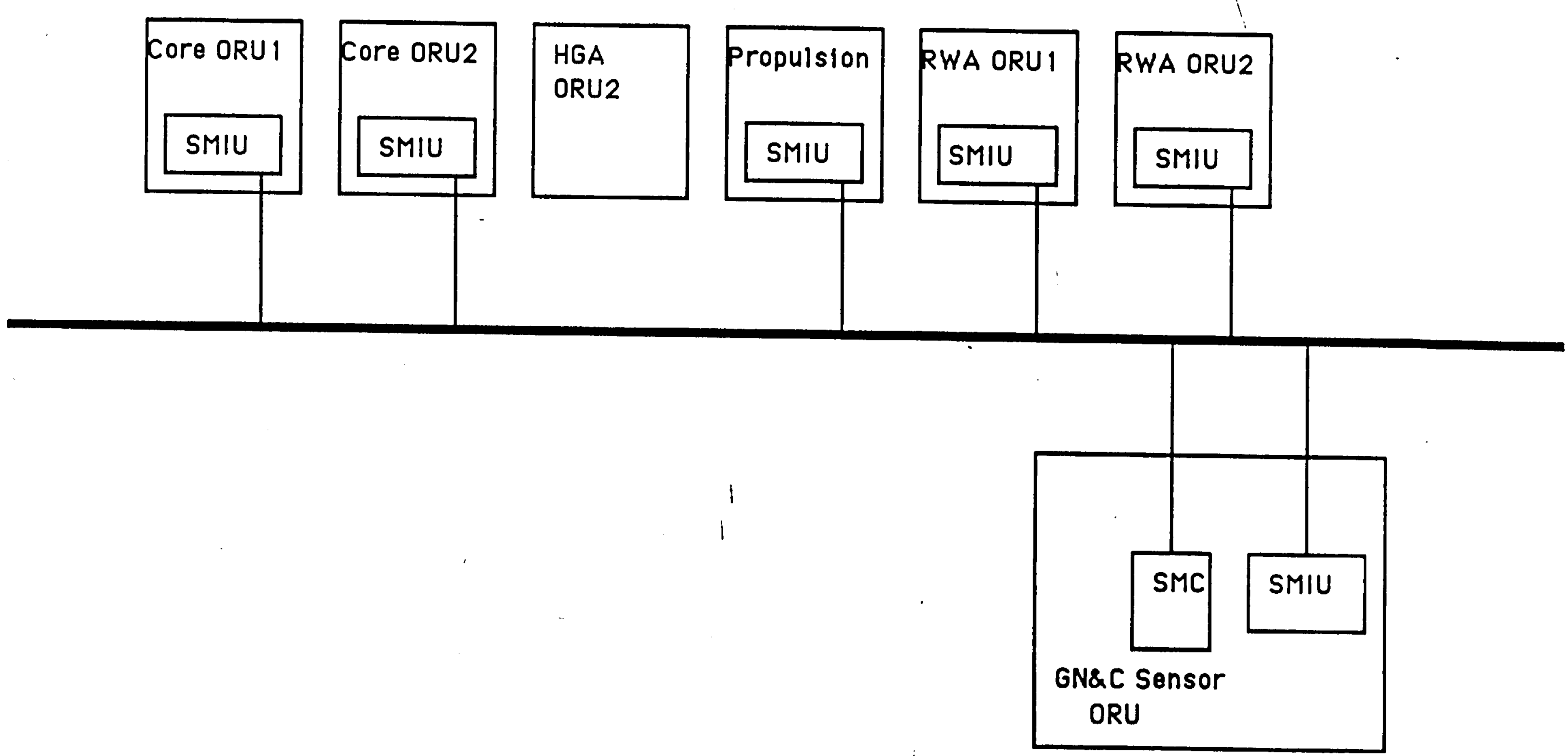

FIGURE 6

C&DH SUBSYSTEM BLOCK DIAGRAM

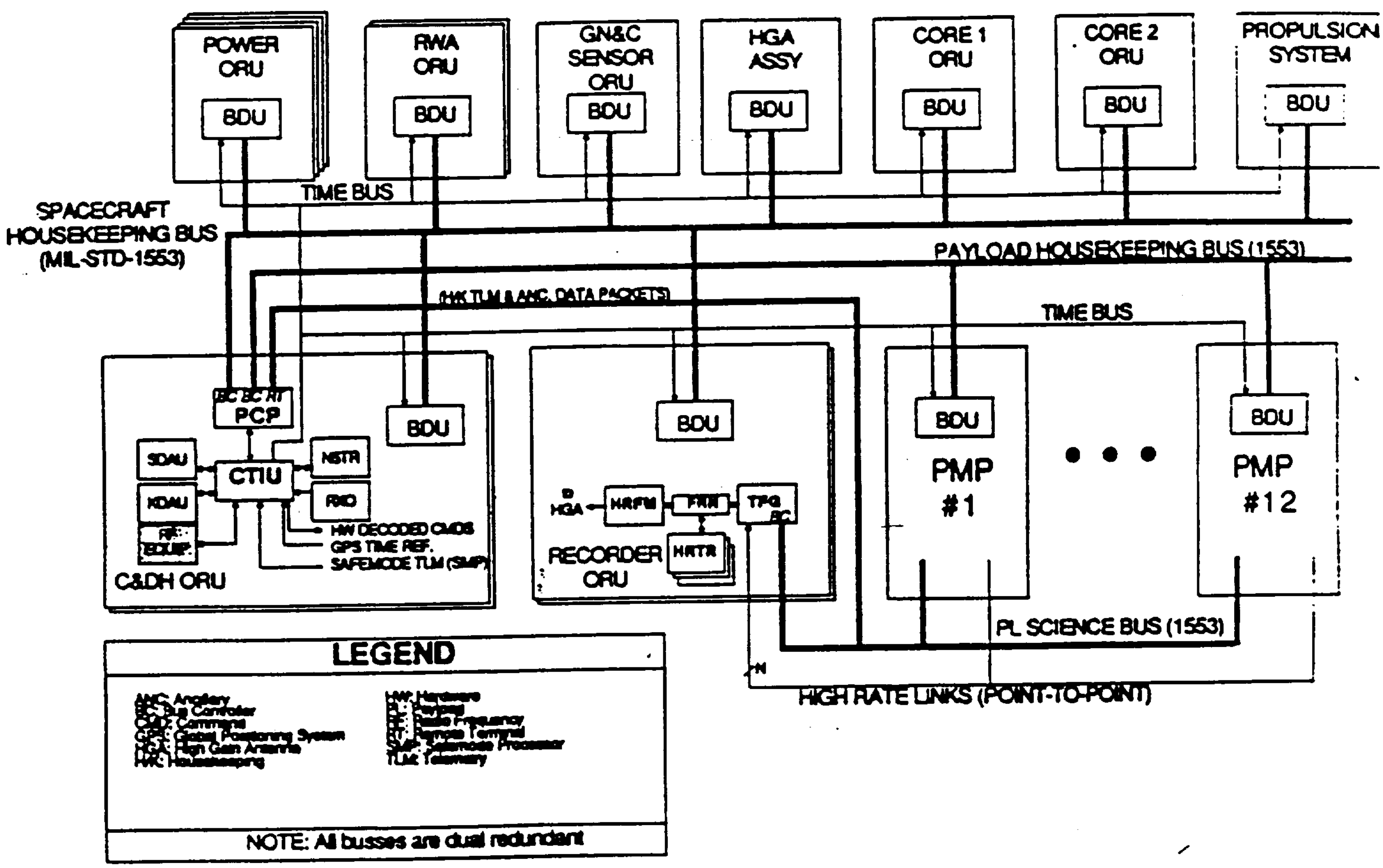

FIGURE 7

RETURN LINK TRANSFER FORMATS

STANDARD SERVICE (13.9 % MIN. FRAME OVERHEAD) = CODED VIRTUAL CHANNEL DATA UNIT (CVCDU)

SYNC	PRIMARY HEADER	M-PDU HDR	PKT HDR (48)	DATA UNIT ZONE	CLCW (32)	REED-SOLOMON PARITY FIELD (255,223) CODE
32	64	16	7056			1024

HIGH THROUGHPUT SERVICE (1.4 % FRAME OVERHEAD) = VIRTUAL CHANNEL DATA UNIT (VCDU)

SYNC	PRIMARY HEADER	M-PDU HDR	PKT HDR (48)	DATA UNIT ZONE	ERROR CONTROL FIELD
32	64	16	8064		16
8192					

FORMATS BASED ON CCSDS 701.00-R-3

Notes:
1) Minimum overhead calculations assume no CLCW
2) M-PDU = Multiplexed Protocol Data Unit
   CLCW = Command Link Control Word
3) CLCW only in frames on Low Rate Data Virtual Channel

[shaded box] = TFG applied frame fields

FG3 2_10

TABLE 1

Preliminary H/K Bus Allocations

0 1.5 5.0 7.5

1 EPS	2 GN&C	3 CMD/ MEM LOAD	4 TLM
5 HKPG	GN&C	CMD/ MEM LOAD	TLM
EPS	GN&C	CMD/ MEM LOAD	TLM
HKPG	GN&C	CMD/ MEM LOAD	TLM
EPS	GN&C	CMD/ MEM LOAD	TLM
HKPG	GN&C	CMD/ MEM LOAD	TLM
EPS	GN&C	CMD/ MEM LOAD	TLM
HKPG	GN&C	CMD/ MEM LOAD	TLM
EPS	GN&C	CMD/ MEM LOAD	TLM
HKPG	GN&C	CMD/ MEM LOAD	40 TLM

10

100 MSEC

2.5 MSEC

10 MSEC

EPS: Electrical Power Subsystem
GN&C: Guidance, Navigation, & Control Subsystem
HKPG: Other Housekeeping Subsystems
CMD: Command Data Transfer
TLM: Telemetry Data Transfer
Mem Load: Downloads to BDUs, TFG, GPS R/P, etc.

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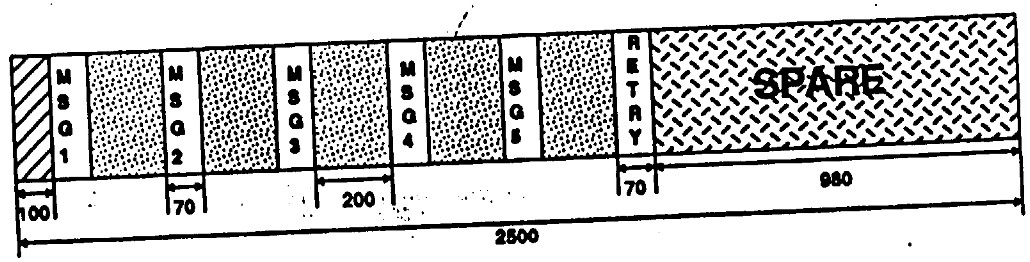
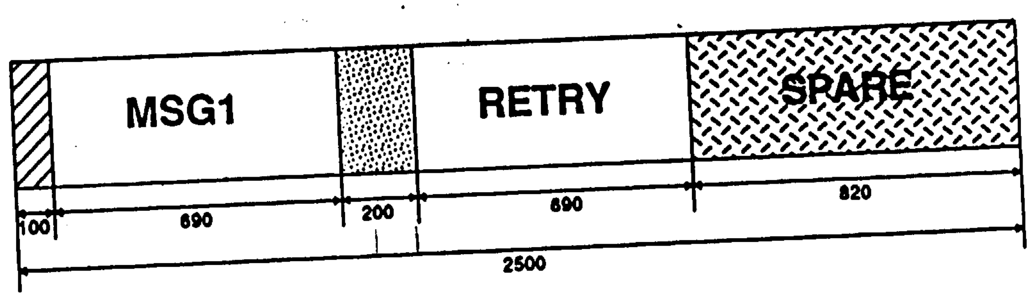
TABLE 2

Typical Bus Cycles



Minor Cycle of Single-Word Messages



Minor Cycle of 32-Word Messages

Note: All times in microseconds

Legend

- BC Response to "Start-of-Message" Interrupt
- BC Inter-message Response Time (Includes 1553 Inter-message gap)
- Unused (Spare/Margin) Bus Time

BUSCYCLE\RMF 10/28/

TABLE 3

HOUSEKEEPING BUS TIMING

ALLOCATION OF GN&C TRAFFIC TO BUS CYCLES

1 IRU(2) ACC(1)	2 SAC(1) SAD(1)	3 ESA(2)	4 RS-AB(2) RS-CD(2)	5 RC-AB(2) RC-CD(2)	6 GPS(10)	7	8	9	10
11 IRU(2) ACC(1)	SAC(1) SAD(1)	ESA(2)			HGA(3)				20
21 IRU(2) ACC(1)	SAC(1) SAD(1)	ESA(2)	RS-AB(2) RS-CD(2)	RC-AB(2) RC-CD(2)	HGC(3)				30
31 IRU(2) ACC(1)	SAC(1) SAD(1)	ESA(2)			TAM(3) MTC(3)				40
41 IRU(2) ACC(1)	42 SAC(1) SAD(1)	43 ESA(2)	44 RS-AB(2) RS-CD(2)	45 RC-AB(2) RC-CD(2)	46 ST-P(3) ST-B(3)	47	48	49	50

NOTES:
- GN&C BUS CYCLES START AT 10 MSEC INTERVALS
- NUMBERS IN UPPER RIGHT CORNERS INDICATE SLOT NUMBER
- PARENTHESIZED NUMBERS INDICATE NUMBER OF WORDS TRANSFERRED
- EVERY SLOT POTENTIALLY CONTAINS A THRUSTER CONTROL COMMAND, TC(2), ACTIVE DURING PROPULSIVE MANEUVERS

on est 4TSS?

APPROXIMATELY 50% OF AVAILABLE GN&C BANDWIDTH IS SPARE.

WORST-CASE GN&C BUS CYCLE (SLOT 46)

THRUSTER CNTL

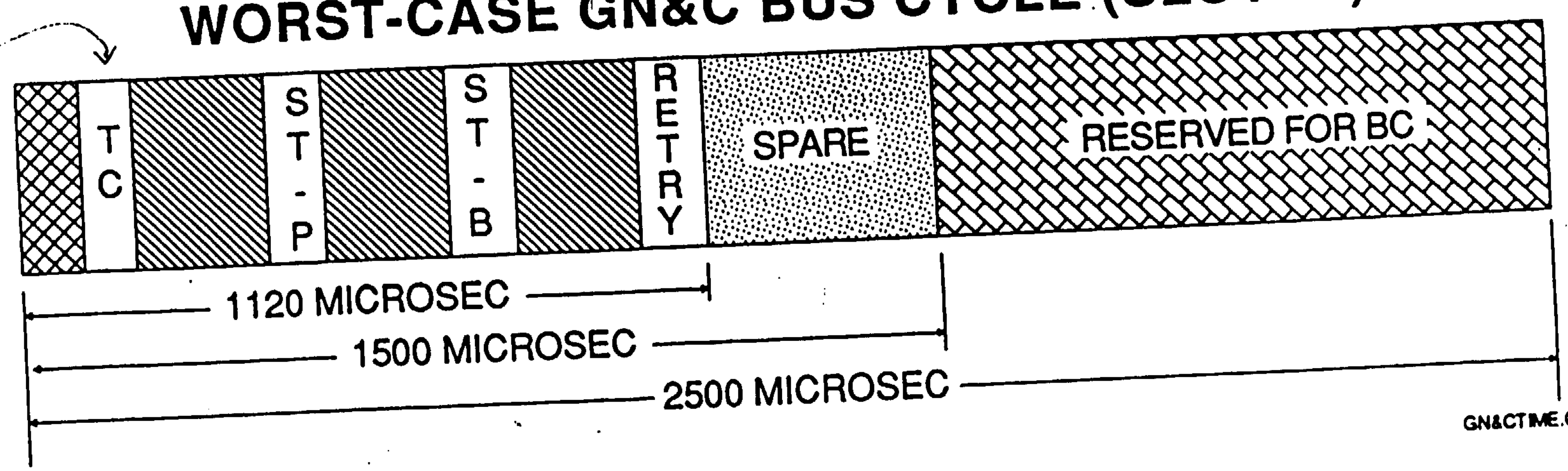


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TABLE 4

P/L Eng. Bus Allocations

Preliminary

1 ANCIL DATA	2 P/L MSG	3 CMD/ MEM LOAD	4 P/L TLM
5 HKPG		CMD/ MEM LOAD	H/K TLM
		CMD/ MEM LOAD	P/L TLM
HKPG		CMD/ MEM LOAD	H/K TLM
		CMD/ MEM LOAD	P/L TLM
HKPG	P/L MSG	CMD/ MEM LOAD	H/K TLM
		CMD/ MEM LOAD	P/L TLM
HKPG		CMD/ MEM LOAD	H/K TLM
		CMD/ MEM LOAD	P/L TLM
HKPG		CMD/ MEM LOAD	40 H/K TLM

100 MSEC

2.5 MSEC

10 MSEC

ANCIL DATA: Ancillary Data
HKPG: P/L Plate Housekeeping
CMD: Command Data Transfer
P/L TLM: P/L Eng.Telemetry Data Transfer
H/K TLM: Plate H/K Telemetry Data Transfer
P/L MSG: P/L-to-P/L Messages
Mem Load: Downloads to BDUs, Instruments
Blank: Spare

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TABLE 5A

DATA BUS TRAFFIC REQUIREMENTS
C&DH SUBSYSTEM

Message Type	Data Source	Data Dest	Bus Used	Max Words /Msg	Min Period (msec)	Slot Acronymn	Comments
Housekeeping TLM Samples	HK BDUs	PCP	HK ENG	32	10	TLM	HK + PL <= 50 Kbps
BDU Sample Table Load	PCP	BDU	HK ENG	32	10	CMD/MEM LOAD	Infrequent after BDU init
CPU Load (Housekeeping)	PCP	GPS R/P	HK ENG	32	10	CMD/MEM LOAD	Keep up w/ K-band link
Housekeeping Cmd Distrib	PCP	HK BDUs	HK ENG	2	100	CMD/MEM LOAD	Real-time and stored
TFG Sample Table Load	PCP	TFG	HK ENG	32	10000	CMD/MEM LOAD	Only on P/L config change
Payload TLM Samples	PL BDUs	PCP	PL ENG	32	10	TLM	HK + PL <= 50 Kbps
BDU Sample Table Load	PCP	BDU	PL ENG	32	10	CMD/MEM LOAD	Infrequent after BDU init
CPU Load (Payload)	PCP	P/Ls	PL ENG	32	50	CMD/MEM LOAD	Keep up w/ K-band link
PL-to-PL Messages	P/L	P/L	PL ENG	32	50	P/L MSG	Must be prescheduled
Ancillary Data	PCP	P/L's	PL ENG	32	100	ANCIL DATA	Broadcast to PL instruments
Payload Cmd Distrib	PCP	PL BDUs	PL ENG	2	100	CMD/MEM LOAD	Real-time and stored
Science Data Packets	P/Ls	TFG	PL SCI	512	40		Assumes max size packets
Telemetry Packets	PCP	TFG	PL SCI	128	100		1 packetized TLM frame
Ancillary Data Packets	PCP	TFG	PL SCI	32	100		Same as on PL ENG bus

TABLE 5B

DATA BUS TRAFFIC REQUIREMENTS
GN&C SUBSYSTEM

Message Type	Data Source	Data Dest	Bus Used	Max Words /Msg	Min Period (msec)	Slot Acronymn	Comments
Thruster Control Commands	PCP	PMEA	HK ENG	2	10	TC	Pulse granularity of 10 msec
Inertial Ref. Unit Samples	IRU	CPU	HK ENG	3	100	IRU	3 axes, 2 bytes each
Accelerometer Samples	ACU	PCP	HK ENG	1	100	ACC	During delta-V maneuvers only
Solar Array Step Commands	PCP	SAD	HK ENG	1	100	SAC	Assumes 1st-order control
Solar Array Pos'n Samples	SAD	PCP	HK ENG	1	100	SAD	Array position (2 bytes)
Reaction Wheel Torque Cmds	PCP	RWA A/B	HK ENG	2	200	RC-AB	Torque demands for 2 wheels
Reaction Wheel Torque Cmds	PCP	RWA C/D	HK ENG	2	200	RC-CD	Torque demands for 2 wheels
Reaction Wheel Speed Sample	RWA A/B	PCP	HK ENG	2	200	RS-AB	Wheel speeds for 2 wheels
Reaction Wheel Speed Sample	RWA C/D	PCP	HK ENG	2	200	RS-CD	Wheel speeds for 2 wheels
Earth Sensor Samples	ESA	PCP	HK ENG	2	250	ESA	Asynchronous, use Oversampling
HGA Pointing Commands	PCP	HGA	HK ENG	3	500	HGC	Az, El, Status bits
HGA Position Samples	HGA	PCP	HK ENG	3	500	HGA	Az, El, Status bits
GPS State Vectors	GPS R/P	PCP	HK ENG	10	1000	GPS	Extrapolator in PCP SW
Sun Sensor Samples	4πSS	PCP	HK ENG	3	1000	4πSS	X, Y, Head #
3-axis Magnetometer Samples	TAM	CPU	HK ENG	3	5000	TAM	3 axes, 2 bytes each
Mag Torque Rod Commands	PCP	MTR	HK ENG	3	5000	MTC	3 axes, 2 bytes each
Star Tracker Samples (Pri)	SSST	CPU	HK ENG	3	10000	ST-P	X & Y Pos'ns and Magnitude
Star Tracker Samples (B/U)	SSST	CPU	HK ENG	3	10000	ST-B	B/U tracker always active

TABLE 6

HOUSEKEEPING BUS DATA GENERATION RATES

Group	Message Type	Max. Words /Msg	Min Period (msec)	Actual Alloc- ation	Words/ second	Group Total
EPS	Electrical Power Subsystem	32	20	20	1600	1600
HKPG	Other Housekeeping Subsystems	32	20	20	1600	1600
TLM	Telemetry Data Transfer					
	Housekeeping TLM Samples (HK BDUs)	32	10	10	3200	3200
CMD	Command Data Transfer					
	BDU Sample Table Load	32	10	10	3200	6424
	CPU Load (Housekeeping)	32	10	10	3200	
	Housekeeping Cmd Distribution	2	100	100	20	
	TFG Sample Table Load	32	10000	10000	4	
GN&C	Guidance, Navigation, & Control Subsystem					379
	Transfer Control Commands (TC)	2	10	10	200	
	Intertial Ref. Unit Samples (IRU)	3	100	100	30	
	Accelerometer Samples (ACC)	1	100	100	10	
	Solar Array Step Commands (SAC)	1	100	100	10	
	Solar Array Pos'n Samples (SAD)	1	100	100	10	
	Reaction Wheel Torque Cmds (RC-AB)	2	200	200	10	
	Reaction Wheel Torque Cmds (RC-CD)	2	200	200	10	
	Reaction Wheel Speed Sample (RS-AB)	2	200	200	10	
	Reaction Wheel Speed Sample (RS-CD)	2	200	200	10	
	Earth Sensor Samples (ESA)	2	250	100	20	
	HGA Pointing Commands (HGC)	3	500	500	6	
	HGA Position Samples (HGA)	3	500	500	6	
	GPS State Vectors (GPS)	10	1000	500	20	
	Sun Sensor Samples (4 SS)	3	1000	1000	3	
	3-axis Magnetometer Samples (TAM)	3	5000	500	6	
	Mag Torque Rod Commands (MTC)	3	5000	500	6	
	Star Tracker Samples (ST-P)	3	10000	500	6	
	Star Tracker Samples (ST-B)	3	10000	500	6	

TABLE 7

HOUSEKEEPING BUS: CALCULATION OF GN&C DATA GENERATION AND NUMBER OF RETRIES

Allocation of GN&C Traffic to Bus Cycles:
GN&C cycles start at 10 ms intervals. Fifty slot (500 ms) GN&C cycle with instruments and data generated/transfered in words is given below:

Slot #	Instruments 1 , 2, 3, 4	Instrument data 1 + 2 + 3 + 4	Total data	Retry data
1	IRU, ACC, TC	2 + 1 + 2	5	2
2	SAC, SAD, TC	1 + 1 + 2	4	2
3	ESA, TC	2 + 2	4	2
4	RS-AB, RS-CD, TC	2 + 2 + 2	6	2
5	RC-AB, RC-CD, TC	2 + 2 + 2	6	2
6	GPS, TC	10 + 2	12	10
7	TC	2	2	2
8	TC	2	2	2
9	TC	2	2	2
10	TC	2	2	2
11	IRU, ACC, TC	2 + 1 + 2	5	2
12	SAC, SAD, TC	1 + 1 + 2	4	2
13	ESA, TC	2 + 2	4	2
14	TC	2	2	2
15	TC	2	2	2
16	HGA, TC	3 + 2	5	3
17	TC	2	2	2
18	TC	2	2	2
19	TC	2	2	2
20	TC	2	2	2
21	IRU, ACC, TC	2 + 1 + 2	5	2
22	SAC, SAD, TC	1 + 1 + 2	4	2
23	ESA, TC	2 + 2	4	2
24	RS-AB, RS-CD, TC	2 + 2 + 2	6	2
25	RC-AB, RC-CD, TC	2 + 2 + 2	6	2
26	HGC, TC	3 + 2	5	3
27	TC	2	2	2
28	TC	2	2	2
29	TC	2	2	2
30	TC	2	2	2
31	IRU, ACC, TC	2 + 1 + 2	5	2
32	SAC, SAD, TC	1 + 1 + 2	4	2
33	ESA, TC	2 + 2	4	2
34	TC	2	2	2
35	TC	2	2	2
36	TAM, MTC, TC	3 + 3 + 2	8	3
37	TC	2	2	2
38	TC	2	2	2
39	TC	2	2	2
40	TC	2	2	2

Continued on next page

TABLE 7 (Cont.)

HOUSEKEEPING BUS: CALCULATION OF GN&C DATA GENERATION AND NUMBER OF RETRIES

Slot #	Instruments 1, 2, 3, 4	Instrument data 1 + 2 + 3 + 4	Total data	Retry data	
41	IRU, ACC, TC	2 + 1 + 2	5	2	
42	SAC, SAD, TC	1 + 1 + 2	4	2	
43	ESA, TC	2 + 2	4	2	
44	RS-AB, RS-CD, TC	2 + 2 + 2	6	2	
45	RC-AB, RC-CD, TC	2 + 2 + 2	6	2	4 SS = 3 words/sec
46	ST-P, ST-B, TC	3 + 3 + 2	8	3	Average data/slot
47	TC	2	2	2	187/50+3/100 = 3.77
48	TC	2	2	2	Average retry = 2.24
49	TC	2	2	2	
50	TC	2	2	2	
		Total	187	112	

TABLE 8

WORST CASE AND AVERAGE DELAYS FOR THE HOUSEKEEPING BUS (SLOTTED ALLOCATIONS)

	Worst Delay Time (WDT) (ms)	Average Delay Time (ADT) (ms)
EPS	20	10
GN&C	10	5
CMD / MEM LOAD	10	5
TLM	10	5
HKPG	20	10

TABLE 9

OVERALL AVERAGE WORST CASE DELAY FOR HOUSEKEEPING BUS (SLOTTED ALLOCATIONS)

Overall Average Worst Delay Time

$$= 5/40\ (WDT\ (HKPG)) + 5/40\ (WDT\ (EPS)) + 10/40\ (WDT\ (CMD)) + 10/40\ (WDT\ (GN\&C)) + 10/40\ (WDT\ (TLM))$$

$$= 5/40(20) + 5/40(20) + 10/40(10) + 10/40(10) + 10/40(10)$$

$$= 1/40(\ 100 + 100 + 100 + 100 + 100\ )$$

$$= 500/40$$

$$= 12.5\ ms$$

TABLE 10

OVERALL AVERAGE DELAY FOR HOUSEKEEPING BUS (SLOTTED ALLOCATIONS)

Overall Average Delay Time

$$= 5/40\,(ADT\,(HKPG)) + 5/40\,(ADT\,(EPS)) + 10/40\,(ADT\,(CMD)) + 10/40\,(ADT\,(GN\&C)) + 10/40\,(ADT\,(TLM))$$

$$= 5/40(10) + 5/40(10) + 10/40(5) + 10/40(5) + 10/40(5)$$

$$= 1/40(\,50 + 50 + 50 + 50 + 50\,)$$

$$= 250/40$$

$$= 6.25\ \text{ms}$$

TABLE 11

Calculations for the Worst Case Delay Value for H/K Bus Without Slotting
Polling Cycle: Once Every 5 Frames Like the Frame Shown in Table 1

These delay values are applicable to any data source/instrument that is polled every 5 frames like the frame shown in Table 1. Examples are HGA Pointing CMD and HGA Position Sample in GN&C.

Case 1: Controller Transmission and Retries are Included

Data Source	Max. Data Rate (words/sec)	Average Data Rate (words/sec)
EPS:	1,600	800
HKPG:	1,600	800
GN&C:	379	379
CMD/MEMLOAD:	6,424	3,212
TLM:	3,200	1,600
BUS CONTROLLER:	12,800	6,400
RETRY:		
General	9,600	4,800
GN&C Component	224	224

Maximum Total Data Rate = 35,827 words/sec
Average Data Rate = 18,215 words/sec

Service Rate = 1000,000 bits/sec
(1553 BUS) = 50,000 words/sec

Overall utilization factor ρ = 18,215 / 50,000
= 0.3643 < 1 (System is stable)

Number of Polls Required in 5 Frames.

DATA SOURCE	NUMBER OF POLLS	
EPS:	25	
	25	(Retry)
GN&C:	95	(As per GE allocation)
	50	(Retry)
CMD/MEMLOAD:	105.05	
	50	(Retry)
TLM:	50	
	50	(Retry)
HKPG:	25	
	25	(Retry)
Bus Controller	200	

Total Number of Polls Np = 700 . 05

TABLE 11 (Continued)

Equations (1), (2), (3), (4), and (5) of Section 4.2.1.4 are used to calculate the delay values.

Poll Time = 20 + 20 + 10 = 50 microsec

Bus Controller Response Time:

Start of Cycle = 100 microsec
Inter Message = 200 microsec

Walk Time L = (100 + 50) + (Number of Polls - 1)(200 + 50) microsec

Walk Time L for 5 Frame Cycle = 150 + 699.05 X 250
= 174,912.5 microsec
= 174.913 ms

$$\text{Scan Time } T_c = L / (1 - \rho)$$

$$= 174.913 / (1 - 0.3643)$$
$$= 275.15 \text{ ms}$$

Average delay = Tc / 2 = 137.57 ms

Case 2: Controller Transmissions are Excluded, Retries are Included

---

Average Total Data Rate = Total Data Rate in Case 1 - Bus Controller Transmissions
= 18,215 - 6,400
= 11,815 words/sec

Overall utilization factor ρ = 11,815 / 50,000
= 0.2363

Total Number of Polls Np = Total Number of Polls in Case 1 - Number of Polls for Bus Controller
= 700 . 05 - 200
= 500 . 05

Walk Time L = 150 + (500.05 - 1) X 250
= 124,912 . 5 microsec
= 124 . 912 ms

Scan Time Tc = 124.912 / (1 - 0.2363)
= 163.56 ms

Average delay = 81.78 ms

TABLE 11 (Continued)

Case 3: Controller Transmissions and Retries are Excluded

Average Total Data Rate = Total Data Rate in Case 1
- (Bus Controller Transmissions + Retries)
= 18,215 - (6,400 + 5,024)
= 6,791 words/sec

Overall utilization factor ρ = 6,791 / 50,000
= 0.13582

Total Number of Polls Np = Total Number of Polls in Case 1
- Number of Polls for Bus Controller
- Number of Polls for Retries
= 700 . 05 - (200 + 200)
= 300 . 05

Walk Time L = 150 + (300.05 - 1) X 250
= 74912 . 5 microsec
= 74.912 ms

Scan Time Tc = 74.912 / (1 - 0.13582)
= 86.69 ms

Average delay = Tc / 2 = 43.34 ms

TABLE 12

Delay Values for H/K Bus Without Slotting
Polling Cycle: Once Every 1/5 th Frame as Shown in Table 1

This case is applicable to EPS and HKPG.

Case 1: Controller and Retries are Included

EPS	GN&C	CMD/ MEMLOAD	TLM	HKPG	GN&C	CMD/ MEMLOAD	TLM

Number of Polls Required in 1/5 Frame Cycle:

DATA SOURCE	NUMBER OF POLLS	
EPS:	1	
	1	(Retry)
GN&C:	3	(Three Instruments)
	1	(Retry)
CMD/MEMLOAD:	3	(Three Instruments)
	1	(Retry)
TLM:	1	
	1	(Retry)
HKPG:	1	
	1	(Retry)
GN&C:	3	(Three Instruments)
	1	(Retry)
CMD/MEMLOAD:	3	(Three Instruments)
	1	(Retry)
TLM:	1	
	1	(Retry)
Bus Controller	8	

Total Number of Polls Np = 32

ρ = 0.3643 as before in Table 11, Case 1

Walk Time L = 150 + (32 - 1) X 250 microsec
= 8,150 microsec
= 8.15 ms

Scan Time Tc = L / (1 - ρ)
= 8.15 / (1 - 0.3643) = 12.82 ms

Average delay = Tc / 2 = 6.41 ms

TABLE 12 (Continued)

Case 2: Controller Transmissions are Excluded, Retries are Included

ρ = 0.2363 as before in Table 11, Case 2

Total Number of Polls Np = 24

Walk Time L = 150 + (24 - 1) X 250
= 5900 microsec
= 5.9 ms

Scan Time Tc = 5.9 / (1 - 0.2363)
= 7.72 ms

Average delay = Tc / 2 = 3. 86 ms

Case 3: Controller and Retries are Excluded

ρ = 0.13582 as before in Table 11, Case 3

Total Number of Polls Np = 16

Walk Time L = 150 + (16 - 1) X 250
= 3900 microsec
= 3.9 ms

Scan Time Tc = 3.9 / (1 - 0.13582)
= 4.513 ms

Average delay = Tc / 2 = 2.256 ms

TABLE 13

Delay Values for House Keeping Bus Without Slotting
Polling Cycle: Once every 1/10 th Frame as shown in Table 1

These delay values are applicable to overall GN&C, CMD/MEMLOAD, and TLM systems.

Case 1: Controller and Retries are Included

EPS --- HKPG	GN&C	CMD/ MEMLOAD	TLM

Number of Polls Required in 1/10 Frame Cycle:

DATA SOURCE	NUMBER OF POLLS	
EPS/HKPG:	1	
	1	(Retry)
GN&C:	3	(Three Instruments)
	1	(Retry)
CMD/MEMLOAD:	3	(Three Instruments)
	1	(Retry)
TLM:	1	
	1	(Retry)
BUS CONTROLLER	4	

Total Number of Polls Np = 16

ρ = 0.3643 as before in Table 11, Case 1

Walk Time L = 150 + (16 - 1)(200 + 50) microsec
= 3900 microsec
= 3.9 ms

Scan Time Tc = L / (1 - ρ)
= 3.9 / (1 - 0.3643)
= 6.135 ms

Average delay = Tc / 2 = 3.07 ms

TABLE 13 (Continued)

Case 2: Controller Transmissions are Excluded, Retries are Included

ρ = 0.2363 same as before Table 11, Case 2

Total Number of Polls Np = 12

Walk Time L = 150 + (12 - 1) X 250
= 2900 microsec
= 2.9 ms

Scan Time Tc = 2.9 / (1 - 0.2363)
= 3.8 ms

Average delay = Tc / 2 = 1.9 ms

Case 3: Controller and Retries are Excluded

ρ = 0.13582 same as before Table 11, Case 3

Total Number of Polls Np = 8

Walk Time L = 150 + (8 - 1) X 250
= 1900 microsec
= 1.9 ms

Scan Time Tc = 1.9 / (1 - 0.13582)
= 2.199 ms

Average delay = Tc / 2 = 1.1 ms

TABLE 14

Summary of Delay Values for the Housekeeping Bus

SLOTTED ALLOCATION SCHEME

Data Source	Worst Delay Time (ms)	Overall Average Worst Delay (ms)*	Average Delay Time (ms)	Overall Average Delay Time (ms)*
EPS	20		10	
GN&C	10		5	
CMD/MEM LOAD	10	12.5	5	6.25
TLM	10		5	
HKPG	20		10	
HGA Pointing CMD **	500		250	
HGA Position Samples **	500		250	

* Excluding the HGA Pointing CMD and HGA Position Samples.
** These are instruments in GN&C.

UNSLOTTED ALLOCATION SCHEME
Average Delay (ms)

Data Source	Case 1	Case 2	Case 3
EPS:	6.41	3.86	2.256
HKPG:	6.41	3.86	2.256
GN&C:	3.07	1.9	1.1
CMD/MEMLOAD:	3.07	1.9	1.1
TLM:	3.07	1.9	1.1
Weighted Average:	3.91	2.39	1.39

Weighted Average Delay Calculations:

Case 1: Weighted Average Delay = 1/8 (6.41 + 6.41) + 1/4 (3 X 3.07) = 3.91 ms

Case 2: Weighted Average Delay = 1/8 (3.86 + 3.86) + 1/4 (3 X 1.9) = 2.39 ms

Case 3: Weighted Average Delay = 1/8 (2.256 + 2.256) + 1/4 (3 X 1.1) = 1.39 ms

TABLE 15

WORST CASE AND AVERAGE DELAY FOR THE P/L ENGINEERING BUS (SLOTTED ALLOCATIONS)

SOURCE OF DATA	WORST DELAY TIME(WDT) (MS)	AVERAGE DELAY TIME(ADT) (MS)
ANCIL DATA	100	50
P/L MSG	50	25
CMD/MEMLOAD	10	5
TLM	10	5
HKPG	20	10

TABLE 16

OVERALL AVERAGE WORST DELAY TIME FOR P/L ENGINEERING BUS (SLOTTED ALLOCATIONS)

OVERALL AVERAGE WORST DELAY TIME =
1/40(WDT (ANCIL DATA)) + 2/40(WDT (P/L MSG)) +
10/40(WDT (CMD/MEMLOAD)) + 10/40(WDT (TLM)) +
5/40(WDT (HKPG)).

= 1/40(100 ms) + 2/40(50 ms) + 10/40(10 ms) +
10/40(10) + 5/40(20 ms).

=(100 + 100 + 100 + 100 + 100)/40 = 500/40 = 12.5 ms

TABLE 17

OVERALL AVERAGE DELAY TIME FOR P/L ENGINERING BUS (SLOTTED ALLOCATIONS)

OVERALL AVERAGE DELAY TIME =
1/40(ADT (ANCIL DATA)) + 2/40(ADT (P/LMSG)) +
10/40(ADT (CMD/MEMLOAD)) + 10/40(ADT (TLM)) +
5/40(ADT (HKPG)).

= 1/40(50 ms) + 2/40(25 ms) + 1/40(50 ms) +
10/40(5) + 5/40(10ms).

=(50 + 50 + 50 + 50 + 50)/40 = 250/40 = 6.25 ms

TABLE 18

CALCULATIONS FOR AVERAGE DELAYS FOR P/L ENGINEERING BUS WITHOUT SLOTTING

Delays values for CMD/MEMLOAD as a Group and TLM.

(Empty slots are not considered in calculations)

Case 1. Controller Transmission and Retries are included

SOURCE OF DATA	AVERAGE DATA RATE(words/sec)
ANCIL DATA	160
P/L MSG	320
CMD/MEMLOAD	1930
TLM	1600
HKPG	800
BUS CONTROLLER	12800
RETRY	12800

Total Average Data Rate = 30410
Sevice Rate = 50,000 words/sec
Utilization Factor ρ= 30410/50000 = 0.6082 < 1 (System is stable)

SOURCE OF DATA	REQUIRED NUMBER OF POLLS
ANCIL DATA	1
	1 Retry (R)
P/L MSG	1
	1 (R)
CMD/MEMLOAD	3
	1 (R)
TLM	1
	1 (R)
BUS CONTROLLER	4

Total Number of Polls = Np = 14
Poll Time = 20 + 20 + 10 = 50 microsec
Bus Controller Response Time : Start Time = 100 microsec
Intermessage Time = 200 microsec
Walk Time = L = (100 + 50) + (Number of Polls - 1)(200+50)
= 150 + (14 - 1)(250) = 3400 microsec = 3.4 ms
Scan Time = Tc = L /(1 - ρ) = 3.4/(1 - 0.6082) = 8.678 ms
Average Delay Time = E(D) = Tc/2 = 8.678/2 = 4.339 ms

Case 2. Controller Transmission is Excluded

Total average data rate = Total average data rate in Case 1 - data rate for Bus Controller = 30410 - 12800 = 17610
Utilization Factor ρ= 17610/50000 = 0.3522
Number of Polls = Np = Number of Polls in Case 1 - Number of Polls for Bus Controller = 14 - 4 = 10
Walk Time = L = 150 + (9)(250) = 2.4 ms
Scan Time = Tc = 2.4/(1 - 0.3522) = 3.704 ms
Average Delay Time = E(D) = Tc/2 = 3.704/2 = 1.852 ms

Case 3. Controller Transmission and Retries are excluded

Total Average Data Rate = Total Average Data Rate in Case 1 - Average Data Rates for Bus Controller and Retries = 4810
Utilization Factor ρ = 4810/50000 = 0.0962
Number of Polls = Np = Number of Polls in Case 1 - Number of Polls for Bus Controller and for retries = 6
Walk Time = L = 150 + (5)(250) = 1.4 ms
Scan Time = Tc = 1.4/(1 - 0.0962) = 1.549 ms
Average Delay Time = E(D) = Tc/2 = 1.549/2 = 0.7745 ms

Case 4. 50% Controller Transmission and 50% Retries are Excluded.

The result of this Case will be the same as in Case 2.
Thus Average Delay Time = E(D) = 1.852 ms.

Case 5. Retries are Excluded

The result of this Case will be the same as in Case 2.
Thus Average Delay Time = E(D) = 1.852 ms.

Case 6. 50% Controller Transmission is Excluded

Total Average Data Rate = Total Average Data Rate in Case 1 - 0.5(Average Data Rates for Bus Controller) = 24010 words/sec.
Utilization Factor ρ = 24010/50000 = 0.4802
Number of Polls = Np = Number of Polls in Case 1 - 0.5(Number of Polls for Bus Controller) = 12
Walk Time = L = 150 + (11)(250) = 2.9 ms
Scan Time = Tc = 2.9/(1 - 0.4802) = 5.579 ms
Average Delay Time = E(D) = Tc/2 = 5.579/2 = 2.789 ms

Case 7. 50% Retries are Excluded

The result of this Case will be the same as in Case 6
Thus Average Delay time = E(D) = 2.789 ms

Case 8. Controller Transmission and 50% Retries are Excluded

Total Average Data Rate = Total Average Data Rate in Case 1 - Average Data Rates for Bus Controller - 0.5(Retries) = 11210 words/sec.
Utilization Factor ρ = 11210/50000 = 0.2242
Number of Polls = Np = Number of Polls in Case 1 - Number of Polls for Bus Controller - 0.5(Retries) = 8
Walk Time = L = 150 + (7)(250) = 1.9 ms
Scan Time = Tc = 1.9/(1 - 0.2242) = 2.449 ms
Average Delay Time = E(D) = Tc/2 = 2.449/2 = 1.2245 ms

Case 9. Retries and 50% Controller Transmission are Excluded

The result of this Case will be the same as in Case 8.
Thus Average Delay Time = E(D) = 1.2245 ms.

TABLE 19

CALCULATIONS FOR THE AVERAGE DELAYS FOR P/L ENGINEERING BUS WITHOUT SLOTTING

Delay Values For HKPG

Case 1. Controller Transmission and Retries are Included

SOURCE OF DATA	REQUIRED NUMBER OF POLLS
HKPG	1
	1 (R)
CMD/MEMLOAD	2
	2 (R)
TLM	2
	2 (R)
BUS CONTROLLER	5

Utilization Factor = 0.6082 Same as in Case 1 in Table 17
Total Number of Polls = Np = 15
Walk Time = L = 150 + (14)(250) = 3.65 ms
Scan Time = Tc = 3.65/(1 - 0.6082) = 9.315 ms
Average Delay Time = E(D) = Tc/2 = 9.315/2 = 4.657 ms

Case 2. Controller Transmission is Excluded

Utilization Factor ρ = 0.3522 Same as in Case 2 in Table 17
Total Number of Polls = Np = Number of polls in case 1 - Number of polls for Bus Controller = 15 - 5 = 10
Walk Time = L = 150 + (9)(250) = 2.4 ms
Scan Time = Tc = 2.4/(1 - 0.3522) = 3.7048 ms
Average Delay Time = E(D) = Tc/2 = 3.7048/2 = 1.852 ms

Case 3. Controller Transmission and Retries are Excluded

Utilization Factor ρ = 0.0962 Same as in Case 3 in Table 17
Total Number of Polls = Np = Number of polls in case 1 - number of polls for Bus Controller and for Retries = 5
Walk Time = L = 150 + (4)(250) = 1.15 ms
Scan Time = Tc = 1.15/(1 - 0.0962) = 1.273 ms
Average Delay Time = E(D) = Tc/2 = 1.273/2 = 0.636 ms

Case 4. 50% Controller Transmission and 50% Retries are Excluded

The result in this Case will be the same as in Case 2.
Thus Average Delay Time = E(D) = 1.852 ms

Case 5. Retries are Excluded

The result of this Case will be the same as in Case 2.
Thus Average Delay Time = E(D) = 1.852 ms

Case 6. 50% Controller Transmission is Excluded

Utilization Factor ρ = 0.4802 Same as in Case 6 in Table 17
Total Number of Pollas = Np = Number of polls in case 1 - 0.5(number of polls for Bus Controller) = 12.5
Walk Time = L = 150 + (11.5)(250) = 3.025 ms
Scan Time = Tc = 3.025/(1 - 0.4802) = 5.819 ms
Average Delay Time = E(D) = Tc/2 = 5.819/2 = 2.909 ms

Case 7. 50% Retries are Excluded

The result of this Case will be the same as in Case 6.
Thus Average Delay Time = E(D) = 2.909 ms

Case 8. Controller Transmission and 50% retries are Excluded

Total Average Data Rate = Total Average Data Rate in Case 1 - Average Data Rates for Bus Controller - 0.5(Retries) = 11210 words/sec.
Utilization Factor ρ= 11210/50000 = 0.2242
Total Number of Polls = Np = Number of Polls in Case 1 - Number of Polls for Bus Controller - 0.5(Retries) = 7.5
Walk Time = L = 150 + (6.5)(250) = 1.775 ms
Scan Time = Tc = 1.775/(1 - 0.2242) = 2.287 ms
Average Delay Time = E(D) = Tc/2 = 2.287/2 = 1.1435 ms

Case 9. Retries and 50% Controller Transmission are Excluded

The result of this Case will be the same as in Case 8.
Thus Average Delay Time = E(D) = 1.1435 ms

TABLE 20

CALCULATIONS FOR THE AVERAGE DELAYS FOR P/L ENGINEERING BUS WITHOUT SLOTTING

Delay Values For P/L MSG

Case 1. Controller Transmission and Retries are Included

SOURCE OF DATA	REQUIRED NUMBER OF POLLS
P/L MSG	1
	1 (R)
CMD/MEMLOAD	7
	5 (R)
TLM	5
	5 (R)
HKPG	3
	3 (R)
BUS CONTROLLER	14

Utilization Factor ρ = 0.6082 Same as in Case 1 in Table 17
Total Number of Polls = Np = 44
Walk Time = L = 150 + (43)(250) = 10.9 ms
Scan Time = Tc = 10.9/(1 - 0.6082) = 27.82 ms
Average Delay Time = E(D) = Tc/2 = 27.82/2 = 13.910 ms

Case 2. Controller Transmission is Excluded

Utilization Factor ρ = 0.3522 Same as in Case 2 in Table 17
Total Number of Polls = Np = Number of Polls in Case 1 - Number of Polls for Bus controller = 44 - 14 = 30
Walk Time = L = 150 + (29)(250) = 7.4 MS
Scan Time = Tc = 7.4/(1 - 0.3522) = 11.423 ms
Average Delay Time = E(D) = Tc/2 = 11.423/2 = 5.711 ms

Case 3. Controller Transmission and Retries are excluded

Utilization Factor ρ = 0.0962 Same as in Case 3 in Table 17
Total Number of Polls = Np = Number of polls in Case 1 - Number of Polls for Bus Controller and for Retries = 16
Walk Time = L = 150 + (15)(250) = 3.9 ms
Scan Time = Tc = 3.9/(1 - 0.0962) = 4.315 ms
Average Delay time = E(D) = Tc/2 = 4.315/2 = 2.157 ms

Case 4. 50% Controller Transmission and 50% Retries are excluded

The result of this Case will be the same as in Case 2.
Thus Average Delay Time = E(D) = 5.711 ms

Case 5. Retries Are Excluded

The result of this Case will be the same as in Case 2.
Thus Average delay Time = E(D) = 5.711 ms

Case 6. 50% Controller Transmission is Excluded

Utilization Factor ρ = 0.4802 Same as in Case 6 in Table 17
Total Number of Pollas = Np = Number of polls in case 1 - 0.5(number of polls for Bus Controller) = 44 - 7 = 37
Walk Time = L = 150 + (36)(250) = 9.15 ms
Scan Time = Tc = 9.15/(1 - 0.4802) = 17.6 ms
Average Delay Time = E(D) = Tc/2 = 17.6/2 = 8.8 ms

Case 7. 50% Retries are Excluded

The result of this Caae will be the same as in Case 6.
Thus Average Delay Time = E(D) = 8.8 ms

Case 8. Controller Transmission and 50% Retries are Excluded

Total Average Data Rate = Total Average Data Rate in Case 1 - Average Data Rates for Bus Controller - 0.5(Retries) = 11210 words/sec.
Utilization Factor ρ = 11210/50000 = 0.2242
Total Number of Polls = Np = Number of Polls in Case 1 - Number of Polls for Bus Controller - 0.5(Retries) = 23
Walk Time = L = 150 + (22)(250) = 5.650 ms
Scan Time = Tc = 5.650/(1 - 0.2242) = 7.282 ms
Average Delay Time = E(D) = Tc/2 = 7.282/2 = 3.641 ms

Case 9. Retries and 50% Controller Transmission are Excluded

The result of this Case will be the same as in Case 8.
Thus Average Delay Time = E(D) = 3.641 ms

TABLE 21

CALCULATIONS FOR AVERAGE DELAY FOR P/L ENGINEERING BUS WITHOUT SLOTTING

Delay Values For ANCIL DATA.

Case 1. Controller Transmission and Retries are Included

SOURCE OF DATA	REQUIRED NUMBER OF POLLS
ANCIL DATA	1
	1 (R)
P/L MSG	2
	2 (R)
CMD/MEMLOAD	13
	10 (R)
TLM	10
	10 (R)
HKPG	5
	5 (R)
BUS CONTROLLER	28

Utilization Factor ρ = 0.6082 Same as in Case 1 in Table 17
Total Number of Polls = Np = 87
Walk Time = L = 150 + (86)(250) = 21.65 ms
Scan Time = Tc = 21.65/(1 - 0.6082) = 55.257 ms
Average Delay Time = E(D) = Tc/2 = 55.257/2 = 27.629 ms

Case 2. Controller Transmission is Excluded

Utilization Factor ρ = 0.3522 Same as in Case 2 in Table 17
Total Number of Polls = Np = Number of Polls in Case 1 - Number of polls for Bus Controller = 87 - 28 = 59
Walk Time = L = 150 + (58)(250) = 14.65
Scan Time = 14.65/(1 - 0.3522) = 22.615 ms
Average Delay = E(D) = Tc/2 = 22.615/2 = 11.307 ms

Case 3. Controller Transmission and Retries are Excluded

Utilization Factor ρ = 0.0962 same as in Case 3 in Table 17
Total Number of Polls = Np = Number of Polls in Case 1 - Number of Polls for bus Controller and for Retries = 31
Walk Time = L = 150 + (30)(250) = 7.65
Scan Time = Tc = 7.65 /(1 - 0.0962) = 8.465 ms
Average Delay Time = Tc/2 = 8.465/2 = 4.232 ms

Case 4. 50% Controller Transmission and 50% Retries are excluded

The result of this Case will be the same as in Case 2.
Thus Average Delay Time = E(D) = 11.307 ms

Case 5. Retries are Excluded

The result of this Case will be the same as in Case 2.
Thus Average Delay Time = E(D) = 11.307 ms

Case 6. 50% Controller Transmission is Excluded

Utilization Factor ρ = 0.4802 Same as in Case 6 in Table 17
Total Number of Pollas = Np = Number of polls in case 1 - 0.5(number of polls for Bus Controller) = 87 - 28/2 = 73
Walk Time = L = 150 + (72)(250) = 18.15 ms
Scan Time = Tc = 18.15/(1 - 0.4802) = 34.9 ms
Average Delay Time = E(D) = Tc/2 = 34.9/2 = 17.45 ms

Case 7. 50% Retries are Excluded

The result of this Case will be the same as in Case 6.
Thus Average Delay Time = E(D) = 17.45 ms

Case 8. Controller Transmission and 50% Retries are Excluded

Total Average Data Rate = Total Average Data Rate in Case 1 - Average Data Rates for Bus Controller - 0.5(Retries) = 11210 words/sec.
Utilization Factor ρ = 11210/50000 = 0.2242
Total Number of Polls = Np = Number of Polls in Case 1 - Number of Polls for Bus Controller - 0.5(Retries) = 87 - 28 - 14 = 45
Walk Time = L = 150 + (44)(250) = 11.15 ms
Scan Time = Tc = 11.15/(1 - 0.2242) = 14.37 ms
Average Delay Time = E(D) = Tc/2 = 14.37/2 = 7.186 ms

Case 9. Retries and 50% Controller Transmission are Excluded

The result of this Case will be the same as in Case 8.
Thus Average Delay Time = E(D) = 7.186 ms

TABLE 22

OVERALL AVERAGE DELAY FOR THE P/L ENG. BUS FOR CASE 1
(UNSLOTTED)

= 1/40(27.629) + 2/40(13.91) + 10/40(4.339)
10/40(4.339) + 5/40(4.657).

= 4.137 ms

TABLE 23

OVERALL AVERAGE DELAY FOR THE P/L ENG. BUS FOR CASE 2
(UNSLOTTED)

= 1/40(11.307) + 2/40(5.711) + 10/40(1.852)
10/40(1.852) + 5/40(1.852)

= 1.725 ms

TABLE 24

OVERALL AVERAGE DELAY FOR THE P/L ENG. BUS FOR CASE 3
(UNSLOTTED)

= 1/40(4.232) + 2/40(2.157) + 10/40(0.7745)
10/40(0.7745) + 5/40(0.636)

= 0.6804 ms

TABLE 25

OVERALL AVERAGE DELAY FOR THE P/L ENG. BUS FOR CASE 4
(UNSLOTTED)

The result of this Case will be the same as in Case 2 Table 22.
Thus Overall Average Delay = 1.725

TABLE 26

OVERALL AVERAGE DELAY FOR THE P/L ENG. BUS FOR CASE 5
(UNSLOTTED)

The result of this Case will be the same as in Case 2 Table 22.
Thus Overall Average Delay = 1.725 ms

TABLE 27

OVERALL AVERAGE DELAY FOR THE P/L ENG. BUS FOR CASE 6
(UNSLOTTED)

= 1/40(17.45) + 2/40(8.8) + 10/40(2.789)
10/40(2.789) + 5/40(2.909)

= 2.633 ms

TABLE 28

OVERALL AVERAGE DELAY FOR THE P/L ENG. BUS FOR CASE 7
(UNSLOTTED)

The result of this Case will be the same as in Case 6 Table 26.
Thus Overall Average Delay = 2.633 ms.

TABLE 29

OVERALL AVERAGE DELAY FOR THE P/L ENG. BUS FOR CASE 8
(UNSLOTTED)

= 1/40(7.186) + 2/40(3.641) + 10/40(1.2245)
10/40(1.2245) + 5/40(1.1435)

= 1.116ms

TABLE 30

OVERALL AVERAGE DELAY FOR THE P/L ENG. BUS FOR CASE 9
(UNSLOTTED)

The result of this Case will be the same as in Case 8 Table 28.
Thus Overall Average Delay = 1.116 ms.

TABLE 31

SUMMARY OF DELAY VALUES (P/L ENG. BUS)

SLOTTED ALLOCATION SCHEME

Source of Data	Worst Delay Time (ms)	Overall Average Worst Delay Time (ms)	Average Delay Time (ms)	Overall Average Delay Time (ms)
ANCIL	100		50	
P/L MSG	50		25	
CMD/MEMLOAD	10	12.5	5	6.25
TLM	10		5	
HKPG	20		10	

UNSLOTTED ALLOCATION SCHEME

Source of Data	Average Delay (ms) CASES 1	2	3	4	5	6	7	8	9
ANCIL	27.629	11.307	4.232	11.307	11.307	17.45	17.45	7.186	7.186
P/L MSG	13.910	5.711	2.157	5.711	5.711	8.8	8.8	1.708	1.708
CMD/MEMLOAD	4.339	1.852	.775	1.852	1.852	2.789	2.789	1.225	1.225
TLM	4.339	1.852	.775	1.852	1.852	2.789	2.789	1.225	1.225
HKPG	4.466	1.852	.636	1.852	1.852	3.15	3.15	1.144	1.144
OVERALL AVERAGE DELAY	5.0	1.725	.681	1.725	1.725	2.664	2.774	1.018	1.018

4.2.3 Delay values for P/L Science Bus

4.2.3.1 Introduction

Terminals are polled sequentially, with the transfer frame generator as bus controller. When an RT has a packet to send it is polled repeatedly untill all the packets have been transfered; that could be up to 16 sequential 1553 messages. The sub-address field is used as a sequence number, with high subaddress (above 16) used as special codes. If individual messages are in error, the subaddress will allow for a straightforward selective retransmission strategy.

One 1553 word is 20 bits long (16 word data plus 4 bit overhead). In one transmission 32 words can be transmitted; i.e., 512 bits of data can be transmitted. Upto sixteen 32 word transmissions can be combined to form one CCSDS packet.

CCSDS packet lengths are variable with a maximum of 8192 bits. As per down link transfer frame formats CCSDS packets can carry the following maximum number of data bits:

Grade 2 Frame - Coded Virtual Channel Data Unit (CVCDU), 6,976 bits (436 words).

Grade 3 Frame Virtual Channel Data Unit (VCDU), 8,016 bits (501 words).

With Grade II service (as per DN# SSP-DN-C&DH-005, dated 10/20/89), i.e., a bit error rate no greater than 10 ** -8, one CCSDS packet will contain 6,976 bits (436 words).

4.2.3.2 P/L Science Bus Traffic Allocation

The P/L Science Bus may be required to carry data from a group of known payload instruments and a group of unknown payload instruments as listed in Table 32. Out of these instruments only the low data rate ones are to be serviced by the 1553 Bus. Figure 6 shows the 1553 Payload Science Bus and the instruments that are serviced by it, and figure 7 shows a typical Transfer Frame Format. For this study only the low data rate known instruments are being considered, to determinw whether the 1553 Bus can handle atlest these instruments. Tables 33A, 33B, and 33C list the relevant low data rate instruments and the corresponding data generation rates. The data generated by the instruments is organized as CCSDS packets at the instrument site before transmission. Then these packets are transmitted using the 1553 Bus protocol. Tables 33A, 33B, and 33C also list the number of CCSDS packets generated by each instrument, CCSDS packetization overhead and total data output of each of these instruments. Table 33A uses a CCSDS packet size of 512 bits, Table 33B uses a CCSDS packet size of 592 bits, and Table 33C uses a CCSDS packet size of 7056 bits. These tables also show the data generation rate, packetization overhead, and total data output due to Telemetry and Ancillary functions.

The CCSDS packet sizes of 512 bits, 592 bits, and 7056 bits were selected after studying the percentage packetization overhead for a number of packet sizes. These results are shown in Table 34. From this table it is seen that packets of size 512 bits will have an overhead of 48.13%, packets of size 592 bits will have overhead of 44.53% and packets of size 7056 bits will have overhead of 26.43%. The instruments are to be polled in certain sequence. The number of times an instrument is polled in a polling cycle depends on the relative amount of data generation rate of that instrument. For the proposed polling scheme lowest rate instruments namely IPEI and COMM having data generation rate of 0.001 Mbps and 0.0 Mbps respectively are polled once per polling cycle, other instruments are assigned proportionately multiple number of polls per second, e.g. instrument ENACEOS with data generation rate of 0.005 Mbps is polled 5 times per cycle. According to this scheme the total number of polls per cycle are 375 as shown in Table 35.

Table 36 shows computation of command data received from the ground for distribution via the 1553 Buses to different instruments.

Table 37 summarizes the delay values for three packet sizes and nine possible cases of various degrees of retries and controller transmissions.

4.2.3.3 Delay Calculations for P/L Science Bus

Delay values were calculated for the following nine combinations of instrument data, degrees of retry, and controller transmissions.

(a) Instrument data + no retry + no controller transmission

(b) Instrument data + 10 % retry + no controller transmission

(c) Instrument data + 20 % retry + no controller transmission

(d) Instrument data + 30 % retry + no controller transmission

(e) Instrument data + 40 % retry + no controller transmission

(f) Instrument data + 30 % retry + 10 % controller transmission

(g) Instrument data + 30 % retry + 20 % controller transmission

(h) Instrument data + 20 % retry + 10 % controller transmission

(i) Instrument data + 20 % retry + 20 % controller transmission

4.2.3.3.1 Case 1: CCSDS packet size of 432 data bits plus an overhead of 80 bits (total packet size = 512 bits).

4.2.3.3.1.1 Bus load considering low data rate known instruments, telemetry and ancillary data only.

# Of Instruments	Max. Data words/sec	# of Packets
14 (P/L Sc)	25,732.5	809
2 (Telem & Ancillary)	1,900.0	60
16	27,632.5	869

4.2.3.3.1.2 Delay Value Calculations:

Delay values were calculated for the following seven cases:

(a) No retries and no Controller transmission.

Instrument data = 27,632.5 words/sec

Number of polls/cycle = N = 375

Utilization factor ρ= 27,632.5 / 50,000 = .5527

Walk time (L) = 150 + (N - 1) X 250 micro sec

$= 150 + (375 - 1) \times 250 = 93650$ micro sec = 93.65 ms

Scan Time $= L / (1 - \rho)$
$= 93.65 / (1 - .5527) = 209.34$ ms

(b) 10 per cent retries and no Controller transmission.

Instrument data = 27,632.5 words/sec

Number of polls/cycle = $N = 375 + 38 = 413$

Retry data = 2,763.25 words/sec

Total data = 27,632.5 + 2,763.25 = 30,395.5 words/sec

Utilization factor ρ = 30,395.5 / 50,000 = 0.6079

Walk time (L) $= 150 + (N - 1) \times 250$ micro sec
$= 150 + (413 - 1) \times 250 = 103,150$ micro sec = 103.15 ms

Scan Time $= L / (1 - \rho)$
$= 103.15 / (1 - .6079) = 263.08$ ms

(c) 20 per cent retries and no Controller transmission.

Instrument data = 27,632.5 words/sec

Number of polls/cycle = $N = 375 + 75 = 450$

Retry data = 5,526.5 words/sec

Total data = 27,632.5 + 5,526.5 = 33,159.0 words/sec

Utilization factor ρ = 33,159 / 50,000 = 0.66318

Walk time (L) $= 150 + (N - 1) \times 250$ micro sec
$= 150 + (450 - 1) \times 250 = 112,400$ micro sec = 112.4 ms

Scan Time $= L / (1 - \rho)$
$= 112.4 / (1 - .66318) = 333.71$ ms

(d) 30 per cent retries and no Controller transmission.

Instrument data = 27,632.5 words/sec

Number of polls/cycle = $N = 375 + 112.5 = 487.5 = 488$

Retry data = 8,289.75 words/sec

Total data = 27,632.5 + 8,289.75 = 35,922.25 words/sec

Utilization factor ρ = 35,922.25 / 50,000
= .7184

Walk time (L) $= 150 + (N - 1) \times 250$ micro sec
$= 150 + (488 - 1) \times 250$
= 121,900 micro sec = 121.9 ms

$$\begin{aligned}\text{Scan Time} &= L / (1 - \rho) \\ &= 121.9 / (1 - .7184) \\ &= 432.88 \text{ ms}\end{aligned}$$

(e) 40 per cent retries and no Controller transmission.

Instrument data = 27,632.5 words/sec

Number of polls/cycle = N = 375 + 150 = 525

Retry data = 11,053 words/sec

Total data = 27,632.5 + 11,053 = 38,685.5 words/sec

$$\begin{aligned}\text{Utilization factor } \rho &= 38{,}685.5 / 50{,}000 \\ &= .7737\end{aligned}$$

$$\begin{aligned}\text{Walk time (L)} &= 150 + (N - 1) \times 250 \text{ micro sec} \\ &= 150 + (525 - 1) \times 250 \\ &= 131{,}150 \text{ micro sec} = 131.15 \text{ ms}\end{aligned}$$

$$\begin{aligned}\text{Scan Time} &= L / (1 - \rho) \\ &= 131.15 / (1 - .7737) \\ &= 579.54 \text{ ms}\end{aligned}$$

(f) 30 per cent retries and 10 per cent Controller transmission.

Instrument data = 27,632.5 words/sec

Number of polls/cycle = N = 375 + 150 = 525

Retry data = 8,289.75 words/sec

Controller data = 0.1 X 23,287.5 = 2,328.75 words/sec

Total data = 27,632.5 + 8,289.75 + 2,328.75 = 38,251 words/sec

$$\begin{aligned}\text{Utilization factor } \rho &= 38{,}251 / 50{,}000 \\ &= .765\end{aligned}$$

$$\begin{aligned}\text{Walk time (L)} &= 150 + (N - 1) \times 250 \text{ micro sec} \\ &= 150 + (525 - 1) \times 250 \\ &= 131{,}150 \text{ micro sec} = 131.15 \text{ ms}\end{aligned}$$

$$\begin{aligned}\text{Scan Time} &= L / (1 - \rho) \\ &= 131.15 / (1 - .765) \\ &= 558.13 \text{ ms}\end{aligned}$$

(g) 30 per cent retries and 20 per cent Controller transmission.

Instrument data = 27,632.5 words/sec

Number of polls/cycle = N = 375 + 187.5 = 562.5 = 563

Retry data = 8,289.75 words/sec

Controller data = 0.2 X 23,287.5 = 4,657.5 words/sec

Total data = 27,632.5 + 8,289.75 + 4,657.5 = 40,579.75 words/sec

$$
\begin{aligned}
\text{Utilization factor } \rho &= 40{,}579.75 / 50{,}000 \\
&= .8116
\end{aligned}
$$

$$
\begin{aligned}
\text{Walk time (L)} &= 150 + (N - 1) \times 250 \text{ micro sec} \\
&= 150 + (563 - 1) \times 250 \\
&= 140{,}650 \text{ micro sec} = 140.65 \text{ ms}
\end{aligned}
$$

$$
\begin{aligned}
\text{Scan Time} &= L / (1 - \rho) \\
&= 140.65 / (1 - .8116) \\
&= 746.55 \text{ ms}
\end{aligned}
$$

4.2.3.3.2 Case 2: CCSDS packet size of 512 data bits plus an overhead of 80 bits (total packet size = 592 bits).

4.2.3.3.2.1 Bus load considering low data rate known instruments, telemetry and ancillary data only.

# Of Instruments	Max. Data words/sec	# of Packets
14 (P/L Sc)	25,107.5	684
2 (Telem & Ancillary)	1,850.0	50
16	26,957.5	734

4.2.3.3.2.2 Delay Value Calculations:

The delay values were calculated for the following ten cases:

(a) No retries and no Controller transmission.

Instrument data = 26,957.5 words/sec

Number of polls/cycle = N = 375

Number of additional polls to transmit per packet = 1

Additional data = 734 X 250
= 183,500 bits/sec
= 9,175 words/sec

Total data = 26,957.5 + 9,175
= 36,132.5 words/sec

Utilization factor ρ = 36,132.5 / 50,000
= .72265

Walk time (L) = 150 + (N - 1) X 250 micro sec
= 150 + (375 - 1) X 250
= 93650 micro sec = 93.65 ms

Scan Time = L / (1 - ρ)
= 93.65 / (1 - .72265)
= 337.66 ms

(b) 10 per cent retries and no Controller transmission.

Instrument data = 26,957.5 words/sec

Number of polls/cycle = N = 375 + 38 = 413

Number of additional polls to transmit per packet = 1

Additional data = 734 X 250 = 183,500 bits/sec = 9,175 words/sec

Instrument plus additional data = 26,957.5 + 9,175
= 36,132.5 words/sec

Retry data = 3,613.3 words/sec

Total data = 36,132.5 + 3,613.3 = 39,745.8

Utilization factor ρ = 39,745.8 / 50,000
= .7949

Walk time (L) = 150 + (N - 1) X 250 micro sec
= 150 + (413 - 1) X 250
= 103,150 micro sec = 103.15 ms

Scan Time = L / (1 - ρ)
= 103.15 / (1 - .7949)
= 502.93 ms

(c) 20 per cent retries and no Controller transmission.

Instrument data = 26,957.5 words/sec

Number of polls/cycle = N = 375 + 75 = 450

Number of additional polls to transmit per packet = 1

Additional data = 734 X 250 = 183,500 bits/sec = 9,175 words/sec

Instrument plus additional data = 26,957.5 + 9,175
= 36,132.5 words/sec

Retry data = 7,226.5 words/sec

Total data = 36,132.5 + 7,226.5 = 43,359.0

Utilization factor ρ = 43,359 / 50,000
= .8671

Walk time (L) = 150 + (N - 1) X 250 micro sec
= 150 + (450 - 1) X 250
= 112,400 micro sec = 112.4 ms

Scan Time = L / (1 - ρ)
= 112.4 / (1 - .8671)
= 845.75 ms

(d) 30 per cent retries and no Controller transmission.

Instrument data = 26,957.5 words/sec

Number of polls/cycle = N = 375 + 112.5 = 487.5 = 488

Number of additional polls to transmit per packet = 1

Additional data = 734 X 250 = 183,500 bits/sec = 9,175 words/sec

Instrument plus additional data = 26,957.5 + 9,175
= 36,132.5 words/sec

Retry data = 10,839.75 words/sec

Total data = 36,132.5 + 10,839.75 = 46,972.25

Utilization factor ρ = 46,972.25 / 50,000 = 0.939445

Walk time (L) = 150 + (N - 1) X 250 micro sec
= 150 + (488 - 1) X 250
= 121,900 micro sec = 121.9 ms

Scan Time = L / (1 - ρ)
= 121.9 / (1 - .939445)
= 2013.046 ms = 2.013 sec

(f) 30 per cent retries and 10 per cent Controller transmission.

Instrument data = 26,957.5 words/sec

Number of polls/cycle = N = 375 + 150 = 525

Number of additional polls to transmit per packet = 1

Additional data = 734 X 250 = 183,500 bits/sec = 9,175 words/sec

Instrument plus additional data = 26,957.5 + 9,175 = 36,132.5 words/sec

Retry data = 10,839.75 words/sec

Controller data = 0.1 X 23,287.5 = 2,328.75 words/sec

Total data = 36,132.5 + 10,839.75 + 2,328.75 = 49,301

Utilization factor ρ = 49,301 / 50,000 = 0.98602

Walk time (L) = 150 + (N - 1) X 250 micro sec
= 150 + (525 - 1) X 250 = 131150 micro sec = 131.15 ms

Scan Time = L / (1 - ρ) = 131.15 / (1 - .98602) = 9.381 sec

(h) 20 per cent retries and 10 per cent Controller transmission.

Instrument data = 26957.5 words/sec

Number of polls/cycle = N = 375 + 112.5 = 487.5 = 488

Number of additional polls to transmit per packet = 1

Additional data = 734 X 250
= 183,500 bits/sec
= 9,175 words/sec

Instrument plus additional data = 26,957.5 + 9,175
= 36,132.5 words/sec

Retry data = 7,226.5 words/sec

Controller data = 0.1 X 23,287.5 = 2,328.75 words/sec

Total data = 36,132.5 + 7,226.5 + 2,328.75 = 45,687.75

Utilization factor ρ = 45,687.75 / 50,000
= .913755

Walk time (L) = 150 + (N - 1) X 250 micro sec
= 150 + (487 - 1) X 250
= 121900 micro sec = 121.9 ms

Scan Time = L / (1 - ρ)
= 121.9 / (1 - .913755)
= 1,413.42 ms
= 1.413 sec

(i) 20 per cent retries and 20 per cent Controller transmission.

Instrument data = 26957.5 words/sec

Number of polls/cycle = N = 375 + 150 = 525

Number of additional polls to transmit per packet = 1

Additional data = 734 X 250
= 183,500 bits/sec
= 9,175 words/sec

Instrument plus additional data = 26,957.5 + 9,175
= 36,132.5 words/sec

Retry data = 7,226.5 words/sec

Controller data = 0.2 X 23,287.5 = 4,657.5 words/sec

Total data = 36,132.5 + 7,226.5 + 4,657.5 = 48,016.5 words/sec

Utilization factor ρ = 48,016.5 / 50,000
= .96033

Walk time (L) = 150 + (N - 1) X 250 micro sec
= 150 + (525 - 1) X 250
= 131150 micro sec = 131.15 ms

Scan Time = L / (1 - ρ)
= 131.15 / (1 - .96033)
= 3306.0245 ms
= 3.306 sec

4.2.3.3.3 Case 3: CCSDS packet size of 6,976 data bits plus an overhead of 80 bits (total packet size = 7,056 bits).

4.2.3.3.3.1 Bus load considering low data rate known instruments, telemetry and ancillary data only.

# Of Instruments	Max. Data words/sec	# of Packets
14 (P/L Sc)	21,977.5	58
2 (Telem & Ancillary)	1,620.0	4
16	23,597.5	62

4.2.3.3.3.2 Delay Value Calculations:

Delay values were calculated for the following five cases:

(a) No retries and no Controller transmission.

Instrument data = 23,597.5 words/sec

Number of polls/cycle = N = 375

Number of additional polls to transmit per packet = 13
Additional data = 62 X 13 X 250 = 3250 X 62
= 201,500 bits/sec
= 10,075 words/sec

Total data = 23,597.5 + 10,075
= 33,672.5 words/sec

Utilization factor ρ = 33,672.5 / 50,000
= .67345

Walk time (L) = 150 + (N - 1) X 250 micro sec
= 150 + (375 - 1) X 250
= 93650 micro sec = 93.65 ms

Scan Time = L / (1 - ρ)
= 93.65 / (1 - .67345)
= 286.79 ms

(b) 10 per cent retries and no Controller transmission.

Instrument data = 23,597.5 words/sec

Number of polls/cycle = N = 375 + 38 = 413

Number of additional polls to transmit per packet = 13
Additional data = 62 X 13 X 250 = 3250 X 62
= 201,500 bits/sec = 10,075 words/sec

Instrument plus additional data = 23,597.5 + 10,075
= 33,672.5 words/sec

Retry data = 3,367.2 words/sec

Total data = 33,672.5 + 3,367.2 = 37,039.7

Utilization factor ρ = 37,039.7 / 50,000 = 0.7408

Walk time (L) = 150 + (N - 1) X 250 micro sec
= 150 + (413 - 1) X 250
= 103,150 micro sec = 103.15 ms

Scan Time = L / (1 - ρ)
= 103.15 / (1 - .7408) = 397.96 ms

(c) 20 per cent retries and no Controller transmission.

Instrument data = 23,597.5 words/sec

Number of polls/cycle = N = 375 + 75 = 450

Number of additional polls to transmit per packet = 13
Additional data = 62 X 13 X 250 = 3250 X 62
= 201,500 bits/sec = 10,075 words/sec

Instrument plus additional data = 23,597.5 + 10,075
= 33,672.5 words/sec

Retry data = 6,734.4 words/sec

Total data = 33,672.5 + 6,734.4 = 40,406.9

Utilization factor ρ = 40,406.9 / 50,000 = 0.80814

Walk time (L) = 150 + (N - 1) X 250 micro sec
= 150 + (450 - 1) X 250 = 112,400 micro sec = 112.4 ms

Scan Time = L / (1 - ρ)
= 112.4 / (1 - .80814) = 585.84 ms

(d) 30 per cent retries and no Controller transmission.

Instrument data = 23,597.5 words/sec

Number of polls/cycle = N = 375 + 112.5 = 487.5 = 488

Number of additional polls to transmit per packet = 13
Additional data = 62 X 13 X 250 = 3250 X 62
= 201,500 bits/sec = 10,075 words/sec

Instrument plus additional data = 23,597.5 + 10,075
= 33,672.5 words/sec

Retry data = 10,101.75 words/sec

Total data = 33,672.5 + 10,101.75 = 43,774.25

Utilization factor ρ = 43,774.25 / 50,000 = 0.8755

Walk time (L) = 150 + (N - 1) X 250 micro sec
= 150 + (488 - 1) X 250 = 121,900 micro sec = 121.9 ms

Scan Time = L / (1 - ρ)
= 121.9 / (1 - .8755)
= 979.12 ms

(f) 30 per cent retries and 10 per cent Controller transmission.

Instrument data = 23,597.5 words/sec

Number of polls/cycle = N = 375 + 150 = 525

Number of additional polls to transmit per packet = 13
Additional data = 62 X 13 X 250 = 3250 X 62
= 201,500 bits/sec = 10,075 words/sec

Instrument plus additional data = 23,597.5 + 10,075
= 33,672.5 words/sec

Retry data = 10,101.75 words/sec

Controller transmission = 0.1 X 23,287.5 = 2,328.75

Total data = 33,672.5 + 10,101.75 + 2,328.75 = 46,102.5

Utilization factor ρ = 46,102.5 / 50,000 = 0.92205

Walk time (L) = 150 + (N - 1) X 250 micro sec
= 150 + (525 - 1) X 250
= 131,150 micro sec = 131.15 ms

Scan Time = L / (1 - ρ)
= 131.15 / (1 - .92205)
= 1682.4888 ms = 1.683 sec

TABLE 32

EOS PAYLOAD INSTRUMENT SUMMARIES

ELEMENT	Low/ High Rate	Violet Set	Violet Option A	Violet Option B	Violet Option C	Violet Option D	Peak Data Rate Mbps	Average Data Rate Mbps	Last Update
Hi-Rate P/Ls									
AIRS	H	X	X	X	X	X	2.000	2.000	5/16/90
HIRIS	H	X	X	X	X	X	100.000	3.000	5/16/90
ITIR	H		X		X		89.200	8.300	5/16/90
MISR	H	X	X	X	X	X	4.800	0.143	5/16/90
MODIS-T	H	X	X	X	X	X	3.000	1.500	5/16/90
MODIS-N	H	X	X	X	X	X	15.000	7.500	5/16/90
POEMS	H			X			0.500	0.013	5/16/90
WBDCS	H	X				X	2.000	0.512	5/16/90
Hi-Rate P/L Peak Rate Sum		126.800	214.000	125.300	214.000	126.800	216.500	22.968	
Avg. Rate Sum	---	14.655	22.443	14.156	22.443	14.655	--------	--------	--------
Lo-Rate P/Ls									
AMSU-A	L		X	X	X	X	0.003	0.003	5/16/90
AMSU-B	L		X	X	X	X	0.004	0.004	5/16/90
ALT	L		X			X	0.085	0.085	5/16/90
CERES-IN	L	X	X	X	X	X	0.010	0.010	5/16/90
ENACEOS	L			X			0.005	0.005	5/16/90
EOSP	L		X	X	X	X	0.088	0.044	5/16/90
GGI	L	X	X	X	X	X	0.050	0.050	5/16/90
HIMSS	L	X	X	X	X	X	0.060	0.060	5/16/90
HIRDLS	L				X		0.015	0.015	5/16/90
IPEI	L			X			0.001	0.001	5/16/90
LIS	L	X	X	X	X	X	0.006	0.001	5/16/90
MOPPITT,TRACE	L					X	0.015	0.015	5/16/90
STIKSCAT	L		X	X	X	X	0.005	0.005	5/16/90
COMM	L	X	X	X	X	X	0.000	0.000	0
Lo-Rate P/L Peak Rate Sum		0.126	0.311	0.232	0.241	0.326	218.847	0.298	
Avg. Rate Sum	---	0.121	0.262	0.183	0.192	0.277	--------	--------	--------
Peak Totals		126.926	214.311	125.532	214.241	127.126	216.847	23.266	
Avg. Totals	---	14.776	22.705	14.339	22.635	14.932	--------	--------	--------
Unknown P/Ls									
ACRIM	L						0.003	0.003	5/16/90
GLRS	H						0.800	0.400	5/16/90
GOS	L						0.008	0.008	5/16/90
MLS	H						1.000	0.900	5/16/90
SAFIRE	H						9.000	9.000	5/16/90
SAGE III	L						0.082	0.015	5/16/90
SCANSCAT	L						0.050	0.050	5/16/90
SEM	L						0.003	0.003	5/16/90
SOLSTICE	L						0.005	0.005	5/16/90
SWIRLS	L						0.001	0.001	5/16/90
TES	H						30.000	5.000	5/16/90
XIE	L						0.050	0.020	5/16/90

TABLE 33 A

LOW DATA RATE PAYLOAD SCIENCE BUS INSTRUMENTS
DATA GENERATION & CCSDS PACKET FORMATION

CCSDS Packet Size = 432 + 80 = 512 bits

Element	Peak Data Rate (Mbs)	Peak Data Rate (words/sec)	Number of Packets	CCSDS Overhead (words/sec)	Total Data (words/sec)
A. Known Payloads					
AMSU-A	0.003	187.5	7	35	222.5
AMSU-B	0.004	250.0	10	50	300.0
ALT	0.085	5,312.5	197	985	6,297.5
CERES-IN	0.010	625.0	24	120	745.0
ENACEOS	0.005	312.5	12	60	372.5
EOSP	0.088	5,500.0	204	1,020	6,520.0
GGI	0.050	3,125.0	116	580	3,705.0
HIMSS	0.060	3,750.0	139	695	4,445.0
HIRDLS	0.015	937.5	35	175	1,112.5
IPEI	0.001	62.5	3	15	77.5
LIS	0.006	375.0	14	70	445.0
MOPPITT, TRACE	0.015	937.5	35	175	1,112.5
STIKSCAT	0.005	312.5	12	60	372.5
COMM	0.000	0.0	1	5	5.0
B. Additional Payloads					
TELEMETRY	0.02048	1,280.0	48	240	1,520.0
ANCILLARY	0.00512	320.0	12	60	380.0
Instruments (16)	0.3726	23,287.5	869	4,345	27,632.5

TABLE 33 B

LOW DATA RATE PAYLOAD SCIENCE BUS INSTRUMENTS
DATA GENERATION & CCSDS PACKET FORMATION

CCSDS Packet Size = 512 + 80 = 592 bits

Element	Peak Data Rate (Mbs)	Peak Data Rate (words/sec)	Number of Packets	CCSDS Overhead (words/sec)	Total Data (words/sec)
A. Known Payloads					
AMSU-A	0.003	187.5	6	30	217.5
AMSU-B	0.004	250.0	8	40	290.0
ALT	0.085	5,312.5	167	835	6,147.5
CERES-IN	0.010	625.0	20	100	725.0
ENACEOS	0.005	312.5	10	50	362.5
EOSP	0.088	5,500.0	172	860	6,360.0
GGI	0.050	3,125.0	98	490	3,615.0
HIMSS	0.060	3,750.0	118	590	4,340.0
HIRDLS	0.015	937.5	30	150	1,087.5
IPEI	0.001	62.5	2	10	72.5
LIS	0.006	375.0	12	60	435.0
MOPPITT, TRACE	0.015	937.5	30	150	1,087.5
STIKSCAT	0.005	312.5	10	50	362.5
COMM	0.000	0.0	1	5	5.0
B. Additional Payloads					
TELEMETRY	0.02048	1,280.0	40	200	1,480.0
ANCILLARY	0.00512	320.0	10	50	370.0
Instruments (16)	0.3726	23,287.5	734	3,670	26,957.5

TABLE 33 C

LOW DATA RATE PAYLOAD SCIENCE BUS INSTRUMENTS
DATA GENERATION & CCSDS PACKET FORMATION

CCSDS Packet Size = 6976 + 80 = 7056 bits

Element	Peak Data Rate (Mbs)	(words/sec)	Number of Packets	CCSDS Overhead (words/sec)	Total Data (words/sec)
A. Known Payloads					
AMSU-A	0.003	187.5	1	5	192.5
AMSU-B	0.004	250.0	1	5	255.0
ALT	0.085	5,312.5	13	65	5,377.5
CERES-IN	0.010	625.0	2	10	635.0
ENACEOS	0.005	312.5	1	5	317.5
EOSP	0.088	5,500.0	13	65	5,565.0
GGI	0.050	3,125.0	8	40	3,165.0
HIMSS	0.060	3,750.0	9	45	3,795.0
HIRDLS	0.015	937.5	3	15	952.5
IPEI	0.001	62.5	1	5	67.5
LIS	0.006	375.0	1	5	380.0
MOPPITT, TRACE	0.015	937.5	3	15	952.5
STIKSCAT	0.005	312.5	1	5	317.5
COMM	0.000	0.0	1	5	5.0
B. Additional Payloads					
TELEMETRY	0.02048	1,280.0	3	15	1,295.0
ANCILLARY	0.00512	320.0	1	5	325.0
Instruments (16)	0.3726	23,287.5	62	310	23,597.5

TABLE 34

CCSDS VARIABLE LENGTH DATA PACKET OVERHEAD

	1553 Bus	CCSDS	Total	1553 Bus		Overhead	
Words	Data (bits)	Overhead (bits)	Data (bits)	Words	Bits	(bits)	%
1	16	80	96	6	120	104	650.0
2	32	80	112	7	140	108	337.5
3	48	80	128	8	160	112	233.3
4	64	80	144	9	180	116	181.25
5	80	80	160	10	200	120	150.0
6	96	80	176	11	220	124	129.17
7	112	80	192	12	240	128	114.29
8	128	80	208	13	260	132	103.13
9	144	80	224	14	280	136	94.45
10	160	80	240	15	300	140	87.5
32	512	80	592	37	740	228	44.53
57	912	80	992	62	1,240	328	35.97
75	1,200	80	1,280	80	1,600	400	33.33
94	1,504	80	1,584	99	1,980	476	31.65
113	1,808	80	1,888	118	2,360	552	30.53
188	3,008	80	3,088	193	3,860	852	28.33
282	4,512	80	4,592	287	5,740	1,228	27.22
313	5,008	80	5,088	318	6,360	1,352	27.00
436	6,976	80	7,056	441	8,820	1,844	26.43

TABLE 35

LOW DATA RATE PAYLOAD SCIENCE BUS INSTRUMENTS
PROPORTIONAL NUMBER OF POLLS FOR WALK TIME CALCULATION

One poll per 0.001 Mbps data has been assumed as the reference for calculation of proportional polls.

Element	Peak Data Rate (Mbs)	(words/sec)	Number of Polls/cycle
A. Known Payloads			
AMSU-A	0.003	187.5	3
AMSU-B	0.004	250.0	4
ALT	0.085	5,312.5	85
CERES-IN	0.010	625.0	10
ENACEOS	0.005	312.5	5
EOSP	0.088	5,500.0	88
GGI	0.050	3,125.0	50
HIMSS	0.060	3,750.0	60
HIRDLS	0.015	937.5	15
IPEI	0.001	62.5	1
LIS	0.006	375.0	6
MOPPITT, TRACE	0.015	937.5	15
STIKSCAT	0.005	312.5	5
COMM	0.000	0.0	1
B. Additional Payloads			
TELEMETRY	0.02048	1,280.0	21
ANCILLARY	0.00512	320.0	6
Instruments (16)	0.3726	23,287.5	375

TABLE 36

BUS CONTROLLER COMMAND DATA

Bus controller gets command data through Ku-band and S-band uplinks. Total command data has been worked out in this table.

Ku-band commands	100 Kbps
Frame size	592 bits
Command data/frame	408 bits

Ku-band Command data/sec = 100,000 X 408 / 592
= 68,912 bits/sec

S-band	2 Kbps

Case 1.

Frame size	552 bits
Command data/frame	512 bits

S-band Command data/sec = 2,000 X 512 / 552
= 1,856 bits/sec

Case 2.

Frame size	72 bits
Command data/frame	32 bits

S-band Command data/sec = 2,000 X 32 / 72
= 889 bits/sec

Total Command Data	Case 1	=	68,912 + 1,856
		=	70,768 bits/sec
	Case 2	=	68,912 + 889
		=	69,801 bits/sec

Total Command Data (Max) = 70,768 bits/sec

Distributing total command data equally to spacecraft H/K, P/L Eng, and P/L Science buses.

Command Data on each bus = 23,590 bits/sec
= 738 commands/sec (23,590/32)

P/L Science Bus

These commands (738) are for high rate (HR) point to point links and for the P/L Science bus instruments.

For P/L Science Bus instruments = 738 X 16 / 24
= 4[illegible] commands

Contd. 2

TABLE 36

BUS CONTROLLER COMMAND DATA

```
Case A - Distribute one command per poll
         Polls needed = 492
         Additional walk time = 492 X 250 micro sec
                              = 123 ms

Case B - 1553 can take 32 words per poll
         ( 512 bits or 16, 32 bit commands per sec)

         Distribute sixteen commands per poll
         Polls needed =  31    (492/16)
         Additional walk time = 31 X 250 micro sec
                              = 7.75 ms

Case A - Distribute eight commands (average) per poll
         Polls needed =  62    (492/8)
         Additional walk time =  62 X 250 micro sec
                              = 15.5 ms


Command data flow on 1553 bus  =  (70,768 / 3) X (16 / 24) X 1.25
                               =  19,658 bits/sec
```

TABLE 37

LOW DATA RATE PAYLOAD SCIENCE BUS INSTRUMENTS
SUMMARY OF RESULTS

Delay values were calculated for the following nine combinations of instrument data, degrees of retry, and controller transmissions.

(a) Instrument data + no retry + no controller transmission

(b) Instrument data + 10 % retry + no controller transmission

(c) Instrument data + 20 % retry + no controller transmission

(d) Instrument data + 30 % retry + no controller transmission

(e) Instrument data + 40 % retry + no controller transmission

(f) Instrument data + 30 % retry + 10 % controller transmission

(g) Instrument data + 30 % retry + 20 % controller transmission

(h) Instrument data + 20 % retry + 10 % controller transmission

(i) Instrument data + 20 % retry + 20 % controller transmission

Delay Values

	Packet Size (bits)					
	512		592		7056	
Combination	Scan/Cycle Time (ms)		Scan/Cycle Time (ms)		Scan/Cycle Time (ms)	
a	209.34	0.5527	337.66	0.72265	286.79	0.67345
b	263.08	0.6079	502.93	0.7949	397.96	0.7408
c	331.71	0.66318	845.75	0.8671	585.84	0.808
d	432.88	0.7184	2013.00	0.93945	979.12	0.9755
e	579.54	0.7737				
f	558.13	0.765	9381.00	0.98602	1683.00	0.9221
g	746.55	0.8116				
h			1413.00	0.9138		
i			3306.00	0.9603		

5. CONCLUSIONS:

A delay analysis of the performance of the 1553 Bus used either as H/K, P/L Eng., or P/L Science Bus is presented. The performance is evaluated by calculating the delays encountered by messages by developing and using a queue theoretic model of the H/K and P/L Engineering Buses implemented with the 1553 Bus.

Delay values are calculated under a slotted allocation scheme suggested by General Electric (GE) Company and also under an unslotted allocation scheme. In the GE slotted allocation scheme every subsystem is assigned fixed 2.5 ms long slot for transmission/reception irrespective of whether the subsystem has data for trasmission/reception. In the unslotted allocation scheme presented here there is no pre-assignment of slots and a subsystem is allowed access to the channel for only the length of time needed for transmission/reception of actual accumulated data.

Worst case and average delay for individual subsystems and overall average delays are presented for the slotted allocation scheme. For the unslotted scheme average delays are presented for the various subsystems under a number of loading conditions. Also overall average delays are presented for these loading conditions. Results are presented in Table forms for easy perusal. Tables (Tables 14 and 31) summarizing and comparing these delays are also presented. It is observed from Table 14 for the H/K Bus that for the sequence of subsystems being served by the 1553 Bus, the delay values for all subsystems under the GE slotted allocation scheme are higher than in the unslotted allocation scheme for the corresponding subsystems. The actual delay value under the unslotted allocation scheme depends on the loading condition. Three cases of loadings are considered as explained in section 4.2.1.4 . The delay values are, as expected, higher in case 1, lower in case 2 and lowest in case 3.

Similarly, for the P/L Engineering Bus the delay values under the slotted scheme are higher than in the unslotted scheme. The actual delay values depend on the loading conditions.

In the slotted allocation scheme all subsystems are assigned fixed 2.5 ms slots that may include transmission and retries by the subsystem, and transmission by the Bus Controller. However, every slot may not require retry and transmission by the Bus Controller. Also the length of the transmission by the subsystems may vary. However, in the slotted scheme, each subsystem is assigned slots of 2.5 ms length irrespective of its need.

The unslotted allocation scheme allows analysis of the Buses under flexible allocation schedule and time. The unslotted allocation scheme is considered here to investigate the effect on delay values, of flexible allocation in terms of the numbers of retries and transmissions by the Bus Controller to the subsystems. A number of cases, in which different number of retries and transmissions by the Controller are allowed, are considered. These results are summarized in Table 14 for the H/K Bus and in Table 31 for the P/L Eng. Bus. It is observed from these tables that the delay values depend on the loading and lower delay values can be realized if the number of retries and the transmission by the Bus Controller can be reduced or eliminated.

Whether slotted allocation scheme or unslotted allocation scheme is more suitable for the H/K and P/L Eng. Buses depends on many considerations. However, the analysis presented here shows the comparative delay values for the two schemes. These results should be helpful in making such a decision.

For the P/L Science Bus the aim was to determine if the 1553 Bus can handle the data produced by the low rate payload instruments listed in table 32.

According to C&DH subsystem specfication [5] dated March 19, 1990, the following conditions are to be satisfied:

a. Aggregate data from all low rate instruments should be less than 200 Kbps.
b. An instrument transmits full packets only.
c. Packet size can be between 80 bits and 8192 bits.
d. Maximum allowed cycle time (latency) = 300 ms.

From tables 32 and 37 it is seen that:

a. The total data rate for only the known low_rate payloads is 347 Kbps which is greater than 200 Kbps. Thus condition ($\bar{a}$) above is violated. If the telemetry, ancillary, command data, and data from unknown payloads are added then the situation becomes even worse.
b. Cycle time (latency) depends on the packet size
    i. for packet size of 512 bits, data from the known payloads plus 10 % retries can be handled.
    ii. for packet size of 592 bits and larger, even the data from the known low rate payloads can not be handled.
c. In most of the cases considered (cf Figure 37) the situation is marginal and slight changes in the payload data rate and/or retry and controller transmissions will take the system over the limit. The analysis has been done only for the known low rate payloads. If any other payloads are added (unknown payloads from the list in table 32) then the one 1553 Bus may not be able to handle the load.

6. REFERENCES

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4. Mischa Scwartz, "Telecommunication Networks", Addison Wesley Publishing Company N.Y., 1987.

5. C&DH Subsystem Specifications, March 19, 1990.