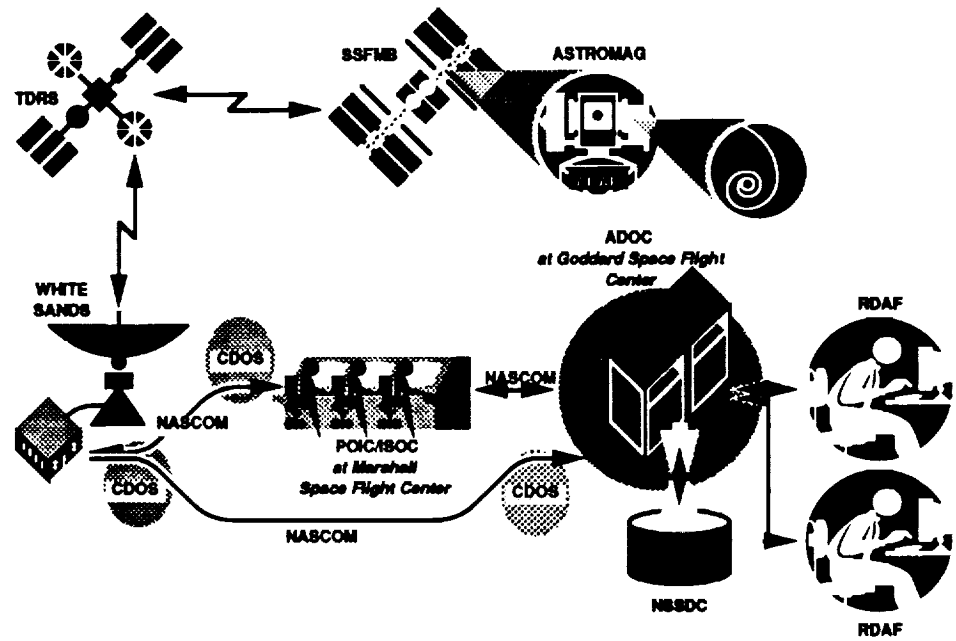
Goddard
256736
P. 45

CTA INCORPORATED

ASTROMAG DATA SYSTEM CONCEPT



(NASA-CR-186341) ASTROMAG DATA SYSTEM CONCEPT Final Report, Aug. - Dec. 1989 (Computer Technology Associates) 45 p CSCL 22B

N91-23211

Unclas
G3/18 0256736

Contract NAS5-30546, Task 103

DECEMBER 29, 1989

CTA INCORPORATED
6116 EXECUTIVE BLVD ROCKVILLE MD 20852

NASA
National Aeronautics and Space Administration

Report Documentation Page

1. Report No.

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle

Astromag Data System Concept

5. Report Date

December 1989

6. Performing Organization Code

7. Author(s)

Darrell Roos
Chieh-San Cheng
Penny Newsome
Nitya Nath

8. Performing Organization Report No.

9. Performing Organization Name and Address

CTA INCORPORATED
6116 Executive Boulevard
Suite 800
Rockville, Maryland 20852

10. Work Unit No.

11. Contract or Grant No.

12. Sponsoring Agency Name and Address

National Aeronautics and SpaceAdministration
Goddard Space Flight Center
Greenbelt, Maryland 20771

13. Type of Report and Period Covered

NAS5-30546, Task 103

14. Sponsoring Agency Code

Final Report/August 1989 to December 1989

15. Supplementary Notes

16. Abstract

The purpose of this report is to define a feasible, top-level data system that could accomplish and support the Astromag Data System functions and interfaces necessary to support the scientific objectives of Astromag in the environment that the Space Station Freedom Manned Base (SSFMB) and the other National Aeronautics and Space Administration (NASA) elements are anticipated to provide.

17. Key Words (Suggested by Author(s))

Astromag
Space Station Freedom
Attached Payload
Data Management System
Ground Data System

18. Distribution Statement

Unclassified - Unlimited

19. Security Classif. (of this report)

20. Security Classif. (of this page)

21. No. of pages

-43-

22. Price

NASA FORM 1626 OCT 86

TABLE OF CONTENTS

Section | Page

List of Figures iv

List of Tables v

Acronym List vi

1.0 Introduction 1-1

1.1 Purpose and Scope 1-1
1.2 Contents of this Report 1-1
1.3 Astromag Attached Payload Overview 1-1

1.3.1 LISA Characteristics 1-2
1.3.2 WiZard Characteristics 1-3
1.3.3 SCINATT Characteristics 1-3

2.0 Astromag Data System (ADS) Required Functions and Interfaces 2-1

2.1 Astromag Space Data System (ASDS) Required Functions and Interfaces 2-1

2.1.1 Astromag-Space Data System (ASDS) Required Functions and Interfaces 2-1
2.1.2 Required Functions and Interfaces for the Astromag Space Data System (ASDS) based on the Interface with the APAE and SSFMB 2-4
2.1.3 Summary of the Required Functions and Interfaces for the Astromag Space Data System (ASDS) 2-6

2.2. Astromag Ground Data System (AGDS) Required Functions and Interfaces 2-6

2.2.1 Astromag Ground Data System (AGDS) Required Functions based on Support of the Instruments and the Core Facility 2-6
2.2.2 Required Functions and Interfaces for the Astromag Ground Data System (AGDS) based on the Interface with the Space Network (SN) and other NASA Facilities 2-9

3.0 Astromag Data Systems Concept of Operations 3-1

4.0 Astromag Space Data System (ASDS) 4-1

4.1 Astromag Space Data System (ASDS) Overview 4-1
4.2 Astromag Space Data System (ASDS) Interfaces 4-2
4.3 Astromag Space Data System (ASDS) Functions 4-4

TABLE OF CONTENTS

Section Page

4.3.1 Astromag Instruments 4-4
4.3.2 Astromag Core Facility 4-4

4.3.2.1 Communications and Data Handling (C&DH) System 4-4
4.3.2.2 Thermal System 4-4
4.3.2.3 Power System 4-6

4.3.3 APAE Data Handling System (DHS) 4-6

4.4 Astromag Space Data System (ASDS) Architecture 4-6

5.0 Astromag Ground Data System (AGDS) 5-1

5.1 Astromag Ground Data System (AGDS) Overview 5-1
5.2 Astromag Ground Data System (AGDS) Functions 5-3

5.2.1 CDOS 5-4
5.2.2 POIC 5-4
5.2.3 ISOC 5-4

5.2.3.1 Discipline Operations Facility (DOF) 5-4
5.2.3.2 Command ManagementSystem (CMS) 5-7

5.2.4 Astromag Data Operations Center (ADOC) 5-7

5.2.4.1 Remote Operations Facility (ROF) 5-7
5.2.4.2 Data Processing Facility (DPF) 5-8
5.2.4.3 Data Management Facility (DMF) 5-8
5.2.4.4 Data Analysis Facility (DAF) 5-8

5.2.5 Remote Data Analysis Facilities (RDAFs) 5-8

5.3 Astromag Ground Data System (AGDS) Interfaces 5-9
5.4 Astromag Ground Data System (AGDS) Conceptual Architecture 5-9

6.0 Astromag Data Systems Issues 6-1

LIST OF FIGURES

Figure Number		Page
1	Astromag Data System Block Diagram	2-2
2	Astromag Space Data System Interface Overview	2-3
3	APAE DHS Architecture: Proposed by GE	2-5
4	Astromag Data Systems Concept of Operations	3-2
5	Astromag Space Data System Interface (N-Squared) Chart	4-3
6	Astromag Space Data System Interface Mediums and Elements	4-5
7	Feasible Astromag Space Data System Architecture	4-7
8	Alternate Astromag Space Data System Architecture	4-10
9	Astromag Ground Data System Top-Level Functionality	5-2
10	Conceptual Astromag Ground Data System N-Squared Diagram	5-5
11	Conceptual Astromag Ground Data System Architecture	5-10

LIST OF TABLES

Table Number Page

1 Required Functions and Interfaces for the Astromag Space Data System 2-7
2 Required Data Rate Capacities 2-8
3 Astromag Space Data System Interface Information Flow 4-2
4 Possible Astromag Space Data System (ASDS) Information Flow 4-9
5 Proposed Instrument Data Rates 5-3
6 Astromag Interfaces 5-6

ACRONYM LIST

ADOC	Astromag Data Operations Center
ADS	Astromag Data System
AGDS	Astromag Ground Data System
ASDS	Astromag Space Data System
APAE	Attached Payload Accommodations Equipment
ASDS	Astromag Space Data System
ATAT	Astromag Technical Advisory Team
BBMF	Balloon-Borne Magnet Facility
CCSDS	Consultative Committee for Space Data Systems
CDOS	Customer Data and Operations System
C&DH	Communications and Data Handling
C&TS	Communications and Tracking System
CMS	Command Management System
CPU	
DAF	Data Analysis Facility
DBMS	Data Base Management System
DHS	Data Handling System
DMF	Data Management Facility
DOF	Discipline Operations Facility
DPF	Data Processing Facility
FTSA	FTS Accommodation
GE	General Electric
GSFC	Goddard Space Flight Center
HRD	High Rate Data
I/O	Input/Output
ISOC	Integrated Science Operations Center
LAN	Local Area Network
LZP	Level Zero Processing
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administrations
NASCOM	NASA Communications Network
NSSDC	National Space Science Data Center
PBAR	
PI	Principal Investigator
PIA	Payload Interface Adapter
POIC	Payload Operations Integration Center
RDAF	Remote Data Analysis Facility
ROF	Remote Operations Facility

SIA	Station Interface Adapter
SN	Space Network
SSFMB	Space Station Freedom Manned Base
SSFP	Space Station Freedom Program
STS	Space Transportation System
TBD	To be Determined
T&F	Time and Frequency
TDRSS	Tracking and Data Relay Satellite System
VCGW	Virtual Channel GateWay
WP-3	Work Package 3
WSC	White Sands Complex

1.0 INTRODUCTION

1.1 Purpose and Scope

The purpose of this report is to define a feasible, top-level data system that could accomplish and support the Data System functions and interfaces necessary to support the scientific objectives of Astromag in the environment that the Space Station Freedom Manned Base (SSFMB) and the other National Aeronautics and Space Administration (NASA) elements are anticipated to provide. The designs, operations, and schedules of SSFMB, Attached Payload Accommodations Equipment (APAE), Astromag, and data support systems are preliminary and fluid at this time. There is however enough information to allow a conceptual definition of the Astromag Data System (ADS) to a level that can be evaluated for feasibility and to define issues that should be resolved early in Phase B in order for the Astromag Project to proceed successfully.

There are two aspects to operating Astromag on SSFMB. There are servicing operations (installation, instrument changeout, etc.) that are addressed in other reports and there are remote and on-board command and telemetry processing operations that are discussed in this report. In order to provide a comprehensive discussion of the ADS, this report includes a Data System Operations Concept. This concept does not address all of the Astromag operations issues but is an attempt to cover the broad requirements that affect the ADS.

1.2 Contents of this Report

Section 1.1 is an Introduction that includes the Purpose and Scope of the report, describes the contents of this report and provides an overview of the Astromag Attached Payload and its scientific objectives and functionality. The second section of this report addresses the required functions and interfaces that the ADS needs to satisfy.

The last three sections of this report define the conceptual design for the ADS. The immaturity of the required functions and of the designs of interfacing systems can only lead to a conceptual design for these items. In Section 3.0, a preliminary data system operations concept for Astromag is presented. In Section 4.0, a conceptual design for the Astromag Space Data System (ASDS) is defined. In Section 5.0, a conceptual design for the Astromag Ground Data System (AGDS) is defined. In Section 6.0, issues that should be analyzed in future studies are described.

1.3 Astromag Attached Payload Overview

An overview of the Astromag Attached Payload/Space Segment and the individual scientific experiments is presented in this section. The primary purpose of this discussion is to facilitate an understanding of the Astromag Attached Payload objectives that drive the science and engineering, uplink and downlink requirements.

The Astromag Attached Payload consists of a Core Facility, two attached experiments/instruments on opposite sides of the Core Facility, APAE elements that support the Core Facility and SSFMB Support Equipment that support the APAE. The Core Facility includes an Astromag Support Structure, a Magnet Cryostat Assembly, and a Communications and Data Handling System (C&DH). The Magnet Cryostat Assembly includes two parallel but oppositely circulating super conducting coils and a Superfluid

Helium Dewar to cool the coils. The instruments are to be replaced on an periodic basis. Typically every two years instruments are changed out for other instruments. The Core Facility and the instruments are to be delivered by a Space Transportation System (STS) to the SSFMB and mounted on the APAE on an outrigger. After initial checkout, instrument alignment, and charging of the magnets, the payload will function on a continuous basis for many (TBD) years. The STS will periodically service the facility, and replace the instruments.

Initially, three flight experiments, a Large Isotope Spectrometer for Astromag (LISA); an experiment to measure the Cosmic Rays including Anti-protons, Positrons, Nuclei and to conduct a search for Antimatter (WiZard); and Spectra, Composition, and interactions of Nuclei above 10 TeV (SCINATT) have been selected. The space resident elements of these experiments are referred to as either experiments or instruments. The complete experimental project including ground system operations and data analysis for each of the three is always referred to as an experiment.

Individual instrument characteristics are discussed in this subsection. Instrument requirements are discussed in Section 2.0. Each instrument measures in different ways the composition and/or characteristics of cosmic rays by detecting the effect of the strong magnet field generated by the Core Facility on the flight path of the cosmic rays.

1.3.1 LISA Characteristics

The objective of LISA is to detect cosmic rays that fall within the following bounds, where Z is the particle rigidity:

- Isotopic Composition, $4 < Z \leq 30$, 2.5 - 4 GeV per nucleon
- Energy Spectrum of Elements, $4 < Z \leq 30$, 2 to 1000 GeV per nucleon
- Anti-nuclei Search, $4 < Z \leq 30$, 2 to 100 GeV per nucleon

- Detectors:

  Scintillating optical fiber trajectory detectors in the central part of the magnetic field and a combination of Cherenkov velocity detectors and time-of-flight scintillators on the outside, jointly determine the nuclear charge, mass, velocity, and magnetic deflection of cosmic ray nuclei that traverse Astromag's magnetic field.

- Observation Technique/On-board Processing:

  Each of the detector subsystems (i.e., trajectory, Cherenkov, and time-of-flight) has its own front-end electronics, which convert analog signals into digitized values. A hodoscope read-out system feeds these values to the LISA central processor, which monitors the separate signals for coincident events within a pre-selected time interval. Only data indicating coincident events are formatted by the central processor for transmission to the ground. Each event produces 700 to 1000 pulses (heights) and addresses from the fiber hodoscopes, 60 Cherenkov photomultiplier pulse heights, and four digitized timing signals. Some additional Cherenkov and timing signals are included with the data stream to check for spurious background incidents. Modest amounts of status, rate, and housekeeping data are also included.

The average rate of a cosmic ray event is 0.3 per second and the maximum rate is 1 per second. The estimated science data rates quoted in Section 2.0 are based on these numbers.

- Heritage:

  Balloon-borne and satellite isotope experiments developed over the past decade.

1.3.2 WiZard Characteristics

The objective of WiZard is to detect cosmic rays that fall within the following bounds:

- Energy Spectrum, anti-proton and positron, to few hundred GeV
- Energy Spectrum, proton, electron, and nuclei ($Z \leq 6$), to ≥ 1 TeV
- Search for primordial anti-matter (i.e., heavier anti-nuclei)

- Detectors:

  Two time-of-flight detectors and a central trajectory tracking system monitor the anti-matter search. For lighter particles, in order to distinguish electrons from anti-protons and positrons from protons, two additional detectors, a transition radiation detector and a calorimeter, are required.

- Observation Technique/On-board Processing:

  Extensive on-board processing and data selection are employed.

- Heritage:

  Two balloon payloads with superconducting magnet spectrometers: the NASA / New Mexico State University Balloon-borne Magnet Facility (BBMF, with half-scale Astromag magnet) and the Boston University PBAR payload.

1.3.3 SCINATT Characteristics

The objective of SCINATT is to detect cosmic rays that fall within the following bounds:

- Composition and Energy Spectrum, cosmic ray nuclei, above 100 TeV

- Energy Spectrum, electron, above 1 TeV

- Transverse Momentum, charged particles and photons from nucleus-nucleus interactions above 1 TeV

- Detectors:

  Passive emulsion chambers are used in two configurations: EMCAL, which is used in balloon-borne composition studies, and MAGIC, which contains an additional section to measure the transverse momenta of charged particles. EMCAL includes a charge identification module, a primary tracking module, and a calorimeter module.

- Observation Technique/On-board Processing:

  Passive detection. No on-board data processing or data transmission.

- Heritage:

  Balloon-borne experiments and accelerator experiments involving heavy ion collisions.

2.0 ASTROMAG DATA SYSTEM (ADS) REQUIRED FUNCTIONS AND INTERFACES

A top-level block diagram for the ADS is depicted in Figure 1. In that diagram the various elements/interfaces/hosts of portions of the ADS are identified. As depicted in the figure, the primary elements that contribute to the ADS are included in the two systems described in this report -- the Astromag Space Data System (ASDS) and the Astromag Ground Data System (AGDS). In this section, the required functions and interfaces of the Astromag Data System are discussed. These required functions and interfaces will typically be formalized as Requirements and Interface Requirements during Phase B. These required ADS functions and interfaces are detailed in the N-squared diagrams presented in Sections 4.0 and 5.0.

2.1 Astromag Space Data System (ASDS) Required Functions and Interfaces

The Astromag Space Data System required functions are based on the informally stated or assumed requirements for the instruments and the Core Facility plus the informally stated or assumed support and constraints from the APAE, SSFMB, and Space Network (SN). Section 2.1.1 discusses the required functions to support the instruments and the Core Facility. Section 2.1.2 discusses the required interfaces with the APAE and/or SSFMB. In Section 2.1.3 the required ASDS functions are summarized in a table.

2.1.1 Astromag Space Data System (ASDS) Required Functions based on Instrument and Core Facility needs

The Astromag Space Segment (Figure 2) includes the on-orbit Core Facility and instruments. All data transport (command and telemetry) into and out of the Space Segment will pass between the Core Facility and the APAE.

Several options are being defined during Phase A and will be analyzed during Phase B relative to the conceptual design of the Core Facility, the instruments' thermal control, etc. In order to address the likely requirements (interfaces and sizing, in particular) on the ASDS it is necessary to make some assumptions regarding the required functions of the ASDS.

Only two of the three experiments will be attached to the Astromag Core Facility at one time. Two of the experiments (LISA and WiZard) require a data interface for commands and telemetry. For the purposes of the ASDS architecture described in this report it is assumed that the Core Facility processor will not provide discrete (analog) commands to Instrument Hardware (Effectors). Either the instrument processors will control their own thermal and power subsystems or the Core Facility processor will send data commands to the instrument processors which generate the required analog commands. The third instrument (SCINATT) requires the ADS to support only commanding and engineering telemetry, not science data telemetry since SCINATT does not generate on-orbit science data. *SCINATT's science data is obtained after returning the instrument to earth.* LISA and WiZard, the most complex expected configuration are depicted in Figure 2.

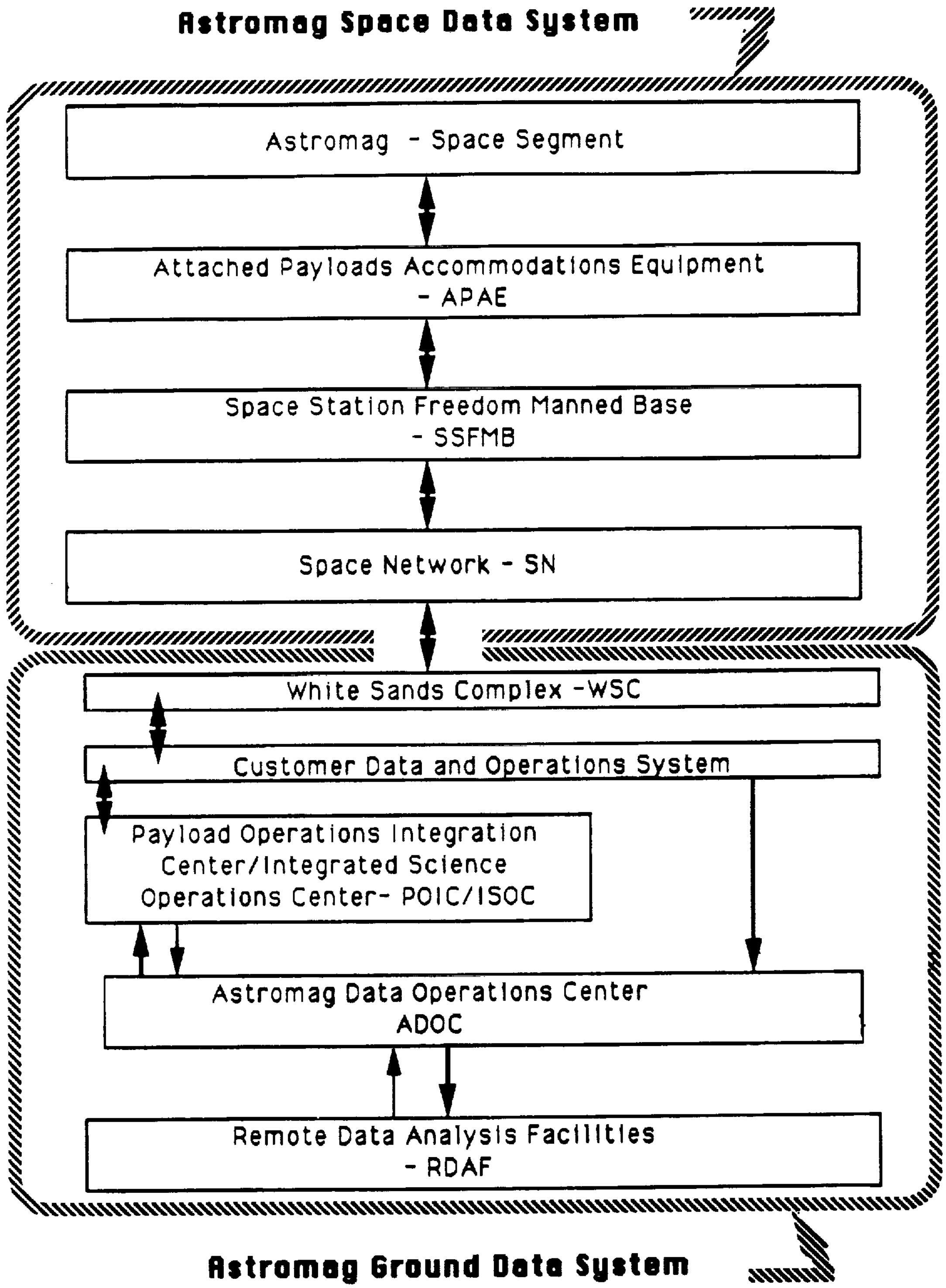


Figure 1. Astromag Data System Block Diagram

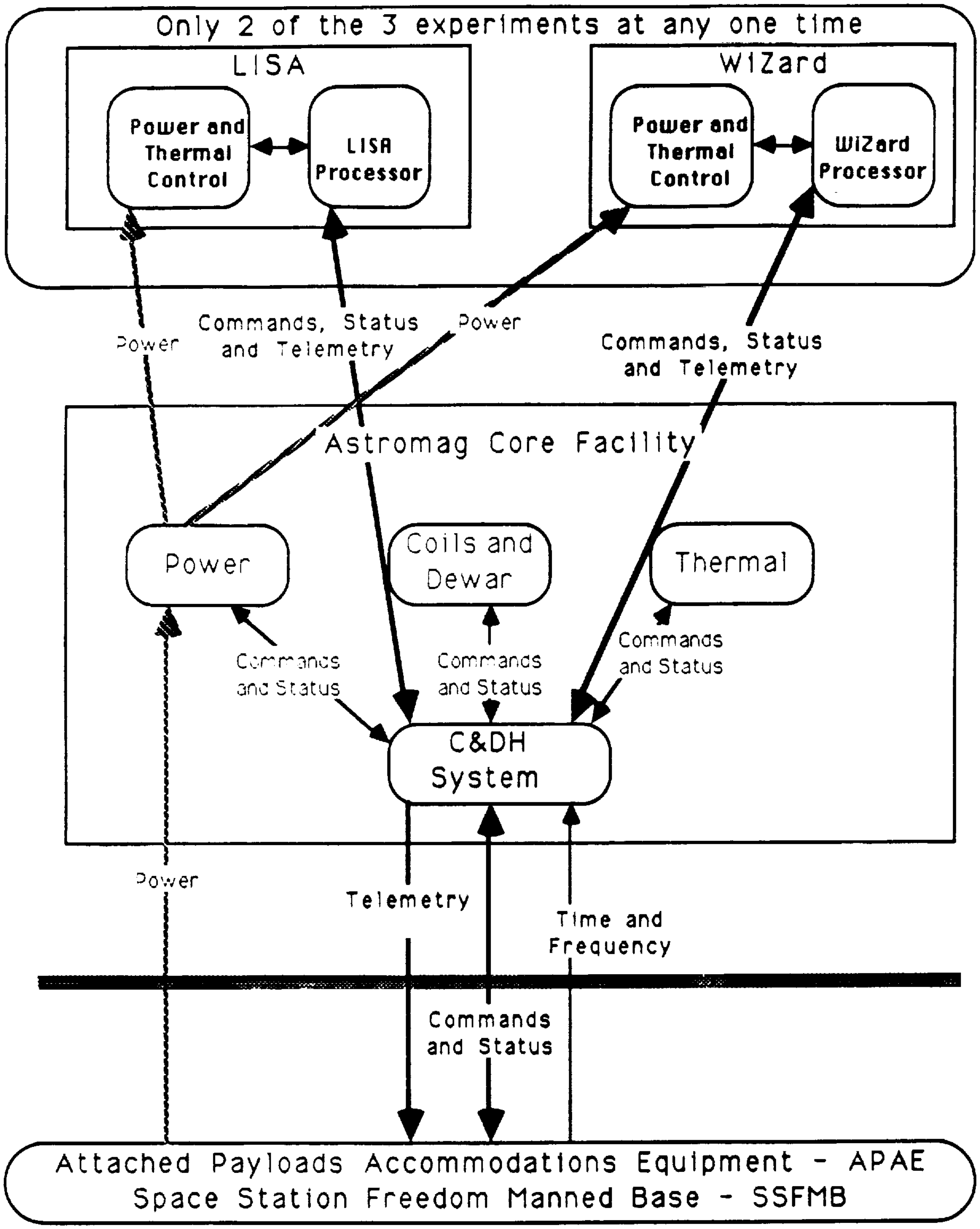


Figure 2. Astromag Space Data System Interface Overview

All instrument telemetry (science and engineering downlink data) will be transmitted to the central processor and routed to the SSFMB Communications and Tracking System (C&TS) via the APAE. Instrument and Core Facility health and status will also be included in downlink packets for processing by the Payload Operations Integration Center (POIC). Time data will be added to the instrument data packets at the instrument if the instrument includes a clock. Orbit, Attitude, and TBD information will be added to the instrument data packets at the instrument or the C&DH packetizer. Since either concept is feasible, this option will be addressed in Phase B.

Certain Core Facility sensor outputs that relate to cryogenic safety issues will be processed on-board by both the C&DH System and by either an APAE or SSFMB processor for redundancy. In addition, both the C&DH System and either the APAE or SSFMB will be able to initiate the discrete commands that can safely shut down the Coils and Dewar if the sensor output indicates that it is warranted. Other Astromag sensor outputs that affect the power or thermal subsystems but do not affect the SSFMB safety, are processed only by the C&DH System and the AGDS.

All Astromag space segment power is provided to Astromag via the APAE. The Core Facility will distribute the power between itself and the instruments as necessary. Control and monitoring of the Core Facility power and thermal subsystems is a requirement on the ASDS. Each instrument will include its own thermal subsystem, presumably with radiators, heaters, sensors, and commandable effectors. The Astromag Core Facility will include its own thermal subsystem with radiators, heaters, sensors, and commandable effectors (unless changed during Phase B).

2.1.2 Required Functions and Interfaces for the Astromag Space Data System (ASDS) based on the Interface with the APAE and SSFMB

The APAE provides interfaces and support for attached payloads on SSFMB. Astromag will be built with a Payload Interface Adapter (PIA) as an integral element of the Core Facility. This PIA will be provided by the APAE and will be designed to interface with the Station Interface Adapter (SIA). All primary interfaces for the Astromag Attached Payload will be through the PIA/SIA.

A proposed APAE Data Handling System (DHS) architecture is depicted in Figure 3. This drawing reflects a working drawing provided by Work Package-3 (WP-3), which was originated by GE Astro Space. The actual APAE Data Handling System (DHS) architecture has not been baselined or formalized. Astromag was substituted for one of the payloads (P/L in the figure) for clarity. Available to the ASDS are a 1553B interface, a local bus (802.4 protocol possibly), a high rate data (HRD) line, and a Time and Frequency (T&F) Bus.

The 1553B is a data bus that can support up to 1 Mbps including overhead. The local bus is likely to support up to 10 Mbps. The HRD line, if provided, would support up to 40 Mbps of downlink capacity. The T&F Bus is an input only device that provides time for time tagging the downlink data (engineering and science) packets. Astromag would receive its commands on the 1553B data bus and could downlink on any of the 1553B data bus, the local bus or the HRD hard line. How these downlink data are transported by or through the APAE DHS to the SSFMB C&TS is transparent to Astromag. The only requirement is that the Astromag packets and the Consultative Committee for Space Data Systems (CCSDS) compliant information (virtual channel, etc.) remains intact when the packets are received at the White Sands Complex (WSC).

APAE DHS ARCHITECTURE: PROPOSED BY GE

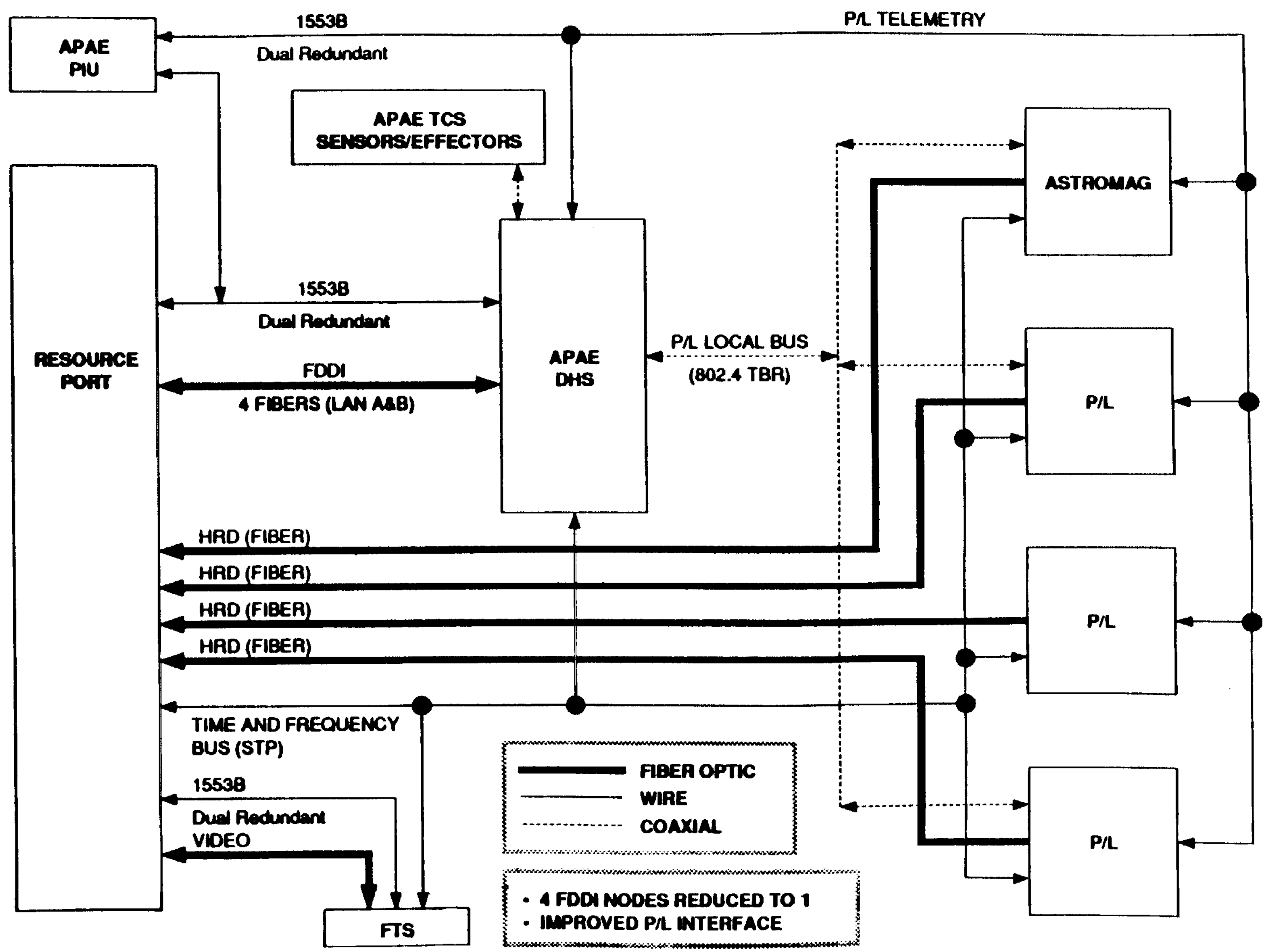


Figure 3. APAE DHS Architecture: Proposed by GE

2.1.3 Summary of the Required Functions and Interfaces for the Astromag Space Data System (ASDS)

The ASDS required functions and interfaces are summarized in Table 1.

The required data rate capacities listed in Table 2 assume that the two most demanding instruments and the Core Facility are active simultaneously, but that there is no reason to command more than one processor at a time. The data rates used to size the ASDS in this report are based on assumptions taken from the experiment proposals and conversations with the Project Scientist and Study Manager. First, the average rate of cosmic ray events detectable by a given experiment is 0.3 per second. Second, the maximum rate detectable by a given instrument is 1 per second. Third, if the instruments experience Solar Particle Events yielding higher rates of particle detection, there is no requirement on the ASDS to collect, store, or process those additional data. The instruments may include their own additional recording capacity for these occurrences, if desired and feasible, as long as there is no impact on the maximum rates experienced by the ADS. Fourth, there is no desire for telescience or rapid generation and transmission of commands for science reasons.

2.2 Astromag Ground Data System (AGDS) Required Functions and Interfaces

The AGDS-required functions are based on the informally stated or assumed requirements for the instruments and the Core Facility plus the informally stated or assumed support functions and constraints from other NASA facilities that exist today or are planned for the Astromag operations timeframe (late 1990s and beyond). Section 2.2.1 discusses the functions required to support the instruments and the Core Facility. Section 2.2.2 discusses the required interfaces with other SN and Space Station Freedom Program (SSFP) elements.

2.2.1 Astromag Ground Data System (AGDS) Required Functions based on support of the Instruments and the Core Facility

In order to provide the necessary operational support of the Astromag space segment, the AGDS will have to generate the commands required by the space segment and process the data transmitted from the space segment. The data processing will involve the processing of science data for analysis and engineering data for command and control purposes and for maintaining the health and status of the attached payload.

Support of the space segment requires that the AGDS generate commands to maintain the health and status of the Core Facility, including, the C&DH subsystem, the

TABLE 1
Required Functions and Interfaces for the Astromag Space Data System

Function	Activity
Command Receipt and Routing	Receive commands through the APAE at a maximum rate of 9 kbps and route these commands to the instruments or the central processor as received
Time and Frequency Data Receipt	Receive time and frequency data on the time and frequency bus
Orbit and Attitude Data Receipt	Receive orbit and attitude data on the command bus
Science Data Receipt	Receive science data telemetry from the instruments at a maximum rate of <280 kbps and an average rate of < 44 kbps combined (see Table 3-4)
Instrument Health and Status Support	Receive Instrument thermal and power health and status data. Process these data, possibly generate appropriate subsystem commands, transmit instrument commands to instrument, and include these data in telemetry packets.
Core Facility Health and Status Support	Receive thermal, power and Magnet Cryostat Assembly health and status data. Process these data, generate appropriate subsystem effector commands and include these data in the telemetry packets.
Generate or Modify and Transmit Packets	Generate and transmit data packets that satisfy standards and protocols and contain: Instrument science data with time, orbit and attitude, or Instrument health and status data with time, or Core Facility health and status data with time.
Attitude	A-posteriori knowledge, $\pm 2^{o}$ rms included in downlink
Orbital State	Required knowledge in downlink

Table 2
Required Data Rate Capacities

Instrument/ Subsystem	**Average Downlink Rate**	**Maximum Downlink Rate**	**Maximum Uplink Rate**
LISA	9 kbps	30 kbps	1 kbps
WiZard	35 kbps	250 kbps**	9 kbps
SCINATT	<1 kbps	1 kbps	<1 kbps
Core Facility	1 kbps	1 kbps	1 kbps
Combined*	**45 kbps**	**281 kbps**	**9 kbps**

** Total of two most demanding instruments and Core Facility when appropriate*
***Includes diagnostic modes and calibration data*

power subsystem, the thermal subsystem, and the Magnet Cryostat Assembly. Normal (pre-planned) commanding activities are sufficient for the C&DH subsystem, the power subsystem, and the thermal subsystem. However, future safety studies may result in some reactive command procedures for the magnet cryostat that imply around the clock monitoring of the Core Facility engineering data.

Support of the space segment requires that the AGDS generate commands to maintain the health and status of the instruments, including their processors, their power subsystems, their thermal subsystems, and their detector assemblies. Normal (pre-planned) commanding activities are sufficient for all instrument command generation activities.

Support of the Space Segment requires that the AGDS process health and status data from the Core Facility including processing engineering data from, the power subsystem, the thermal subsystem, the C&DH subsystem, and the Magnet Cryostat Assembly. Initial processing of these data should be accomplished on-line in support of safety issues. However, trend analysis and detailed analysis of this data can be accomplished off-line in a slower, more cost-effective manner.

Support of the space segment requires that the AGDS process health and status data from the instruments including processing engineering data from, the instrument power subsystems, the instrument thermal subsystems, the instrument processors, and the instrument detector subsystems. All processing of instrument engineering data can be accomplished off-line.

Support of the space segment requires that the AGDS capture and process science data from the instruments, including processing at various levels (Level 0, 1, 2, etc,). In addition, data archiving and distribution are required. Access to these data from remote analysis sites will be provided. The average downlink data rates listed in Table 2 can be used for a preliminary sizing of the AGDS.

2.2.2 Required Functions and Interfaces for the Astromag Ground Data System (AGDS) based on the Interface with the Space Network (SN) and other NASA Facilities

As depicted in Figure 1, Astromag telemetry is received from and commands are sent to the space segment via the WSC. This complex is the boundary between the ASDS and the AGDS. Data will pass into and out of WSC via the Customer Data and Operations System (CDOS). Current plans call for real time attached payload operations to occur at Marshall Space Flight Center (MSFC) in two facilities called the Payload Operations Integration Center (POIC) and the Integrated Science Operations Center (ISOC). Astromag commands will be transmitted from the POIC at MSFC to White Sands via NASA Communications Network (NASCOM) and the CDOS. For the purposes of this discussion CDOS will provide the necessary NASCOM services.

The Astromag Data Operations Center (ADOC) will reside at Goddard Space Flight Center (GSFC). This facility is not called the Mission Operations Center because other aspects (installation,etc.) of Astromag mission operations will be controlled by other SSFP elements. The ADOC will process and retain long-term Astromag science and engineering data, will generate and forward to the POIC Astromag command loads and procedures for reacting to out-of-limit engineering parameters, and will provide access to these data for Principal Investigators (PIs) at either local or remote data analysis facilities. At this time there is no stated requirement for or perceived benefit from telescience (short term reaction to science change requests) for the Astromag project since the instruments, once initialized and calibrated, obtain their science data by detecting cosmic rays (no targets of opportunity). The specific facilities or organizations that accomplish each function are discussed in Section 5.0.

3.0 ASTROMAG DATA SYSTEMS CONCEPT OF OPERATIONS

This section presents the concept of operations for the Astromag data systems. The Astromag data systems are viewed as two components, the space and ground segments. The required functions and interfaces of these components have been discussed in Section 2.0 and feasible architectures for the Astromag space and ground data systems are discussed in Sections 4.0 and 5.0, respectively. This section presents an overview of the data systems operations. Operations related to installation, deinstallation, and servicing of the Astromag attached payload are not included in this report.

The essential features of the concept of operations are shown in Figure 4. At the center of the operations are the POIC and the ISOC at MSFC and the ADOC at GSFC. The POIC and ISOC provide the principal interface between the Astromag-specific ADOC and the SSFP during operations, and are shared facilities for all Space Station attached payloads. The ADOC serves Astromag, but it may share resources with other projects. An important aspect of this concept is that at most the attached payload, the ADOC and the RDAFs are Astromag-dedicated elements. The majority of the interfaces and support are provided by shared resources.

Astromag will be carried as an attached payload on the SSFMB. The Core Facility generates two opposing magnetic fields. Science instruments which measure the composition and the energy spectrum of cosmic rays are attached to the Core Facility. (The spiral in Figure 4 depicts a cosmic ray being detected in an instrument while being bent by the magnetic field generated by the Core Facility.) Two experiments operate at a given time for approximately 2 years, after which new experiments are attached. Astromag is connected to the SSFMB through the APAE, which provides the mechanical, electrical, and data system interfaces between the two systems. Astromag derives its power from the SSFMB/APAE, but all of its thermal (i.e., cooling and venting) requirements are to be provided by the Astromag attached payload. The Core Facility and the individual experiments will each have their own thermal controls.

The Astromag attached payload will be delivered by the STS to the SSFMB and will be mounted on an Station Interface Adapter (APAE element) on an outrigger. After initial checkout, instrument alignment, and charging of the magnets, the Astromag Facility will function on a continuous basis for many years. Periodic servicing and replacements of the instruments will be provided by the SSFP.

The ASDS will handle command receipt and routing to the Core Facility and the instruments. It will collect engineering data (health and status information, power and thermal status, etc.) from all components (sensors and instruments), science data from the instruments, and orbit, attitude, and time information from APAE provided interfaces, and packetize these data for transmission to the ground. The data packets will conform to the CCSDS standards. The Astromag experiments generally involve on-board data processing and data selection, which are performed by the individual experiment processors. A C&DH System performs the final data collection and packetization. The downlinked packets of engineering and science data will be identifiable as such (engineering or science). This will be accomplished by one of the following options to be studied during Phase B. Science and engineering data may be included in different packets with different Virtual Channels (CCSDS), or in different distinguishable subpackets within packets. Anticipated Astromag downlinked science data rates are generally uniform (Table 2), except for occasional pre-processed data dumps that are used for calibration.

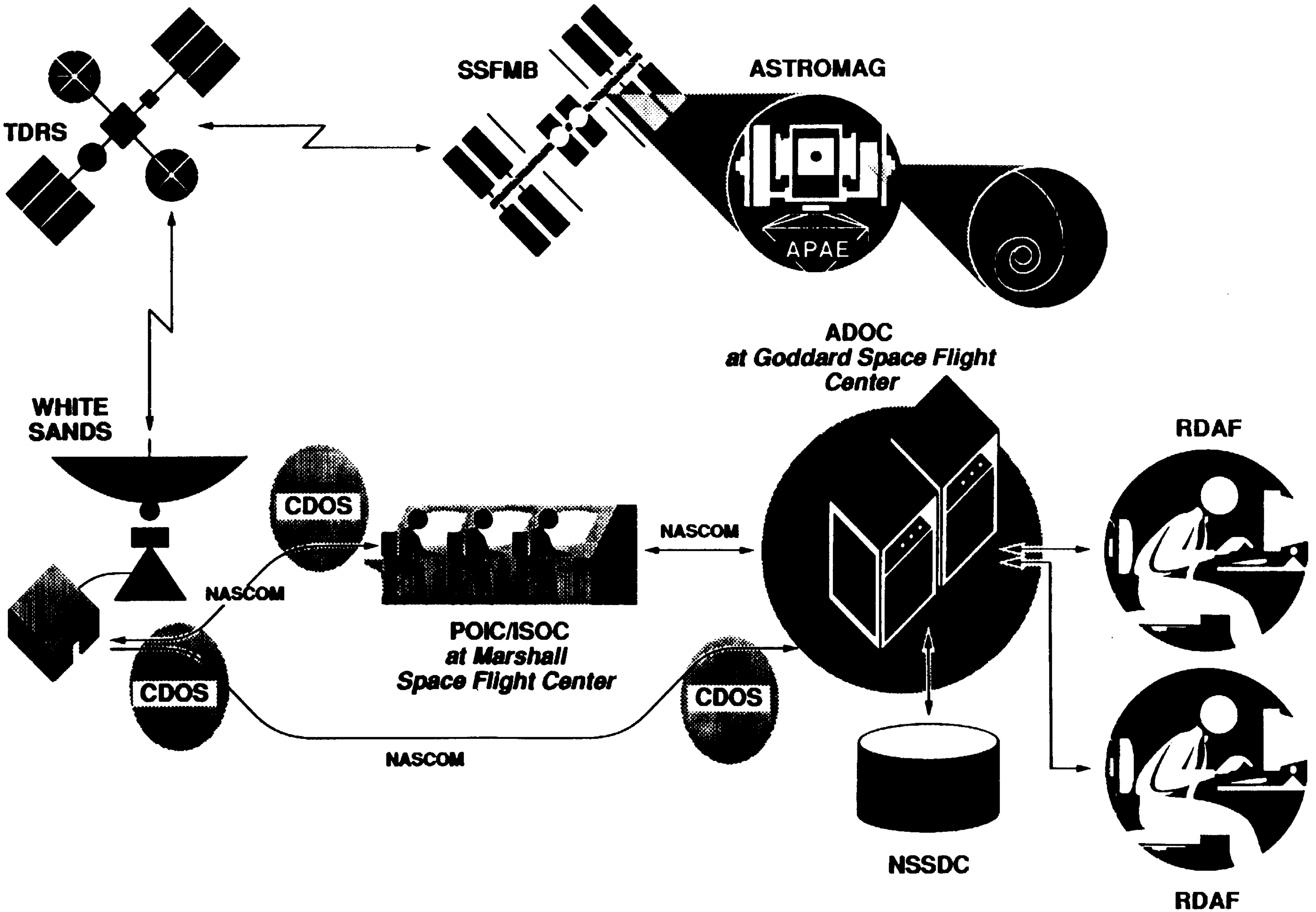


Figure 4. Astromag Data Systems Concept of Operations

The Astromag science and engineering data are transmitted to the WSC via the TDRSS. After receipt at WSC the data will be routed and processed by CDOS. CDOS will forward Astromag engineering data to the POIC and ISOC and Astromag science and engineering data to the ADOC by arrangement with NASCOM. CDOS will accomplish Data Capture and Level Zero Processing (LZP) of Astromag science and engineering data .

Two facilities, the POIC and the ISOC, at MSFC will accomplish some of the the AGDS functions. The primary functions of the POIC are: operations control, command management, and operations integration with other Space Station payloads. The POIC is responsible for the overall health and safety of the SSFMB attached payloads and will control the command loads from different sources. It will uplink Astromag command loads validated by the ADOC. It will provide around-the-clock monitoring of health and status data and, based on ADOC provided procedures, will transmit reactive commands when specified engineering parameters violate predefined limits. The ISOC will integrate Astromag commands received from the ADOC with commands for other SSFMB payloads.

The ADOC at GSFC will be the central science planning, data processing, command generation, and data management facility. It will perform routine Level 1 processing of the Astromag science and engineering data and will provide temporary storage for Level 1 and higher level data. Higher-level data processing will be shared between the ADOC and the various RDAFs. The ADOC will perform quick-look data analysis of the engineering data, for health and safety monitoring and performance evaluation of the space segment. It will develop schedules and command sequences based on inputs from the instrument PIs subject to the allocated resource envelopes provided by the POIC/ISOC. It will coordinate all science planning activities and will coordinate activities with RDAFs and the National Space Science Data Center (NSSDC).

The RDAFs are distributed, remote processing centers, dedicated to the Astromag mission. They share some of the functions of the ADOC and are especially responsible for higher-level science data processing. Initial science planning and scheduling, and generation of command sequences are handled by the RDAFs. All data products are transferred to the ADOC to share with the other RDAFs, and are temporarily stored there.

The NSSDC at GSFC provides the final depository of all Astromag data and data products, after being analyzed by the scientists. It is required that data will be compressed prior to storage. Data compression will be provided by the ADOC.

Astromag commands will originate at the ADOC, based on input from operations personnel at the ADOC and the RDAFs, and will be monitored at the POIC/ISOC, from where they will be transmitted via the CDOS, the WSC, the Tracking and Data Relay Satellite System (TDRSS), the SSFMB and APAE to the Astromag Facility.

Astromag has very little real-time operational requirements. Experiment operations are basically static and run continuously. The only real-time monitoring requirements will be based on the safety of the SSFMB crew. Occasional calibration and adjustment of on-board data processing parameters are required.

4.0 ASTROMAG SPACE DATA SYSTEM (ASDS)

The ASDS collects the instrument telemetry and the ancillary information and generates the data packets for transmission to the ground via the APAE DHS, SSFMB, and SN. The ASDS also receives and routes the commands that control the instruments and the Core Facility. Section 4.1 provides a brief description of the ASDS elements and functions. Sections 4.2 discusses the interfaces and 4.3 addresses the required functions for the ASDS. Section 4.4 proposes a preliminary system architecture (Phase A) for the ASDS.

4.1 Astromag Space Data System (ASDS) Overview

The required functions and interfaces of the ASDS are summarized in Table 1. The ASDS will accomplish the command receipt, validation and routing for the instruments and Core Facility. The ASDS will accomplish the data packetizing and forwarding for the instruments and the Core Facility.

The Astromag C&DH System is the focal point of ASDS. The ASDS includes the Central Processor and the hardware that interfaces with the Astromag internal communications network(s) or bus(ses) and the hardware that interfaces with the external communications networks or busses.

All commands will be received by the Astromag C&DH system from the APAE DHS via the 1553B low rate data bus (proposed APAE DHS architecture). The C&DH system will validate the commands and route them to the appropriate processor. In addition,the C&DH system will receive the time and frequency data off of the T&F bus and will both use these data and route them to instrument processors. Orbit and Attitude data received on the 1553B could be passed on to the instruments as well.

The ASDS receives and processes/routes payload data returned from the Astromag instruments, and transmits the packetized data to the ground. The Astromag instrument data packets consists of science telemetry, plus instrument health and status data (temperature and power sensor data) possibly plus time, attitude and orbit data. This would facilitate LZP by the AGDS. It is assumed that no analog data will cross the interface between the Core Facility and the instruments and that the analog instrument sensor data will be converted to digital form by the instrument before transmission to the C&DH system. The C&DH system will packetize these data (possibly with science data, possibly separate from science data) for downlinking. Other packets will contain Core Facility engineering data.

Certain outputs relating to cryogenic safety issues will be processed by both the Astromag C&DH and by either the APAE DHS or SSFMB for redundancy. In case the Magnet Cryostat Assembly safety alarms are triggered, the Astromag C&DH subsystem plus the APAE DHS, or SSFMB processor or crew members residing at the SSFMB will be able to shut down the coil and Dewar subsystem safely.

The ASDS will send instrument data to the ground at an average rate of 9 kbps for LISA and 35 kbps for WiZard in real time; it will receive commands from the ground at 1 kbps for LISA for 5 minutes a day, and at 9.6 kbps for WiZard for less than 1% of observing time per day. The health and status of SCINATT will be monitored continuously for the entire mission at an estimated rate of less than 1 kbps.

4.2 Astromag Space Data System (ASDS) Interfaces

Figure 5 depicts the interfaces among the Astromag internal and external data systems. This figure also includes a key for the information (telemetry, command and status) transferred to or from each element by assigning an identification number to each of the interface nodes. By correlating the circled from-to key in Figure 5 with the same pair of numbers in the "From-To" column in Table 3, one can identify the information that needs to cross the interface (Table 3, Information Transferred column). The SSFMB is shown for clarity only since all external communications for attached payloads will pass through the APAE DHS physical transport with or without APAE processing.

There are five natural groupings of the interfaces depicted in Figure 5. The instruments are a group that represent a common interface. The internal subsystems are a group that represent a common interface. The downlink data interface is a separate interface. The uplink data interface is a separate interface. The Time & Frequency Bus interface is a separate interface. These five groups are indicated in Table 3 by five different terms in the "Medium" column. These five mediums are:

ASTROm,
C&DHm,
d/l (DownLink),
u/l (UpLink), and
T&F Bus.

Table 3
Astromag Space Data System Interface Information Flow

Source Element	From-To	Medium	Information Transferred
LISA	1-7	ASTROm	Telemetry (Science and Engineering)
WiZard	2-7	ASTROm	Telemetry (Science and Engineering)
SCINATT	3-7	ASTROm	Telemetry (Engineering Only)
Thermal System	4-7	C&DHm	Thermal Status
Power System	5-7	C&DHm	Power Status
Coil and Dewar	6-7	C&DHm	Coil and Dewar Status
C&DH	7-8	d/l	Telemetry (Science and Engineering)
C&DH	7-1	ASTROm	LISA Commands
C&DH	7-2	ASTROm	WiZard Commands
C&DH	7-3	ASTROm	SCINATT Commands
C&DH	7-4	C&DHm	Thermal Control Commands
C&DH	7-5	C&DHm	Power Effector Commands
APAE DHS	8-7	u/l	Commands, Orbit, Attitude
APAE DHS	8-7	T&F Bus	Time and Frequency

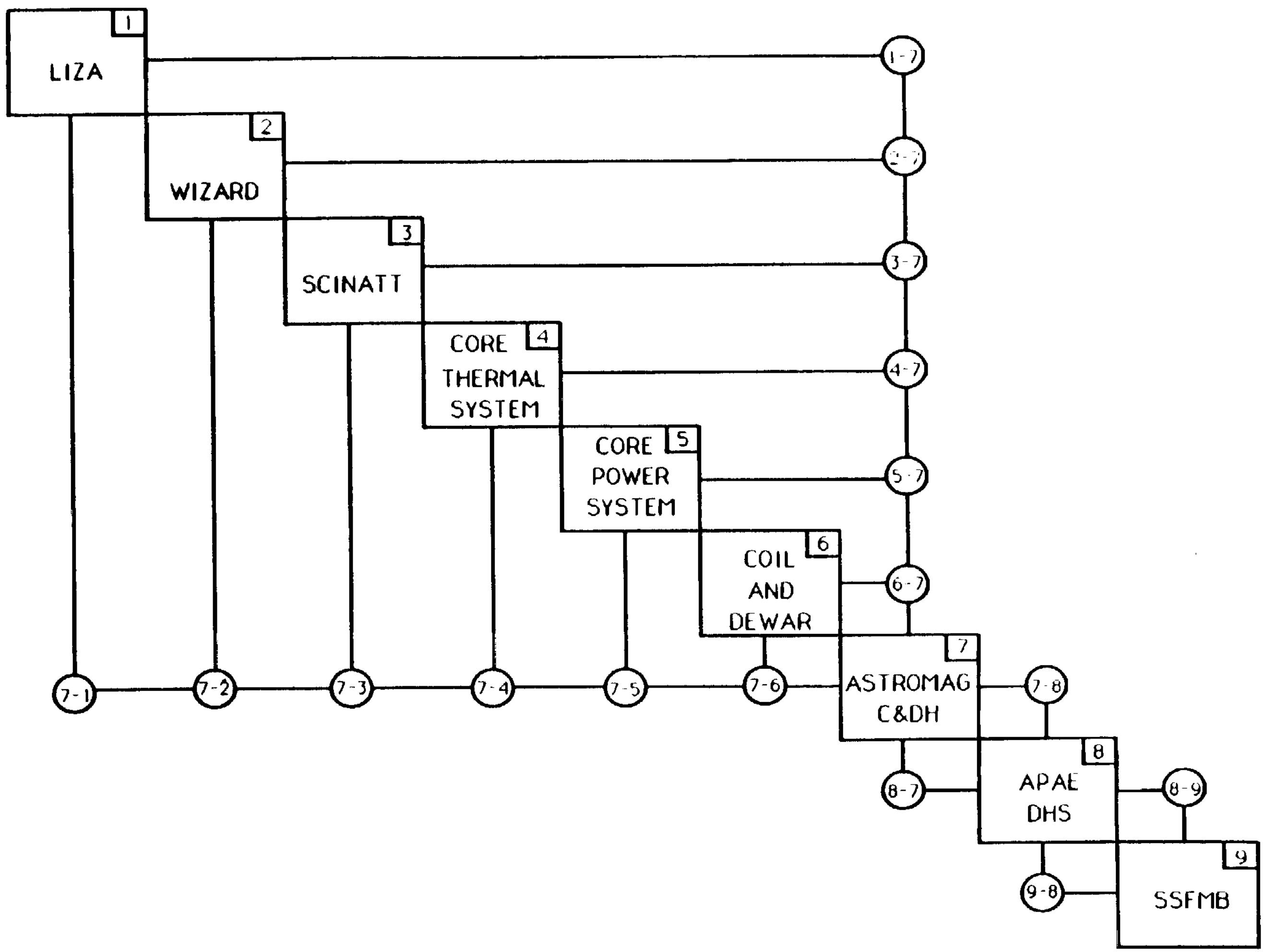


Figure 5. Astromag Space Data System Interface (N-Squared) Chart

These five communications media are defined as follows. ASTROm is the medium that is selected for communication between the Astromag C&DH system and the instruments. C&DHm is the medium(s) (bus) that is selected for communications within the Astromag Core Facility. d/l is the APAE supplied interface (Figure 3) that is selected for downlinking Astromag data. u/l is the APAE supplied interface that is selected for uplinking Astromag data. T&F Bus is the SSFMB/APAE supplied Time & Frequency Bus that provides the indicated operations data from SSFMB. A conceptual relationship between these communications media and the Astromag elements is depicted in Figure 6. The Astromag subsystems that are internal to the Core Facility but are not part of the C&DH Subsystem (Power, Thermal, plus Coils and Dewar) could be interfaced to either the internal C&DH medium or the Astro (instrument) medium.

4.3 Astromag Space Data System (ASDS) Functions

This section describes the functions of the ASDS elements.

4.3.1 Astromag Instruments

The instrument control function is generally accomplished through the use of a microprocessor with a CPU having direct access to the mass memories for data readout and control, and a bus, with control of peripheral subsystems being supported by various input/output (I/O) devices. The temperature and power subsystem sensor data will be converted to the digital form by the instrument. This information will be forwarded to the Astromag Core Facility C&DH system separately for engineering analysis and in science packets for better science data analysis.

4.3.2 Astromag Core Facility

4.3.2.1 Communications and Data Handling (C&DH) System

The Astromag Core Facility C&DH system provides the link between the Astromag payload and the APAE. The C&DH is connected to any attached and operating instruments and to other Astromag subsystems. The C&DH system will perform command decoding and routing, memory loading and dumping, and data packet management and forwarding. The C&DH system will also perform charging/discharging operations and automatic real-time monitoring and control of Astromag payload health and safety. A hardwired system will be implemented to perform nominal payload control and diagnostic data selection in case the Central Processor is unavailable. The hardwired system is controlled and adjusted independently from the computer system.

4.3.2.2 Thermal System

The Astromag Core Facility thermal subsystem controls the thermal condition of Astromag Core Facility to insure the normal operations of Astromag payload. Thermal status will be transmitted to the C&DH system for controlling the health and status of the Core Facility. The Astromag thermal subsystem will be controlled by the discrete commands that are issued by the Astromag C&DH.

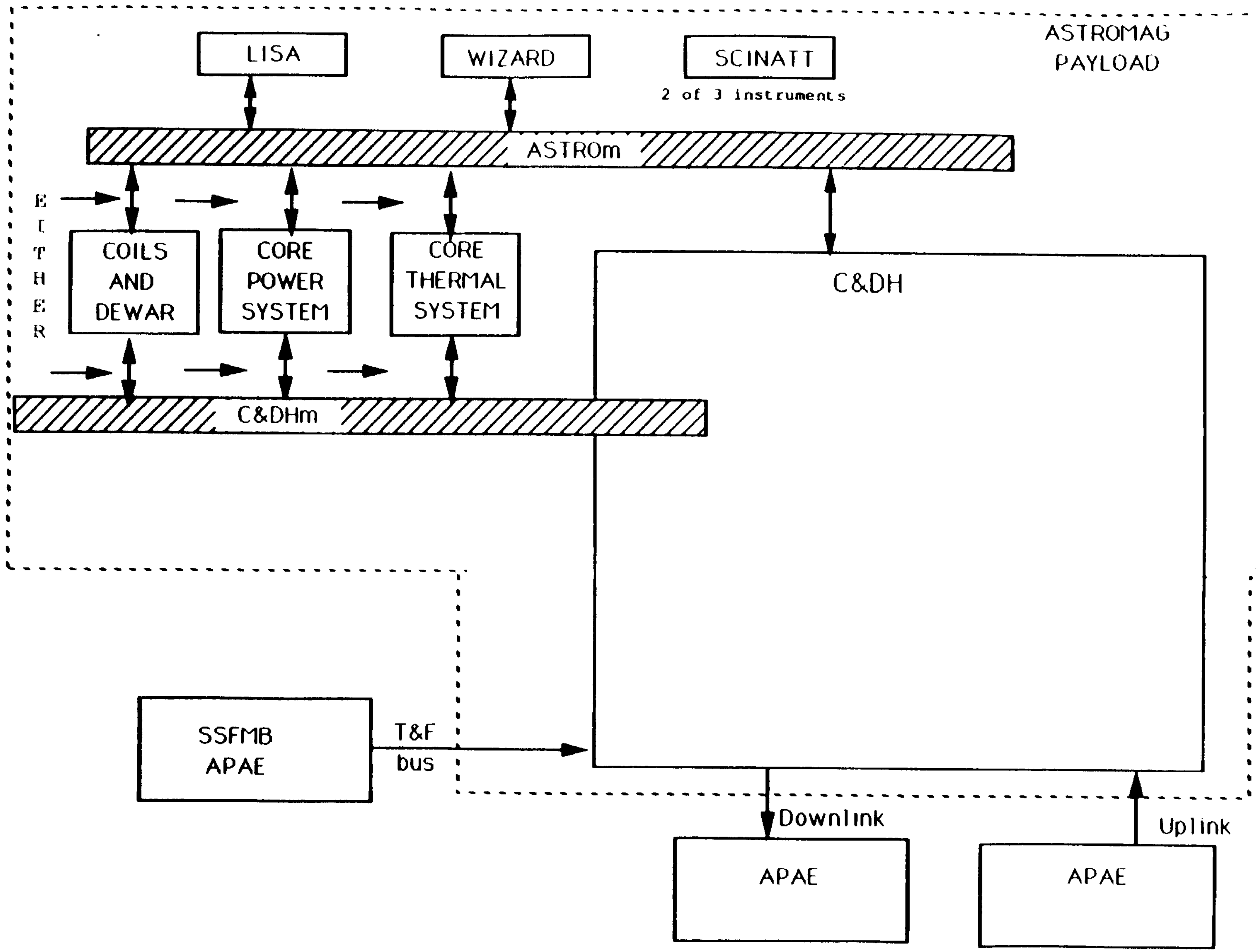


Figure 6. Astromag Space Data System Interface Mediums and Elements

4.3.2.3 Power System

The Astromag Core Facility power system supplies power that is required to perform the operations of the Astromag Payload. The power usage status will be transmitted to the C&DH system for determining the health and status of the Astromag payload. The Astromag power system will be controlled by the discrete commands that are issued by the Astromag C&DH system.

4.3.3 APAE Data Handling System (DHS)

The APAE DHS provides interfaces and support for transmitting commands and telemetry to and from the Astromag payload. All primary interfaces for the Astromag space segment will be through the SIA. The SIA will be interfaced with a Payload Interface Adapter (PIA) which is attached to the Astromag payload. The APAE DHS will route ground or crew commands to the Astromag payload over a 1553 interface that will originate in the APAE or SSFMB. The APAE DHS will also receive payload telemetry, and the Core Facility thermal and power systems status from the Astromag C&DH system. The APAE DHS will route payload telemetry, and the Core Facility thermal and power systems status to the SSFMB C&T System. Time and frequency data will be provided on the T&F bus. Attitude and Orbit data will be provided by the SSFMB/APAE on the 1553B.

4.4 Astromag Space Data System (ASDS) Architecture

The Astromag Space Data System will consist of:

the interface to the instruments processors (ASTROm),
the UpLink interface (1553B LAN proposed for APAE DHS),
the DownLink interface (multiple options proposed for APAE DHS),
the Time & Frequency Bus Interface, and
the Astromag Core Facility C&DH subsystem and internal interfaces.

A proposed ASDS Architecture is included in this report. During Phase B, major changes/improvements to this architecture will occur as a result of more detailed studies and a more defined environment. Figure 7 illustrates a feasible preliminary system architecture for the ASDS.

The proposed APAE DHS would provide commands to Astromag on a 1553 bus. Because this 1553 would have an overall capacity approaching 1 Mbps including overhead and since that would be adequate for Astromag's external uplink and downlink maximum required data rates (< 0.5 Mbps plus overhead), this is acceptable not only for commanding but for downlinking if a 1553 bus were dedicated to Astromag. The proposed APAE DHS would imply that the 1553 is shared with other attached payloads. In this case the single 1553 bus would not be adequate for both uplink and downlink and the local bus (possibly a 802.4) would be used for downlinking Astromag data (Figure 7). Command routing and packetizing may be accomplished by the 386 processor and peripherals (shaded area in Figure 7) or may require other devices.

A 1553 bus would not only be adequate for the command interface but a second (dual redundant) internal 1553 LAN would be acceptable for all internal interfaces. The Astromag C&DH could receive science and engineering telemetry from the Astromag

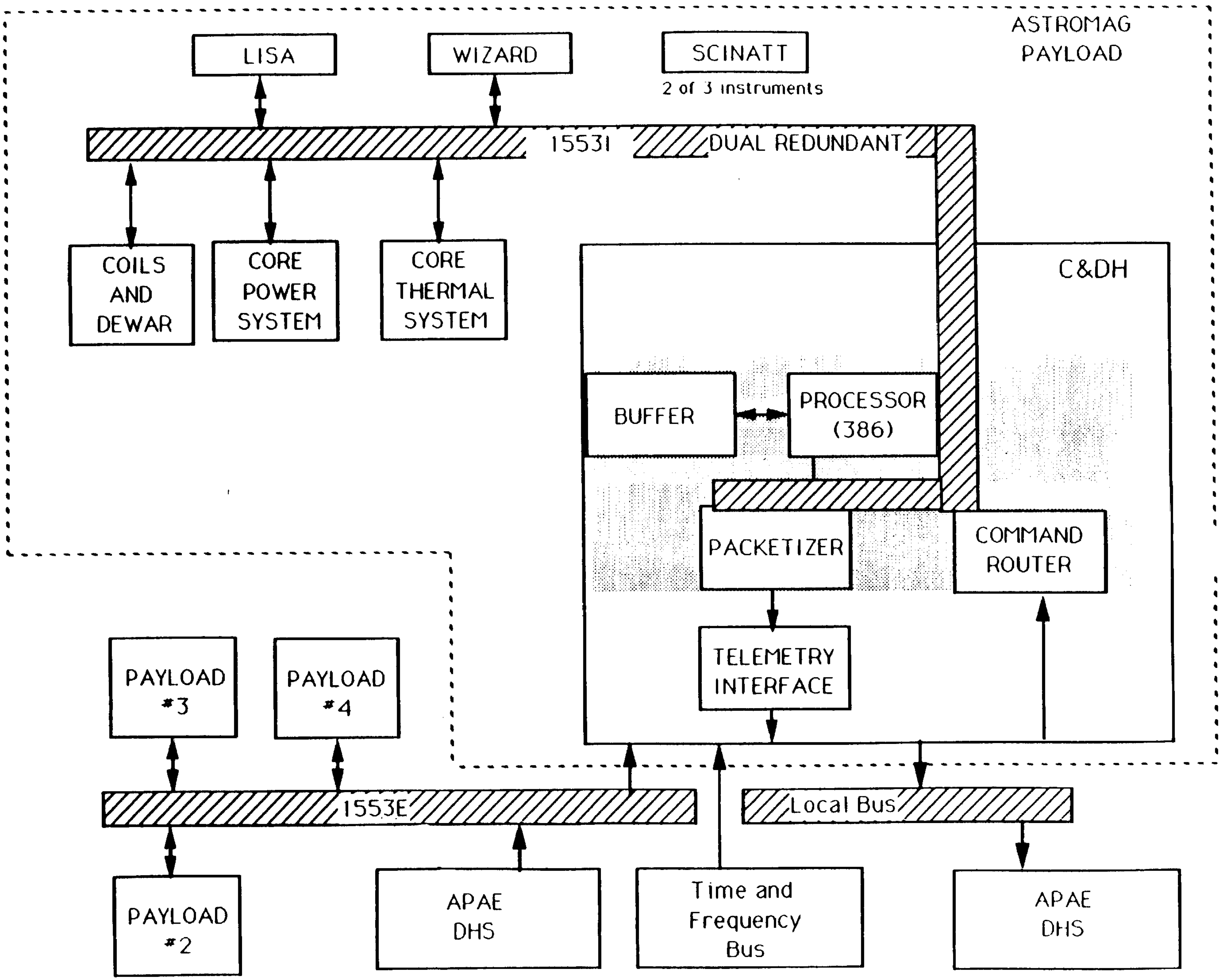


Figure 7. Feasible Astromag Space Data System Architecture

instruments via a 1553 bus, and the internal engineering data could also be carried on the same medium. The selection of 1553 for interfacing the Astromag instruments and subsystems provides the simplicity of interfacing with one type of medium plus the functionality, availability, and reliability of a device which will be used for APAE communications as well.

The basic protocol structure of the 1553 data bus is centered on three elements- a bus controller, remote terminals and a bus monitor. The 1553 device uses three different word types for transferring data between the elements. The bus controller is used to schedule the time-division multiplexing of messages transferred over the 1553 bus and to initiate all corresponding data transfers. The remote terminals provide the interface to the various system components. The 1553 device provides for up to 31 remote terminals to be connected to the data bus simultaneously. The bus monitor stores data bus traffic for later analysis. The 1553 data bus uses three word types: command words, data words, and status words. Each of the three word types is 20 bits long and requires 20 microseconds plus overhead to transmit. Only the bus controller can transmit a command word. Either the bus controller or the remote terminals can transmit the data words. The 1553 data bus has many advantages over other commercially available bus interfaces, such as RS-232 and IEEE-488 compatibility. The 1553 data bus not only provides a very high degree of noise immunity, but also provides a high level of system reliability because it is based on a dual-redundant architecture. In addition, the maximum word error rate on the 1553 data bus is one for every 10 million words ($10E^{-7}$).

If a dedicated 1553 could be available to Astromag for external interfaces, that would simplify the Astromag Space Data System architecture and development substantially. Such a configuration is depicted in Figure 8 Alternate ASDS Architecture.

The proposed Astromag C&DH System consists of a 386-based microprocessor, a buffering device, a packetizer, a command router, and the telemetry and command interface device or devices. Some or all of the command routing and packetizing functions could conceivably be accomplished by the 386 processor and its peripherals, although a more detailed study would have to be accomplished for that to be verified. The 386-based microprocessor provides the computing power for controlling command and telemetry of Astromag payload, monitoring health and status of the Astromag payload, formatting science and engineering data into the packets that are compatible with the CCSDS standards, and buffering the received telemetry for data packetization. The command generator and the command interface device will decode, encode, generate and route commands to the Astromag instruments or the Astromag subsystems. The packetizer and the telemetry interface device will packetize the science and engineering data and transfer the packets to the APAE DHS via a LAN.

Although the proposed APAE DHS would provide other higher rate media for downlinking data, those higher rate links provide excess capacity and would involve the development, test and operations of additional interfaces and increase the complexity of the ASDS. It would be feasible for Astromag to use one dedicated (dual redundant) 1553 interface for all of its external data interfaces. Although the proposed APAE DHS architecture did not provide a dedicated 1553 for any payload, a dedicated 1553 would appear to supply Astromag's required capacity in the simplest manner.

Table 3 is repeated in Table 4 with the assumption that one external 1553 bus and one internal 1553 bus could be available for the ASDS traffic. In this Table 1553I represents a dual redundant internal 1553 bus. 1553E represents a dual redundant external (APAE provided) 1553 bud. This would appear to provide not only a feasible but also a simpler development design for the ASDS.

Table 4
Possible Astromag Space Data System (ASDS) Interface Information Flow

Source Element	From-To	Medium	Information Transferred
LISA	1-7	1553I	Telemetry (Science and Engineering)
WiZard	2-7	1553I	Telemetry (Science and Engineering)
SCINATT	3-7	1553I	Telemetry (Engineering Only)
Thermal System	4-7	1553I	Thermal Status
Power System	5-7	1553I	Power Status
Coil and Dewar	6-7	1553I	Coil and Dewar Status
C&DH	7-8	1553E	Telemetry (Science and Engineering),
C&DH	7-1	1553I	LISA Commands
C&DH	7-2	1553I	WiZard Commands
C&DH	7-3	1553I	SCINATT Commands
C&DH	7-4	1553I	Thermal Control Commands
C&DH	7-5	1553I	Power Effector Commands
APAE DHS	8-7	1553E	Commands, Attitude, Orbit, etc.
APAE DHS	8-7	T&F Bus	Time and Frequency

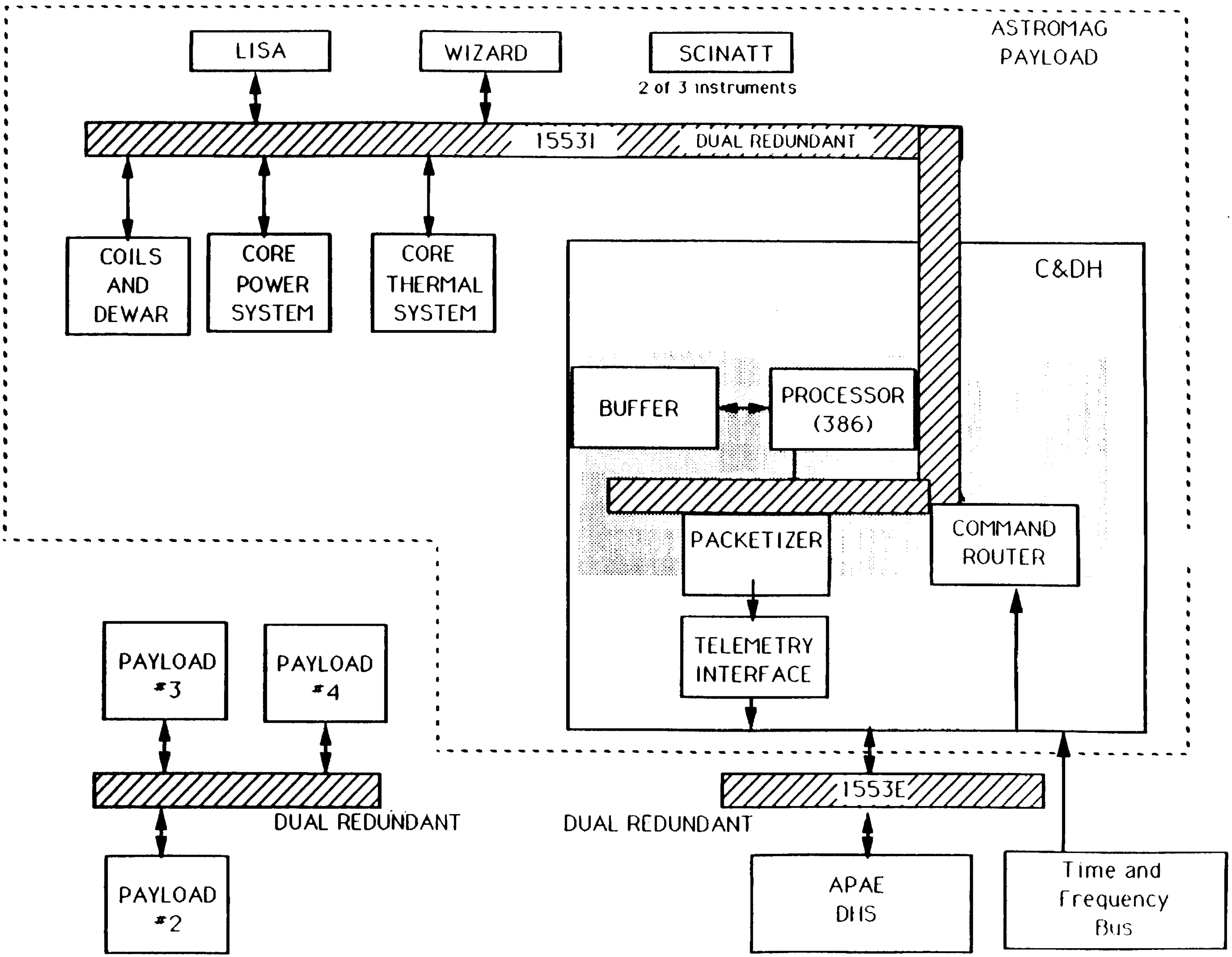


Figure 8. Alternate Astromag Space Data System Architecture

5.0 ASTROMAG GROUND DATA SYSTEM (AGDS)

The AGDS supports the ground data transport and processing of Astromag engineering and science data as well as the command and control of the Astromag Core Facility and instruments. Section 5.1 provides a brief overview of the AGDS and the facilities of which it is comprised. The functions of each of the facilities and their components are discussed in Section 5.2. Section 5.3 describes the data interfaces among the facilities and components by means of an N-squared chart. Finally, Section 5.4 provides a conceptual architecture for the AGDS.

This description of the AGDS is based on both existing NASA capabilities and systems and on conceptual NASA capabilities and systems for the late 1990s and beyond. When conceptual systems are included, the description is based on recent reports and discussions that represent informal baselines but are the best information available.

5.1 Astromag Ground Data System (AGDS) Overview

The AGDS is viewed as consisting of six types of facilities: the WSC; CDOS; the POIC and ISOC, both located at MSFC; the ADOC located at GSFC; and RDAFs located at various scientific and academic institutions throughout the United States. Figure 9 provides a top-level view of the functions to be provided by each of these facilities. CDOS accomplishes the data capture function, separates the science data packets or subpackets from the engineering data packets or subpackets, and routes the data as appropriate. In concert with NASCOM, CDOS ensures that the engineering data is received at the POIC and ISOC and that all data is received at the ADOC.

The POIC and ISOC provide the operational interface between the ASDS and the ADOC. The POIC provides the forward link interface to the SSFMB attached payloads and as such is responsible for uplinking Astromag Core Facility and instrument command sequences. The POIC is also responsible for ensuring that attached payloads do not jeopardize SSFMB crew safety. Consequently, POIC personnel will perform high-level monitoring of Astromag Core Facility health and status parameters. The POIC also requests SSFMB and communications resources using, for the purpose of this discussion, the planning and scheduling capabilities of CDOS.

ISOC is responsible for integrating Astromag with other payloads. Scheduling of command load uplink windows and periods of larger downlink rates for Astromag will be integrated with other SSFMB elements by the ISOC.

All Astromag Core Facility and instrument science data and non-realtime engineering data are assumed to be transmitted to the ADOC via the SN; the WSC; CDOS; and a Virtual Channel GateWay (VCGW). The VCGW routes realtime engineering data to the POIC and ISOC.

The ADOC monitors Core Facility and instrument engineering data and performs routine quick look and Level 1 processing of instrument science data received via the ISOC; stores and manages the Level Zero Data, Level 1 and higher-level data products, and related software; and interfaces with experimenters located at various scientific and academic institutions to exchange science and engineering data. The ADOC also develops schedules and command sequences for the Core Facility and instruments on the basis of allocated resource envelopes received from the POIC via the ISOC and planning and scheduling inputs received from PIs.

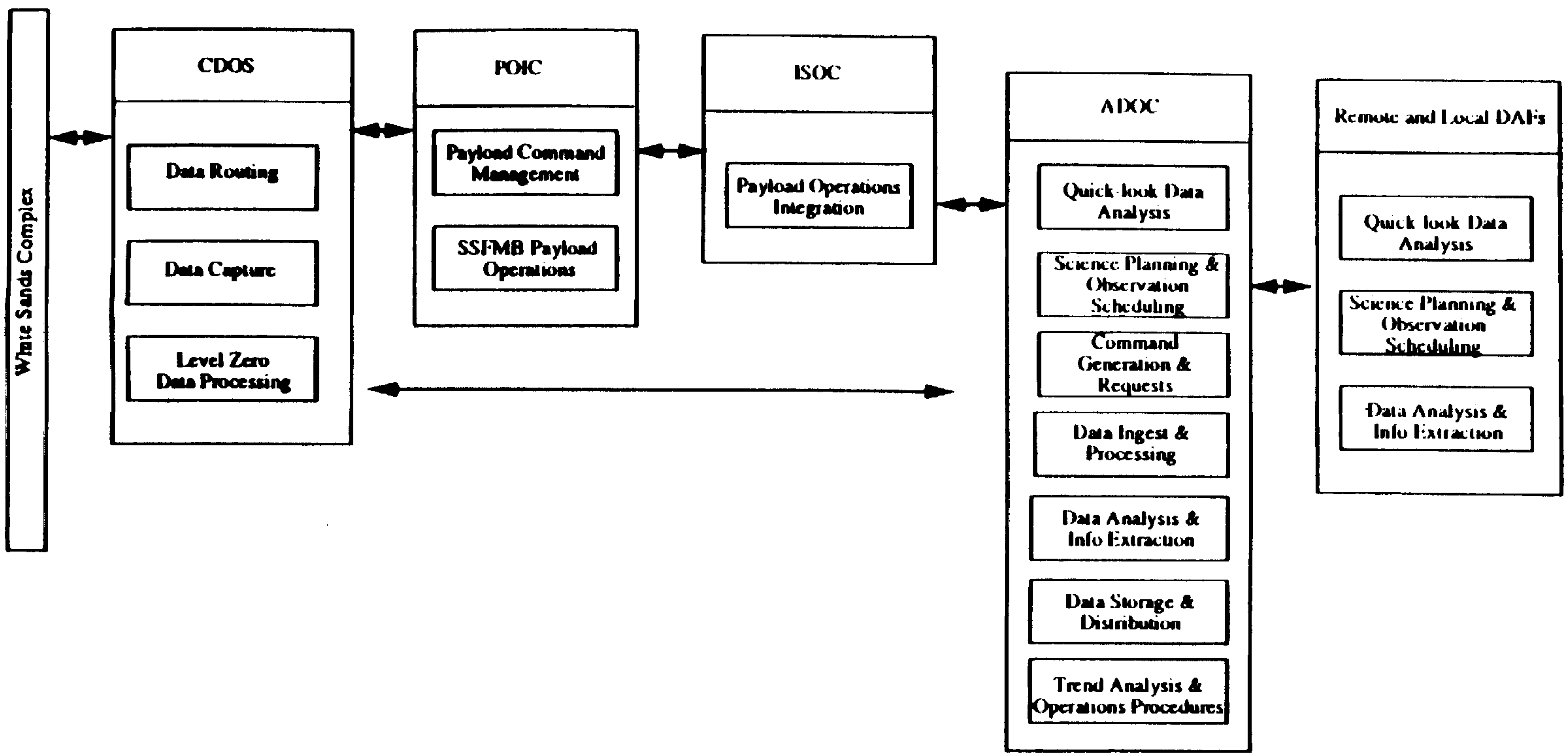


Figure 9. Astromag Ground Data System Top-Level Functionality

The RDAFs analyze science data received from the ADOC and provide science planning and observation scheduling data inputs to the ADOC for integration with similar data from other RDAFs and from the Astromag Core Facility operations personnel.

The POIC and ISOC are assumed to operate on as 24-hour, 7-day-a-week basis in support of SSFMB and attached payloads. While it is understood that Astromag health and safety data are maintained by the ADOC, it is assumed that the POIC/ISOC cadre provides monitoring in accordance with ADOC provided procedures to mitigate the need for around-the-clock ADOC staffing. The POIC personnel that monitor Astromag health and safety data can be monitoring other payloads concurrently.

The ADOC and RDAFs are assumed to operate on a normal 40-hour work-week basis. Continuous operation of these facilities is not required because the POIC and ISOC provide monitoring of Astromag health and safety. The Astromag data acquisition rate is sufficiently low that the ADOC and RDAFs can conduct science operations data processing and data analysis without around-the-clock services. In addition, Astromag requires little or no real-time commanding because it is primarily a pre-planned mission.

Assuming concurrent operation of the LISA and WiZard instruments, the daily data capture and processing requirement is approximately 552 megabytes of data. This value was derived on the basis of the proposed instrument data rates summarized in Table 3-7. These data rates are assumed to include both engineering and science data. Both instruments are assumed to have a 24-hour duty cycle. In addition, LISA is assumed to generate data at average and peak rates in the same proportion as those identified for WiZard: average data rates 97 percent of the time and peak data rates the remaining 3 percent of the time.

Table 5
Proposed Instrument Data Rates

Instrument	Average Data Rate (kbps)	Peak Data Rate (kbps)
LISA	9	30
WiZard	35	250

After two years, either LISA or WiZard will be replaced by SCINATT. Since SCINATT generates only engineering data, the return link data rates and storage and processing capacities that must be supported by the ISOC would be reduced. The 552 megabytes value therefore represents the worst case daily capacity.

5.2 Astromag Ground Data System (AGDS) Functions

This section provides a discussion of the functionality of the AGDS facilities and the components of which those facilities are comprised.

5.2.1 CDOS

CDOS will provide data routing, data capture and LZP functions for Astromag as well as other missions in the Astromag timeframe. VCGWs and Data Interface Functions will be CDOS developments. VCGWs may exist at all prime AGDS locations. VCGW to VCGW communications are assumed to be transparent in Figure 10 and Table 6. Actual data transport will be accomplished by CDOS in cooperation with NASCOM. CDOS will provide Astromag engineering data to the POIC/ISOC in realtime. It will provide Level Zero processed science data to the ADOC (not realtime) and will provide temporary storage of the raw data until the ADOC/RDAFs indicate that initial processing was successful. CDOS will also provide forward transport of commands from MSFC to the WSC.

5.2.2 POIC

The supporting facilities located at MSFC are currently being redefined. The POIC is responsible for the health and safety of the SSFMB. In this capacity, the POIC will conduct high-level monitoring of health and safety data provided by the Astromag space segment (as well as any other attached payloads) and will uplink safing sequences as required to ensure the continued health and safety of the SSFMB. The POIC will request SSFMB and SN resources via CDOS for all attached payloads and communicate these resulting allocations to the ISOC for subsequent allocation to the various U.S. payloads. The POIC will examine command loads received from payload operators via the ISOC to validate the originating source and intended destination of the command loads on-board and to verify that the command loads are contained within allocated resource envelopes. The actual commands and command sequences destined for Astromag will not be examined by the POIC; it is assumed that the ADOC will validate all commands in the load and that on-board hardware and software interlocks will further prevent invalid or unsafe operations. Following command load validation and verification, the POIC will uplink the command loads to Astromag via a secure link to the WSC.

5.2.3 ISOC

The ISOC is the central facility responsible for the integration of all SSFMB attached payloads. The proposed implementation of the ISOC is a result of the Code E desire to provide a single interface between the POIC and multiple experimenters.

The ISOC is comprised of two primary components: the Discipline Operations Facility (DOF), and the Command Management System (CMS). The subsections that follow describe the functions to be accomplished by these components as depicted in Figure 9.

5.2.3.1 Discipline Operations Facility (DOF)

The DOF will be the focal point for ISOC realtime data monitoring. Astromag engineering data received via the SN and CDOS will be quick-look processed and displayed for DOF operations personnel resident at the ISOC. These personnel will be responsible for the health and safety of the Core Facility and the instruments and will monitor the magnetic field, Helium level, Helium flow rate, venting rate, pressure,

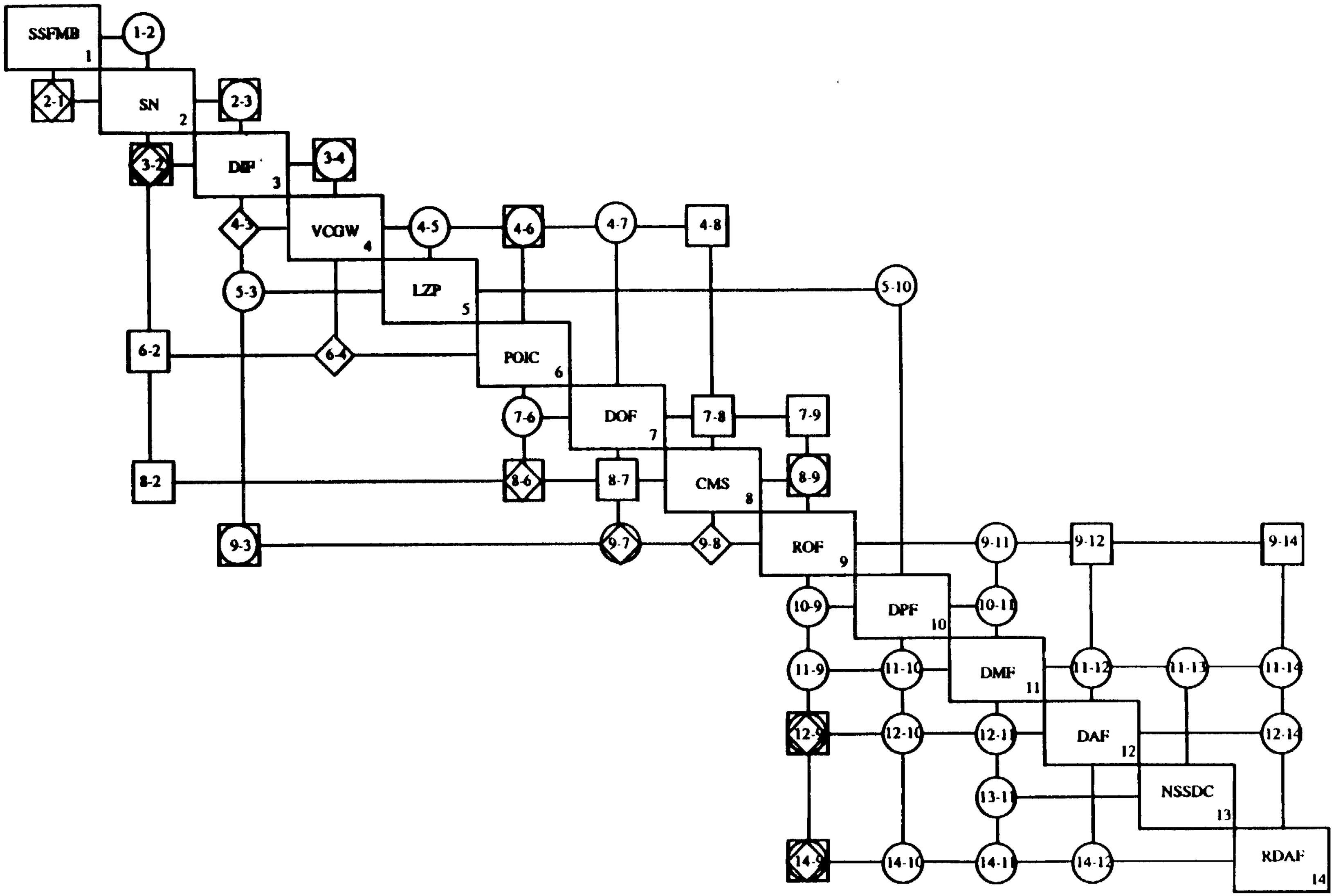


Figure 10. Conceptual Astromag Ground Data System N-Squared Diagram

Table 6. Astromag Interfaces

Element	From-To	Medium	Information Transferred
SSFMB	1-2	K-Band S-Band	Astromag engineering and science data
SN	2-3	LAN	Astromag engineering and science data, resources
DIF	3-4	?	Astromag engineering and science data, Astromag TDRS schedule
VCGW	4-5	?	Astromag engineering and science data
VCGW	4-6	? & LAN	Astromag realtime engineering data, resource schedules
VCGW	4-7	? & LAN	Astromag realtime engineering data
VCGW	4-8	? & LAN	Astromag resource schedules,
LZP	5-10	?	Non-real-time Level-0 data, data processing parameters
POIC	7-8	LAN	Acknowledgements of command loads received
DOF	7-9	Nascom	Acknowledgements of command loads received
CMS	8-9	Nascom	Resource envelopes, Schedules
ROF	9-11	LAN	Trend analysis Results, Data retrieval requests
ROF	9-12	LAN	Planning and scheduling products
ROF	9-14	NSN,SPAN	Planning and scheduling products
DPF	10-11	LAN	Level-1 and higher-level data products, data retrieval requests
DMF	11-12	LAN	Data catalog, requested data sets
DMF	11-13	Physical	All non-proprietary data, Correlative data requests
DMF	11-14	NSN,SPAN	Data catalog, requested data sets
DAF	12-14	NSN,SPAN	Archive assessment, analysis results
RDAF	14-12	NSN,SPAN	Software archive requests, analysis requests
RDAF	14-11	NSN,SPAN	Analysis results, data requests
RDAF	14-10	NSN,SPAN	Processing parameters, Processing Requests
RDAF	14-9	NSN,SPAN	Planning and scheduling inputs, commands, data quality reports
NSSDC	13-11	LAN	Correlative data
DAF	12-11	LAN	Analysis results, data requests
DAF	12-10	LAN	Processing parameters, Processing requests
DAF	12-9	LAN	Planning and scheduling inputs, commands, data quality reports
DMF	11-10	LAN	Data catalog, requested data sets
DMF	11-9	LAN	Data catalog, requested data sets
DPF	10-9	LAN	Data quality reports, processing parameters
ROF	9-8	Nascom	Command loads, Uplink scheduling requests
ROF	9-7	Nascom	Alarm Limits, Reactive Command Procedures, (safing sequences)
ROF	9-3	Nascom	Data quality reports, processing parameters, Reprocessing requests
CMS	8-7	LAN	Command Schedules
DOF	8-6	LAN	Command loads
CMS	8-2	Nascom	Strategic Planning and Scheduling requests
DOF	7-6	LAN	Alarms
POIC	6-4	LAN & ?	Command loads
POIC	6-2	?	Planning and Scheduling requests
LZP	5-3	?	Data Retransmission requests
VCGW	4-3	?	Command loads
DIF	3-2	LAN	Schedule requests, configuration requests, command loads
SN	2-1	K-Band S-Band	Command loads

? indicates that ongoing design activities will determine this medium.

temperature, valve status, and magnet coil location as well as normal housekeeping parameters. Safing sequences developed by the ADOC will be used to respond to any health and safety problems observed.

5.2.3.2 Command Management System (CMS)

The CMS will allocate resource envelopes to Astromag on the basis of the resource allocations received from the POIC for all U.S. payloads. The CMS will integrate the resulting command loads received from the ADOC with command loads received from other attached payload remote operations facilities or generated by the CMS itself. These integrated command loads will be forwarded to the POIC for validation and verification and subsequent uplinking to the SSFMB and attached payloads.

5.2.4 Astromag Data Operations Center (ADOC)

The ADOC provides quick-look and Level 1 processing of engineering and science data received from the ISOC; stores and retrieves Astromag data and required ancillary data; interfaces with PIs and their distributed experiment teams via two-way high-speed links; and generates Astromag command sequences to be uplinked by the POIC. The ADOC also performs science planning, trend analysis, data distribution, and software development functions.

The components of the ADOC include the Remote Operations Facility (ROF), Data Processing Facility (DPF), Data Management Facility (DMF), and the Data Analysis Facility (DAF). The functionality of these components is described in the subsections that follow.

5.2.4.1 Remote Operations Facility (ROF)

The ROF is primarily responsible for monitoring Astromag Core Facility and instrument performance, for analyzing quick-look data to determine the need for instrument reconfiguration, and for providing updates to the command load to reconfigure the payload as required to ensure that scientifically useful data are acquired at all times. The ROF is responsible for these functions during all mission phases, including launch, assembly, operations, and maintenance.

The ROF uses science, experiment, and Core Facility inputs and the allocated resource envelope to generate a proposed command schedule for the Astromag Core Facility and experiments. This proposed command schedule is then iterated with Astromag PIs until an acceptable command schedule is achieved. The ROF then generates and verifies a command sequence to be uplinked via the ISOC and POIC to the Astromag Core Facility for storage in the C&DH. The ROF ensures that the command loads generated as a result of the iteration process are contained within the resource envelope allocated to Astromag by Space Station Freedom. Astromag will require little or no real-time commanding; the bulk of the commanding will be achieved via the command loads generated by the ROF.

Trend analysis for the Astromag Core Facility and instruments will be performed by ADOC personnel. These trend analyses will allow ADOC personnel to maintain the parameter alarm list, limits and procedures to be implemented as necessary by POIC and ISOC personnel.

5.2.4.2 Data Processing Facility (DPF)

The DPF performs Level 1 processing of instrument data received from the ISOC to generate calibrated data products using PI-certified algorithms. Additional science data processing (Level 2, Level 3, etc., or other special processing) can be provided by the DPF on a negotiated basis. The distribution of the various data products to PIs and their experiment teams is also handled by the DPF.

5.2.4.3 Data Management Facility (DMF)

The DMF stores and manages all acquired data and processed data products as well as supporting software developed by Astromag scientists and experiment teams. The DMF is comprised of two elements: a data bank and a data base management system (DBMS). The data bank is the physical storage medium on which the data and software are stored. The DBMS creates and maintains an electronically browsable catalog of all data products and software residing in the data bank and provides the means by which scientists may retrieve stored data products or software. The data include Level Zero instrument data, calibrated/corrected data, science data products generated by the DPF, and higher-level products generated by the DAF or RDAFs. In addition, the DMF can store and distribute other correlative data from the NSSDC. At this time, however, no correlative data requirements have been identified for Astromag. The software stored by the DMF includes analysis routines developed by Astromag scientists or experiment teams that are potentially applicable and useful to other scientists in their analyses of astrophysical science data. The DMF also archives science data and supporting analysis software using the NSSDC.

5.2.4.4 Data Analysis Facility (DAF)

The DAF at GSFC provides analysis and visualizations tools/techniques, hardware, and services for the cosmic ray science team for the LISA experiment that will be operated by GSFC. The DAF also provides facilities for guest observers to analyze Astromag data.

5.2.5 Remote Data Analysis Facilities (RDAFs)

The RDAFs examine real-time mission data received from their instruments via the ADOC to verify instrument performance. Selected processed data subsets are requested from the DPF for detailed analysis by the RDAFs. The resulting higher-level data products may then be stored at the ADOC DMF for reference by other scientists. Experiment operators may use the real-time mission data and processed science data to plan experiment activities and generate the command sequences required to configure the instrument and conduct operations. These command sequences are forwarded to the ADOC for verification and integration with other Astromag (Core Facility and instrument) command sequences and subsequent transmission to Astromag. It is assumed that each experiment operator has knowledge of the allocated resource envelope and works within these constraints.

The RDAFs also provide analysis capabilities for visiting scientists.

5.3 Astromag Ground Data System (AGDS) Interfaces

Figure 10 illustrates the interfaces among the Astromag data transfer, ground network coordination, mission operations, science operations and data processing facilities, and identifies the data transferred to or from each element by assigning an identification number to each of the interface nodes. The Astromag system elements in Figure 10 are numbered, and the data identification numbers are keyed to the element numbers to indicate the origin and destination of the data being transferred. The interface nodes are also identified by a characteristic shape to indicate the type of interface: circles for downlink interfaces and post-event reporting, squares for planning and scheduling interfaces, and diamonds for uplink interfaces. Table 6 lists the Astromag interface elements, their sources and destinations, transmission medium, and type of information transferred.

5.4 Astromag Ground Data System (AGDS) Conceptual Architecture

The Astromag Ground Data System will consist of the WSC, CDOS, POIC, ISOC, ADOC and RDAFs. Figure 11 illustrates the conceptual architecture of the Astromag Ground Data System.

The AGDS conceptual architecture assumes that the data capture and LZP functions are performed by the CDOS for Astromag and all other attached payloads. Return link engineering data will be routed to the POIC and the ISOC by the VCGW. The POIC and the ISOC will monitor engineering data and provide safing in accordance with ADOC-generated and PI-generated procedures to ensure Astromag health and safety as required.

The ADOC will receive real-time and production quality non-real-time Level Zero data products. Real-time Level Zero data will be used for science planning and observation scheduling. Non-real-time production-quality Level Zero data will be processed to Level 1 and higher data products and then distributed to local and remote data analysis facilities for analysis by Astromag PIs and their experiment teams. All data and data products will be stored in the DMF.

The local and remote data analysis facilities will receive Astromag Level Zero, Level 1, or Level 2 data for analysis by Astromag Core Facility and experiment science teams and guest investigators. Resulting data products may be stored in the DMF at the ADOC. Data analysis facility personnel can also identify desired data products through the data catalog provided by the ADOC.

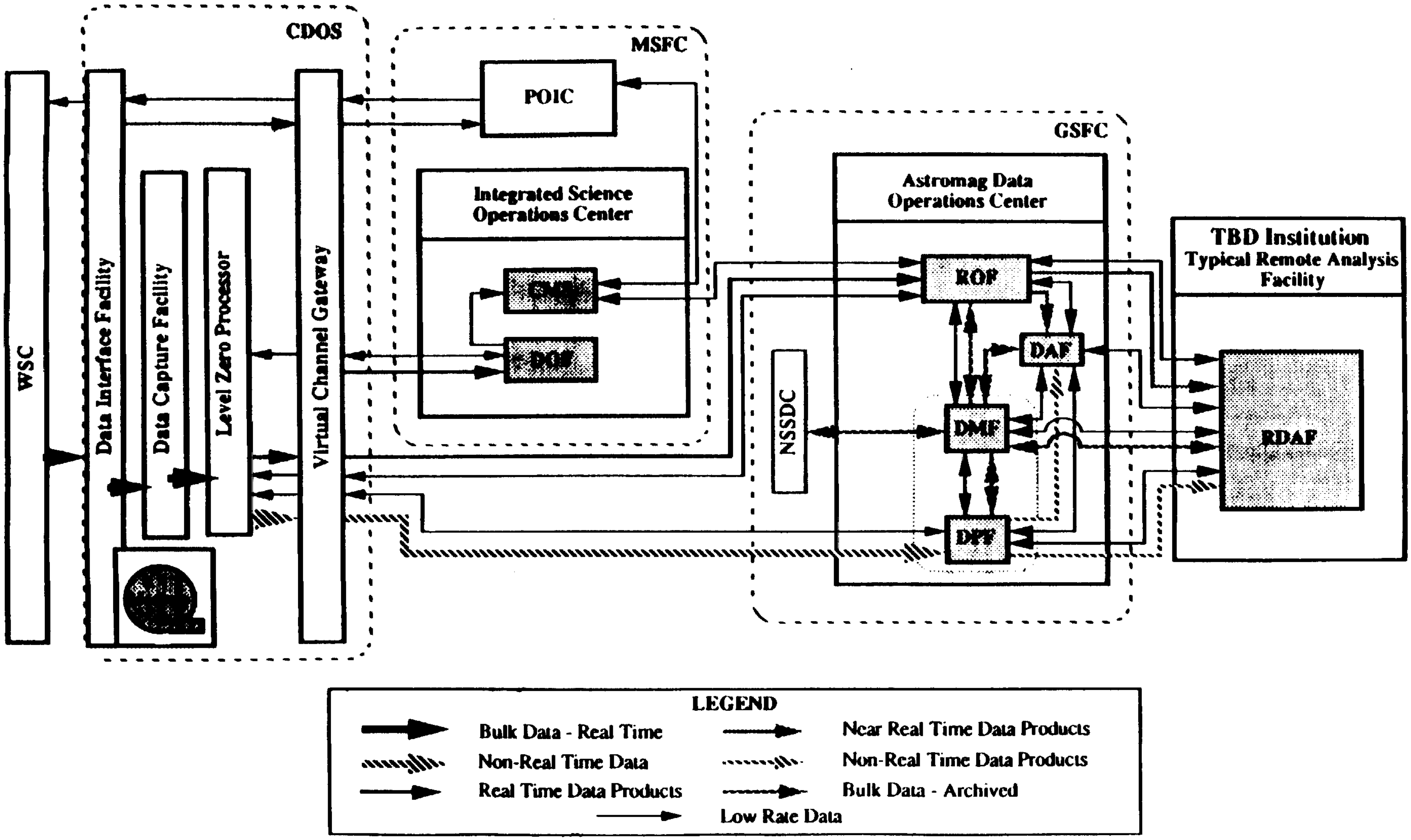


Figure 11. Conceptual Astromag Ground Data System Architecture

6.0 ASTROMAG DATA SYSTEMS ISSUES

There is one issue that warrants mentioning at this time: the APAE DHS interface.

As stated in Section 4.4, a dedicated 1553 bus would provide the Astromag attached payload with sufficient capacity for uplink and downlink data traffic and require fewer interfaces. That is not consistent with the current APAE DHS preliminary architecture but would not imply fewer, not more, APAE resources for Astromag and simplify the Astromag design and development.