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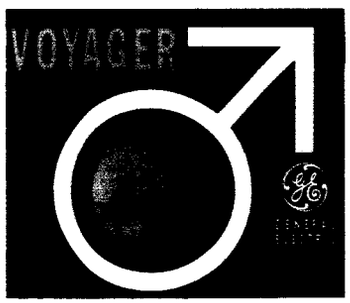

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DATA MANAGEMENT STUDY

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PREPARED FOR
CALIFORNIA INSTITUTE OF TECHNOLOGY
JET PROPULSION LABORATORY
4800 OAK GROVE DRIVE
PASADENA, CALIFORNIA
UNDER CONTRACT NO. 951112

GENERAL ELECTRIC
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Valley Forge Space Technology Center
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TABLE OF CONTENTS

SECTION 1

INTRODUCTION

This final report summarizes the results of the Data Management and Control Study conducted for the Jet Propulsion Laboratory under Contract No. 951112.

It consists of this descriptive volume which contains the study objectives, approach, results, and recommendations, and also includes a group of Appendixes containing integrated contractor data requirement packages (Data Item Matrix, Data Requirement Descriptions, User Flow Diagram, Document Relationship Tree, Phasing and Frequency Chart) for the following functional management categories:

Appendix A	-	Technical Description and Systems Engineering (SE)
Appendix B	-	Planetary Quarantine (PQ)
Appendix C	-	Manufacturing (MG)
Appendix D	-	Configuration Management (CM)
Appendix E	-	Quality Assurance (QA)
Appendix F	-	Test (TE) and Mission Operations (MP)
Appendix G	-	Reliability Assurance (RA)
Appendix H	-	Logistics and Support (LS)
Appendix I	-	Overall Management (MA); Scheduling (SC); and Manning and Financial (MF)
Appendix J	-	Procurement and Contracting (PC)
Appendix K	-	Data Management (DM)
Appendix L*	-	Facilities (FA)
Appendix M*	-	Safety (SA)
Appendix N*	-	Site Activation for Launch (AL)

* Prepared under Contract NAS 7-584

Appendix O* - Science (SI)

Appendix P* - Related Project Interfaces (RP)

Appendix Q* - Advanced Missions (AM)

This final report, with the exception of the updated data package appendixes, contains summaries and excerpts from technical reports previously issued during the study; a bibliography of these reports is included as Section 8 to permit acquisition of the original documents.

It should be noted that many of these reports are identified as "Preliminary"; this is by intent, as final plans (e.g., Contractor Automatic Data Processing Plan) can only be established during Phase C - Design.

* Prepared under Contract NAS 7-584

SECTION 2

OBJECTIVES

The primary objectives of the study have been to support NASA/JPL in the development of the Voyager Data Management System by:

a. Delineating the basic operational aspects of the Voyager Data Management System throughout its operational phases.

b. Developing contractor level information flow and data requirements for the Voyager Design and Acquisition Phases (C and D).

c. Analyzing contractor implementation of selected functions of the Voyager Data Management System.

d. Determining data requirements and reporting systems for project management control of contractor activities.

It has been the objective in all of these studies to use the background and experience of functional management personnel to assure the validity of data and information flow requirements.

In addition, because of its significance, the study of information flow and data requirements pertinent to management control has been identified as a specific task objective.

SECTION 3

APPROACH

The study approach consisted of four basic phases, as listed below and illustrated in Figure 3-1:

a. Phase I - The Data Management System Study resulted in the preparation of a series of system flow diagrams that delineated the data management system, a glossary which identified Voyager application data management terms and a data standards study.

b. Phase II - The Contractor Data Requirements Study resulted in the definition of Phase C and D data requirements by functional managers at the Valley Forge Space Technology Center. This activity included the preparation of Data Item Matrices, Data Requirement Descriptions, User Flow Diagrams, Document Relationship Trees, Phasing and Frequency Charts, and a Subcontractor Data Item Study.

c. Phase III - The Contractor Implementation Studies resulted in a series of studies that analyzed how a Voyager contractor would implement functions of the data management program. This included the preparation of an information system equipment handbook, microfilm compendium, automatic data processing plan, indentured numbering system study and data cost study.

d. Phase IV - The identification of Contractor Management Information Studies resulted in the generation of data requirements for project management control, an automatic data processing plan for project control, a technical performance monitoring study, and a project control room study.

The basic approach used during all phases of the study was to utilize Voyager spacecraft functional personnel to develop data flow and requirements, to utilize Information System personnel to develop methods and media of information flow, and to use Management Practices Operation personnel and consultants to review operational aspects of the program. The use of these personnel and the support provided are illustrated in Figure 3-2.

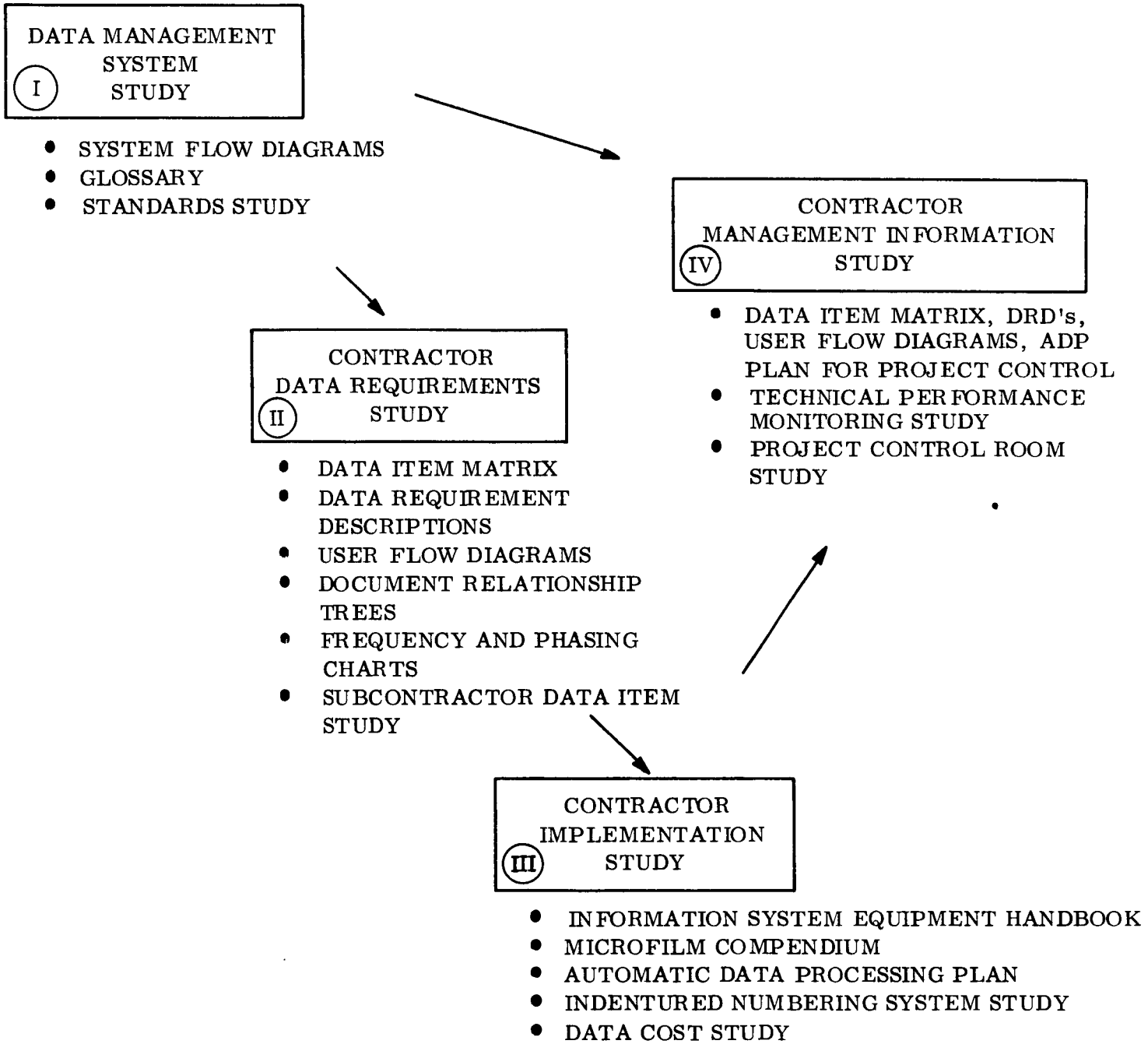


Figure 3-1. Study Approach

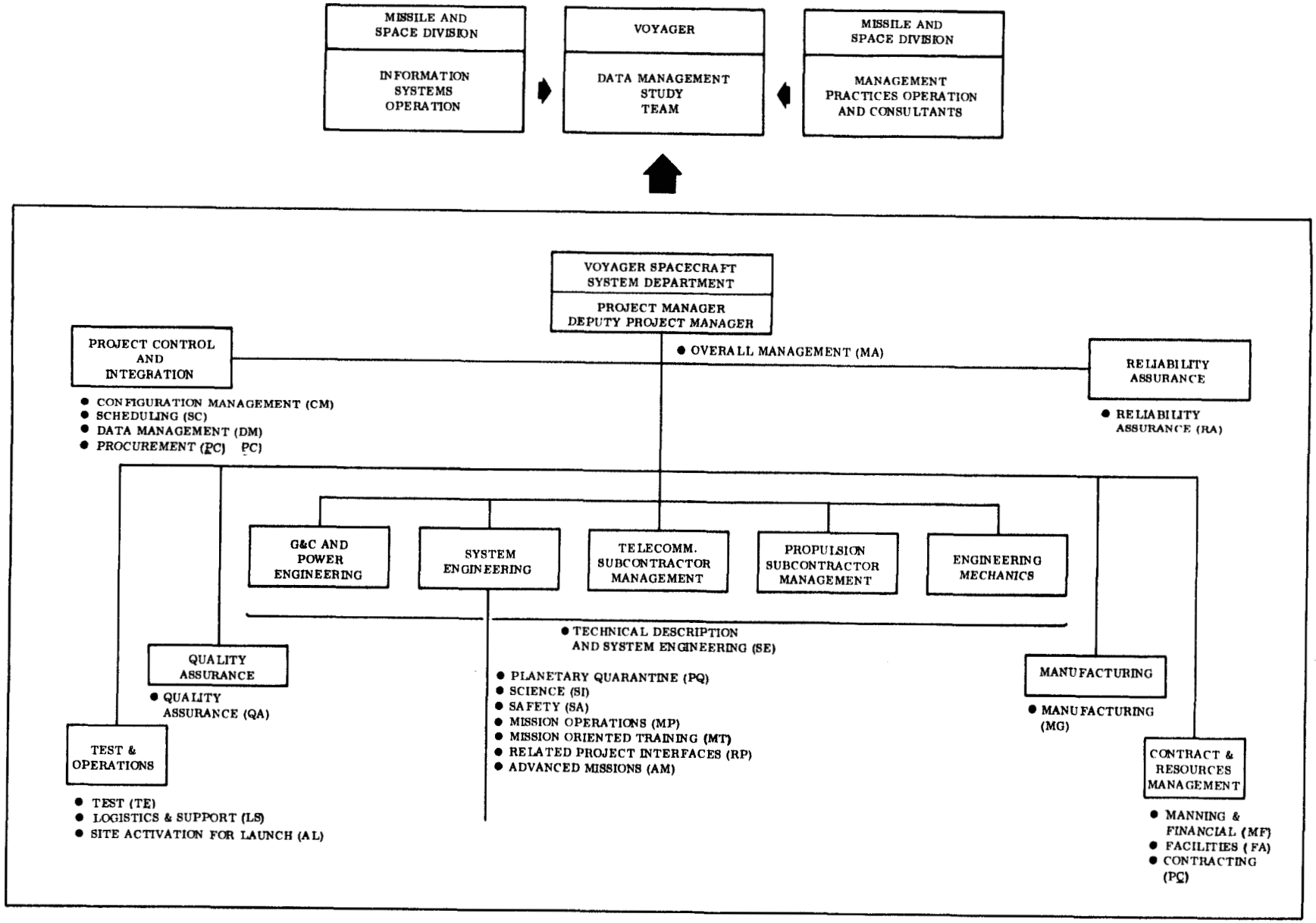


Figure 3-2. Missile and Space Division Study Support

SECTION 4

DATA MANAGEMENT SYSTEM STUDY - PHASE I

4.1 INTRODUCTION

Working closely with JPL, a series of flow diagrams delineating the proposed Voyager Data Management System were prepared during the initial phase of the study.

These diagrams apply to the management of formal data, both hard copy and that maintained by means of automatic data processing equipment. Formal data, which is generally used by multiple project elements, is prepared and processed in accordance with project established requirements and procedures and controls. Informal data, in contrast, is generally used within, and managed internal to a particular project element.

In addition, a glossary defining Voyage data management terms and a report identifying existing specifications and standards relating to the preparation, submittal, and review of data were prepared.

4.2 FLOW DIAGRAMS

The summary flow diagram (Figure 4-1) is vertically divided into three sections. Each section represents a major operational phase of the Voyager data management system, as follows:

a. Establishment of data requirements

b. Data preparation and publication

c. Data handling and processing

The flow diagram is divided horizontally into three bands, as follows:

a. The central band (designated Organization Levels) is further divided into program/project, system, prime contractor, and subcontractor levels

b. The bottom band, designated Voyager Data Management Information System

c. The top band, designated User

The central band, containing the organization levels, presents a continuous flow of the major functions (and their associated data) performed by the various project elements (program/project office, system office, contractor, subcontractor) during the three phases of the data management system. The interrelationships between the project elements and between the phases are indicated, as appropriate.

The bottom band indicates major functions (and their associated data) of the Data Management Information System which provides the means for identifying, tracking and retrieving data. Functions indicated in this band are located parallel to the corresponding function performed by an organization level.

The top band indicates the role played by the generic user in the data management system. Functions performed by the user are shown parallel to, and keyed into the basic flow presented in the central organization level band.

Each of the three operational phases of the data management system has been detailed on separate flow diagrams (which have been issued in VOY-C4-TR-07 and are not included in this report):

a. Phase 1: Establishment of Data Requirements

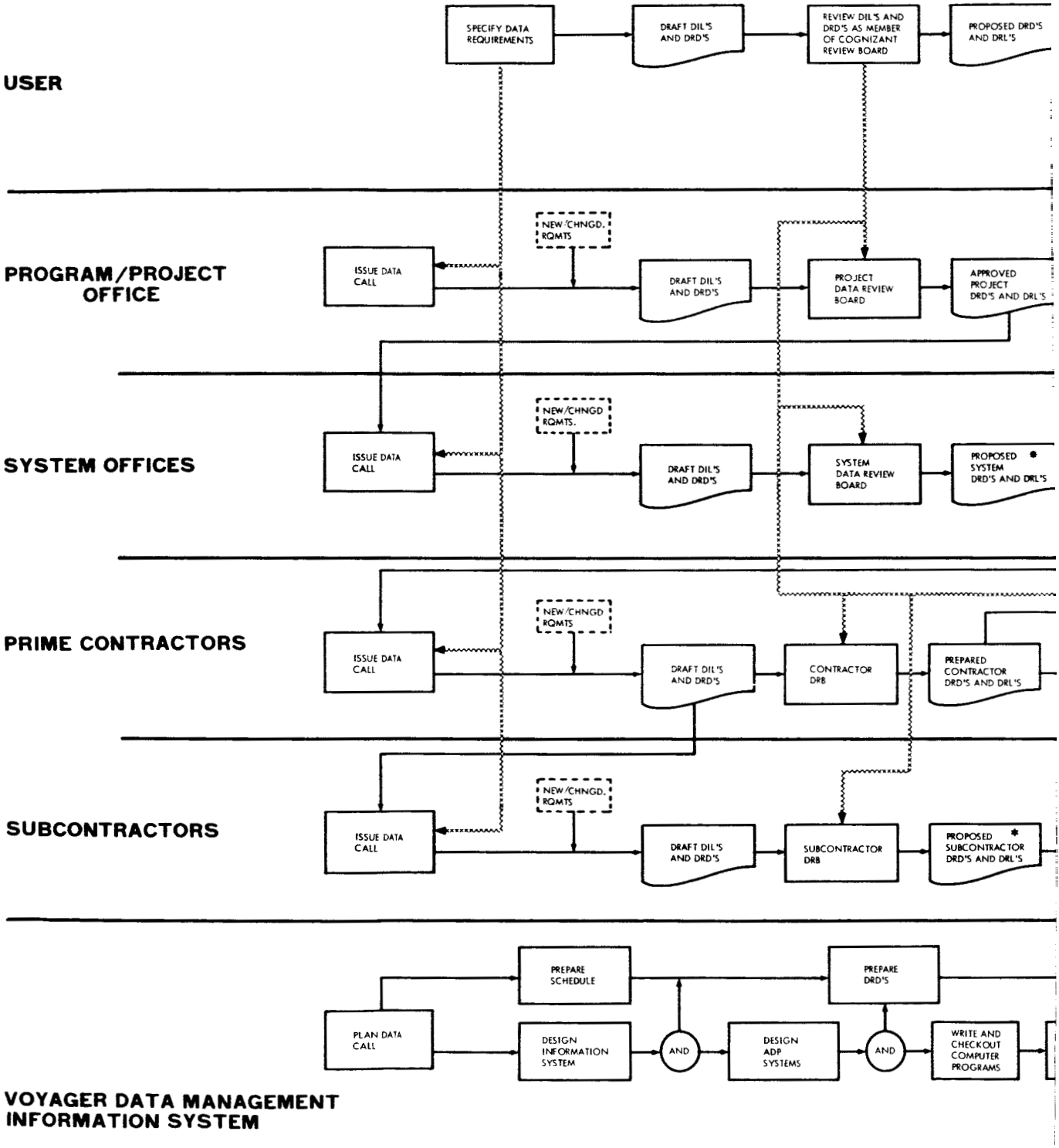
b. Phase 2: Data Preparation and Publication

c. Phase 3: Data Handling and Processing

The detailed flow diagrams generally follow the same horizontal format as the summary diagram (the use of three bands). Continuity across the three diagrams and the parallel relationships between respective activities in the three bands are maintained.

ESTABLISHME

DATA PROGRAM ACTIVITIES BY ORGANIZATIONAL LEVELS



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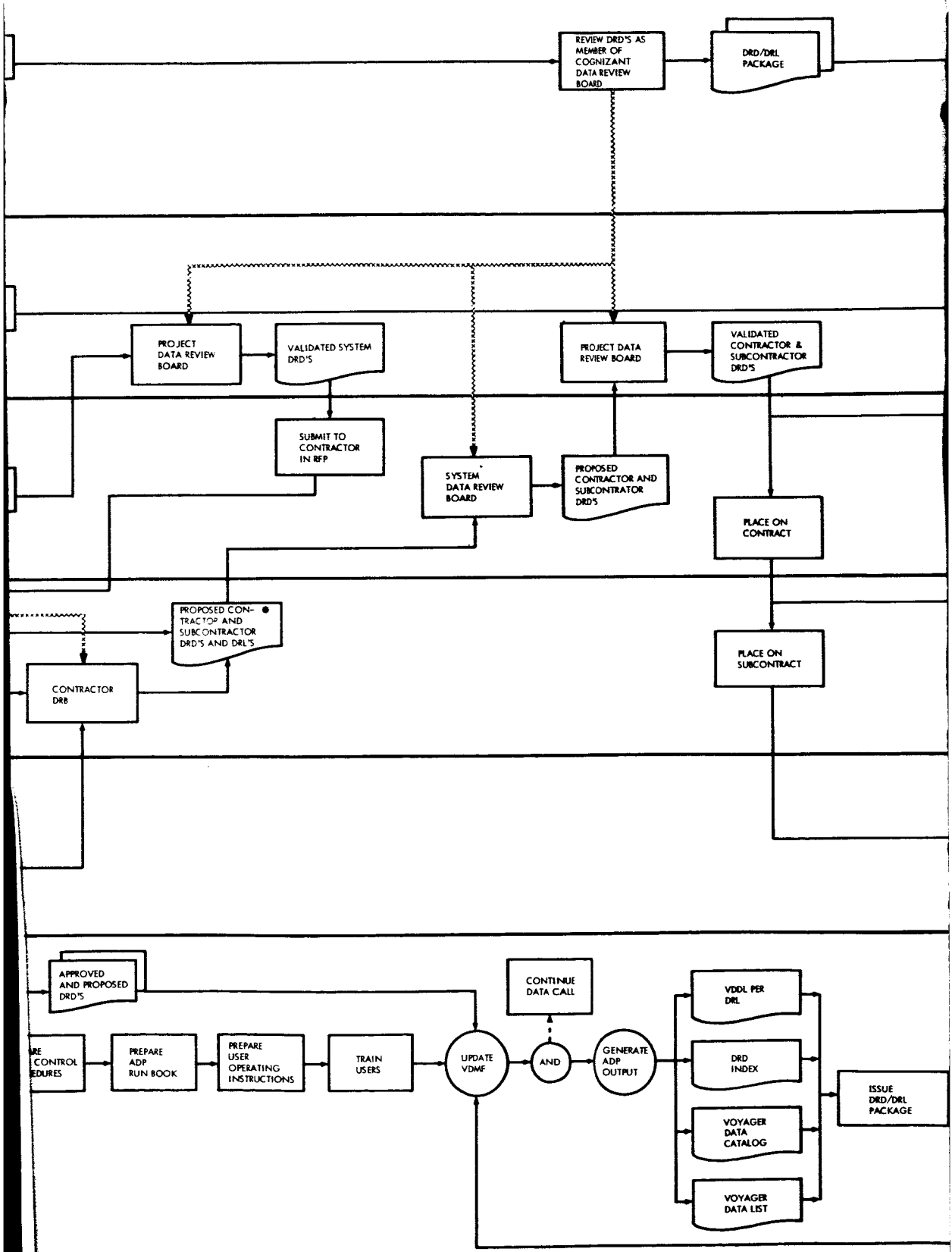

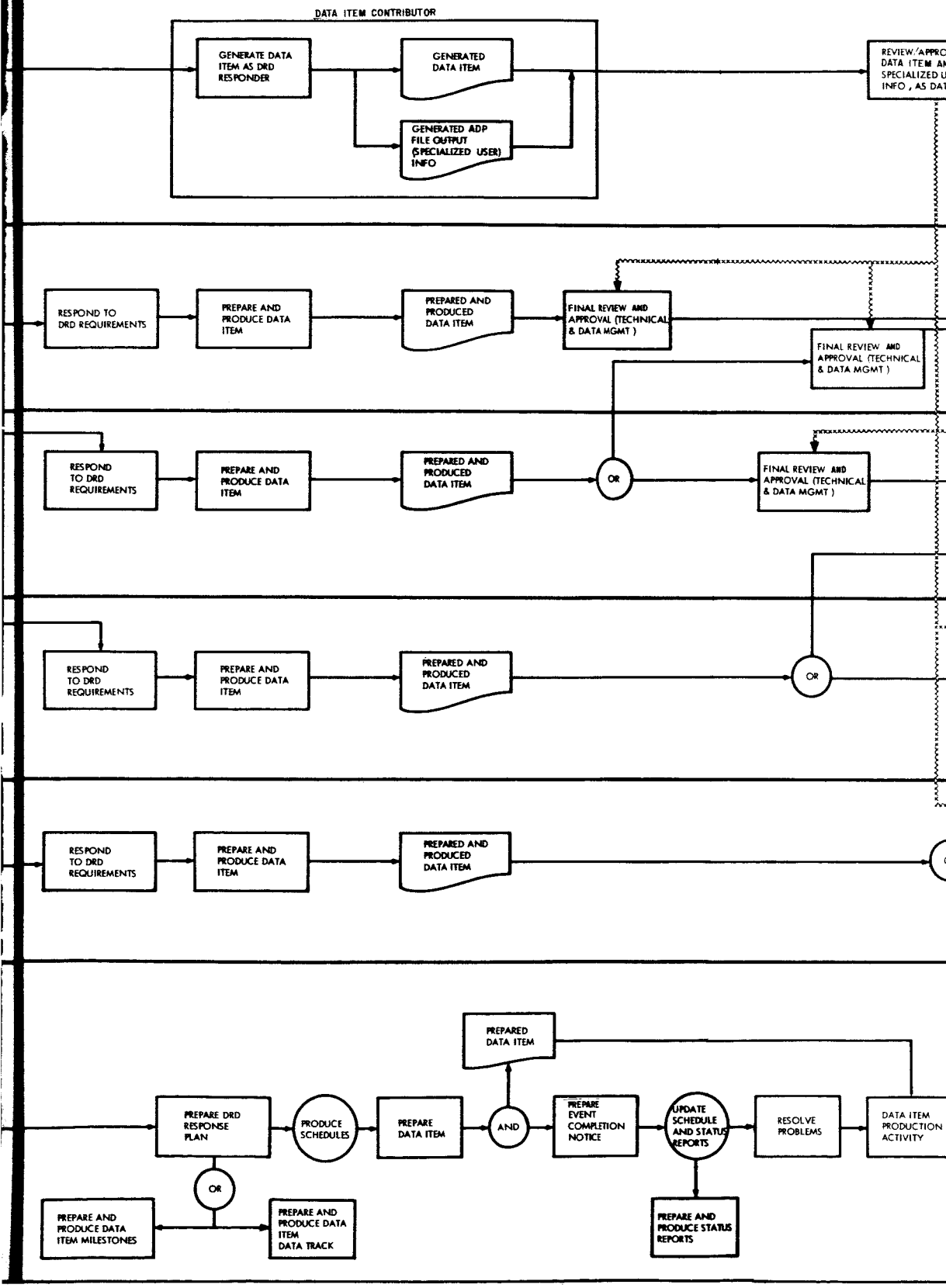
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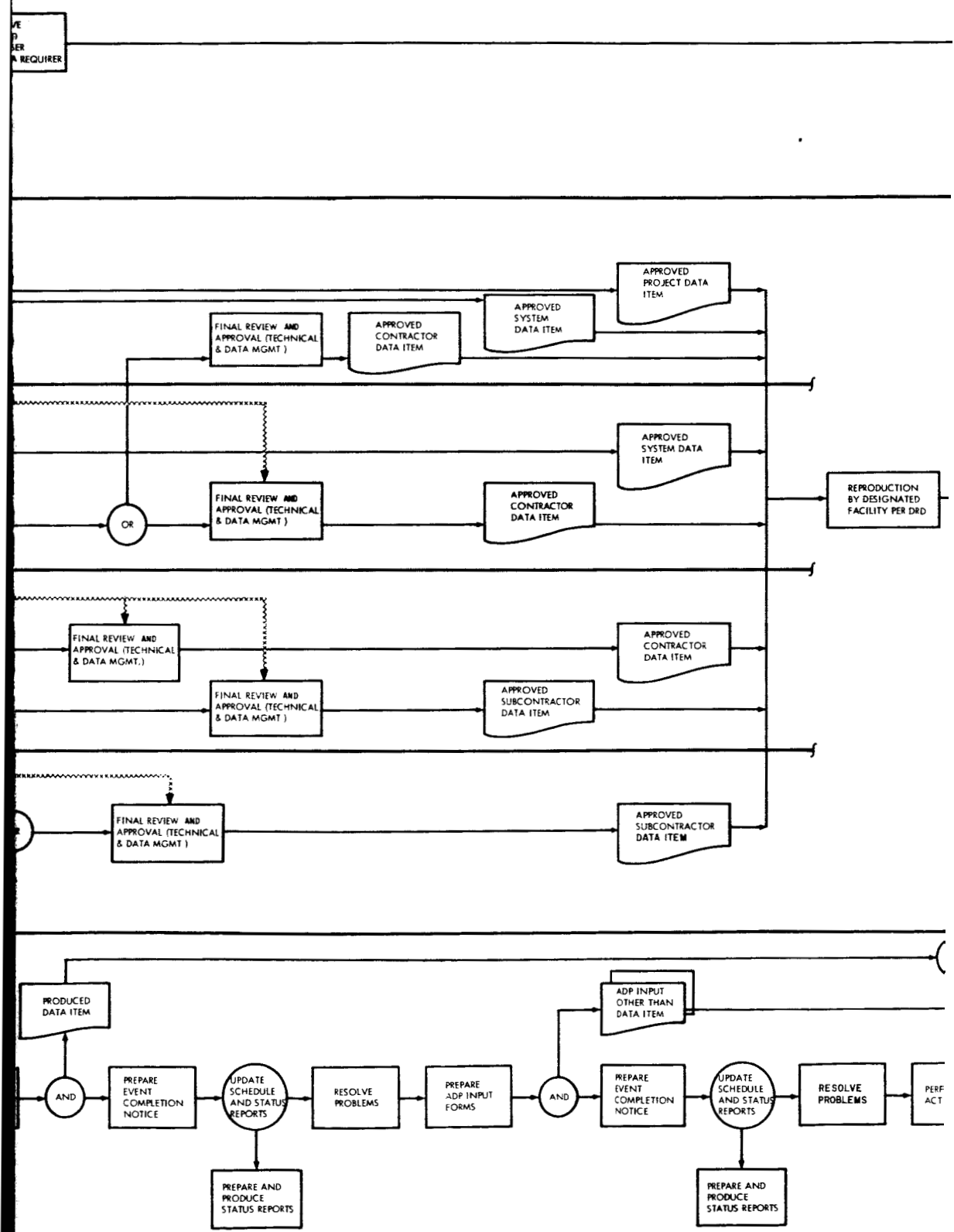
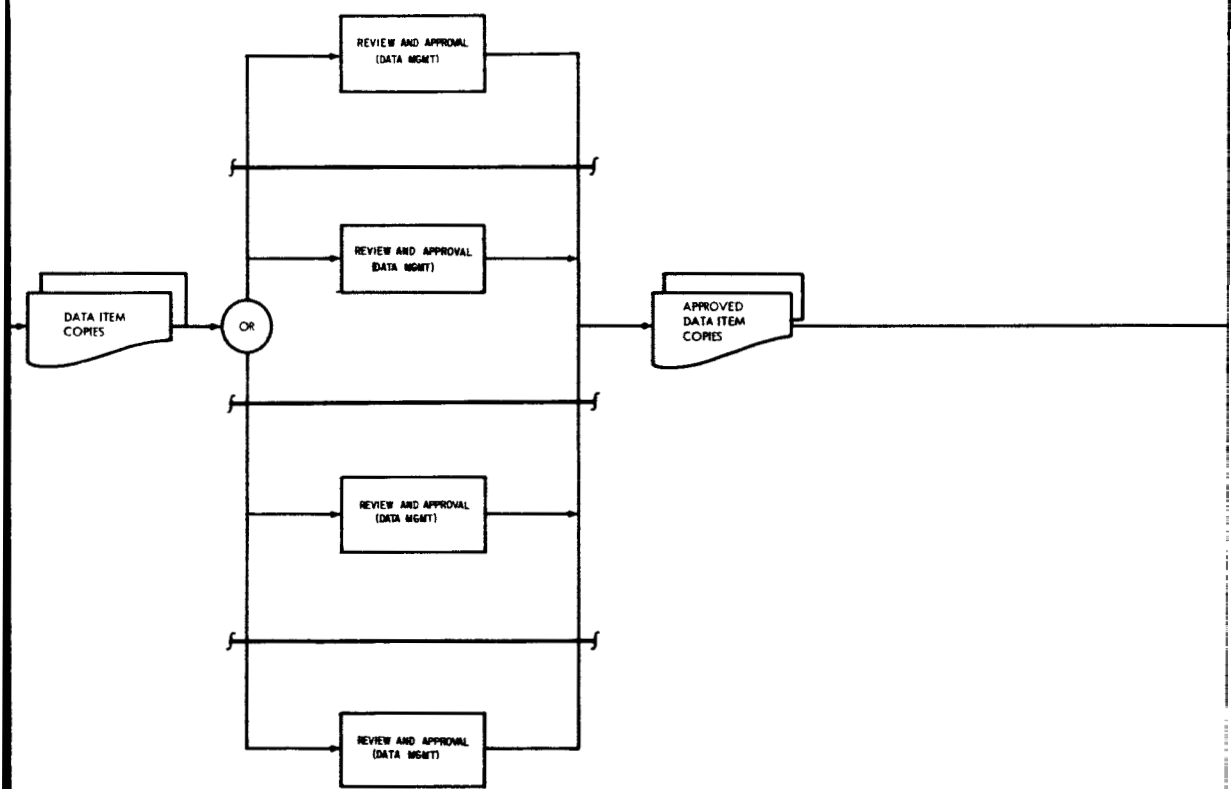
PREPARED AND PRODUCED DATA ITEM
PREPARED DATA ITEM
PREPARE DRD RESPONSE PLAN
PRODUCE SCHEDULES
PREPARE DATA ITEM
AND
PREPARE EVENT COMPLETION NOTICE
UPDATE SCHEDULE AND STATUS REPORTS
RESOLVE PROBLEMS
DATA ITEM PRODUCTION ACTIVITY
OR
PREPARE AND PRODUCE DATA ITEM MILESTONES
PREPARE AND PRODUCE DATA ITEM DATA TRACK
PREPARE AND PRODUCE STATUS REPORTS

DATA PREPARATION AND PUBLICATION

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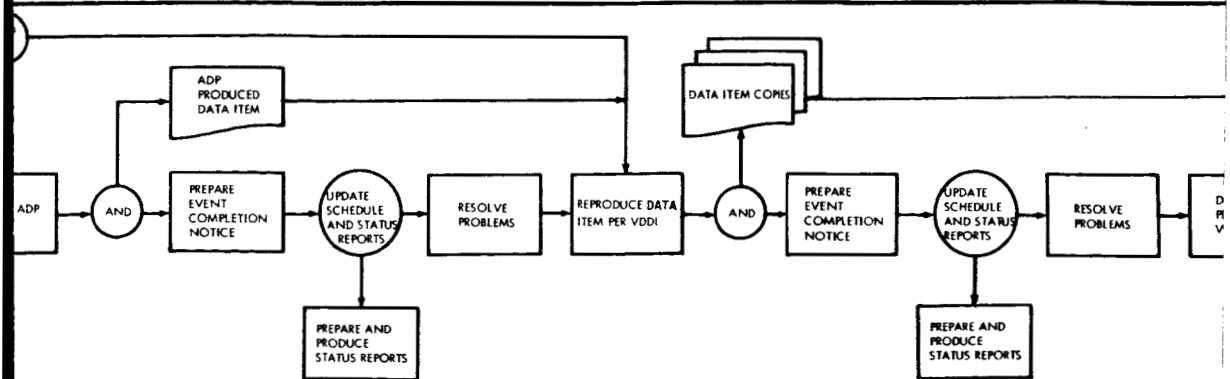
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AND
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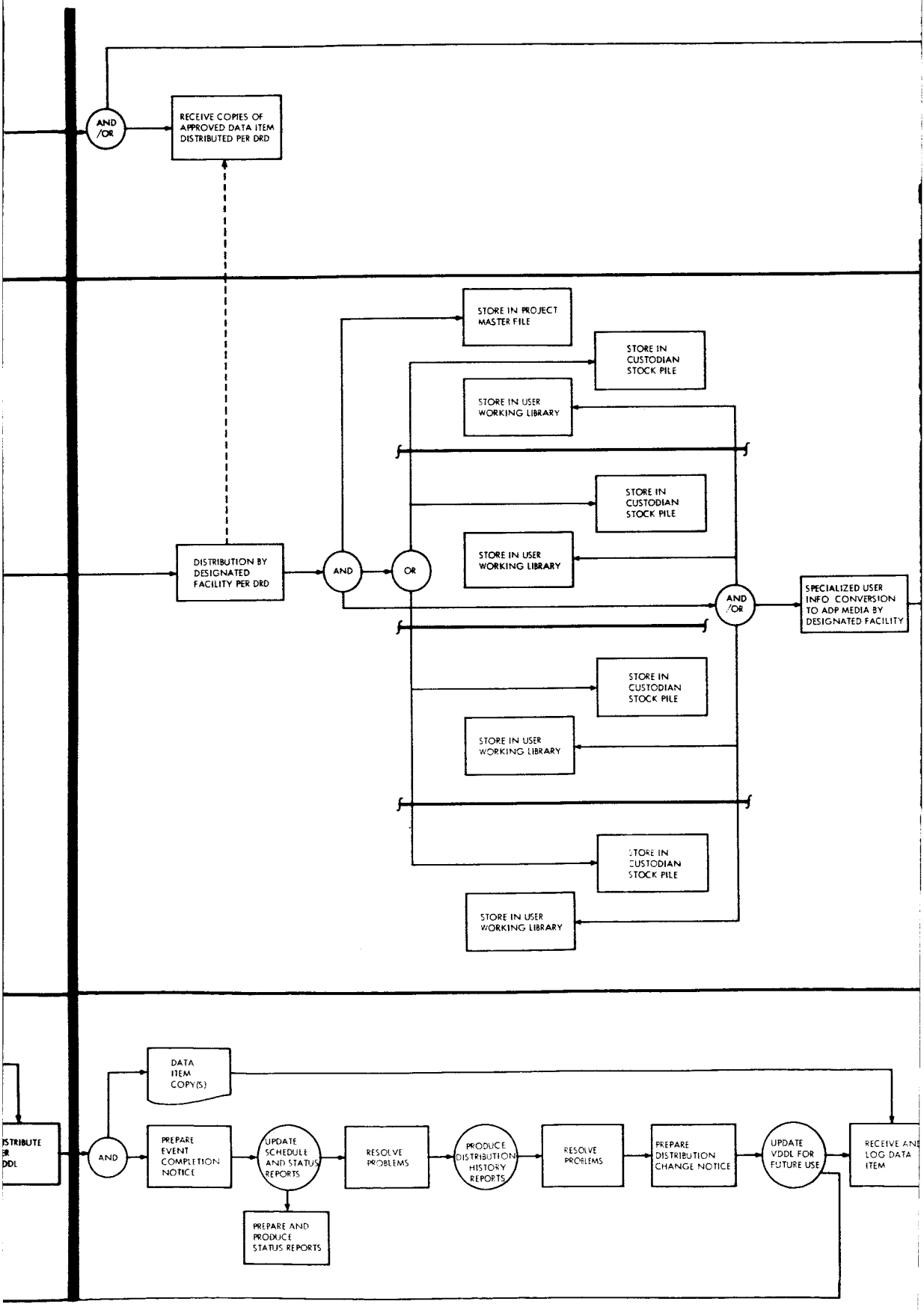

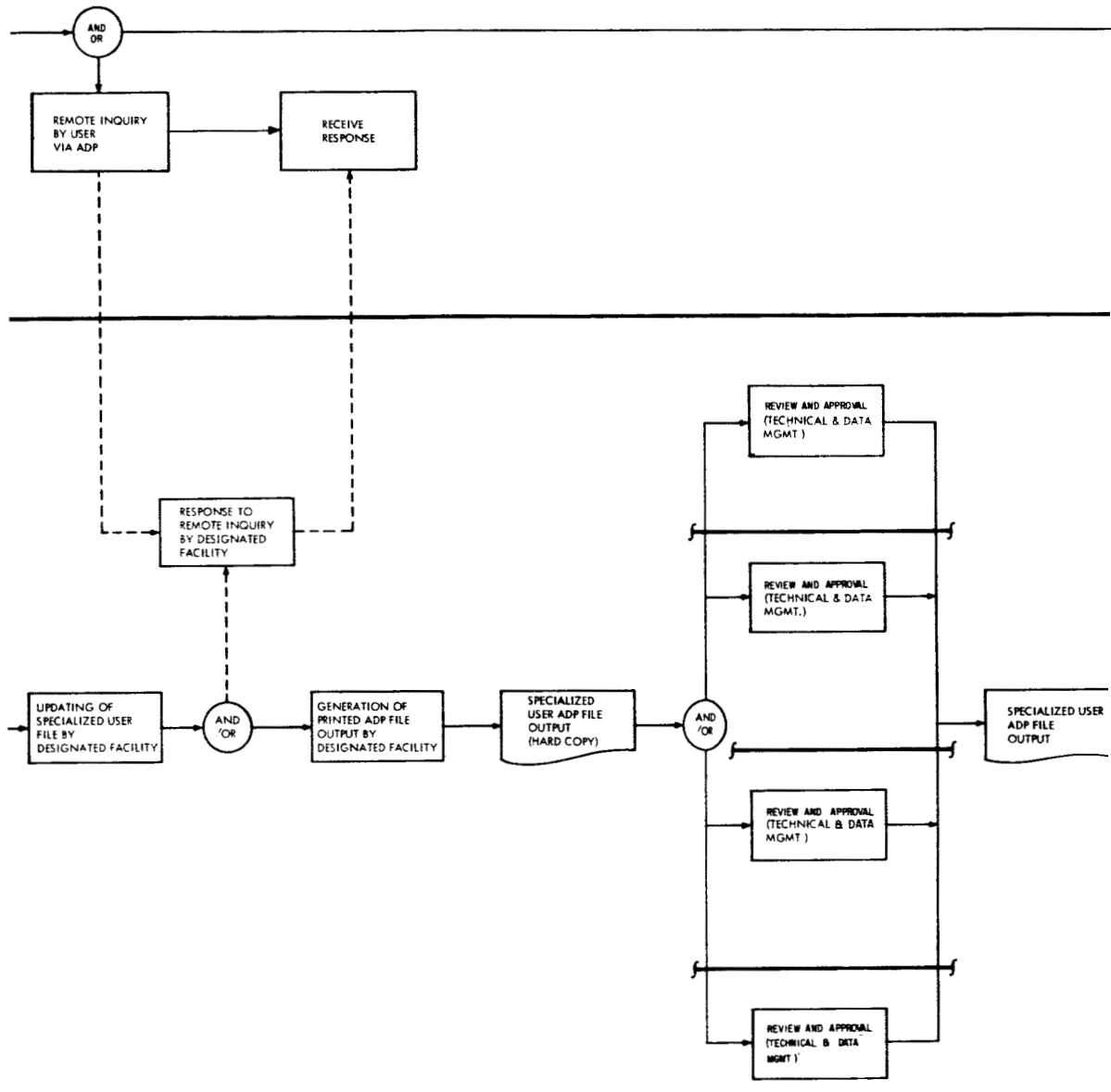
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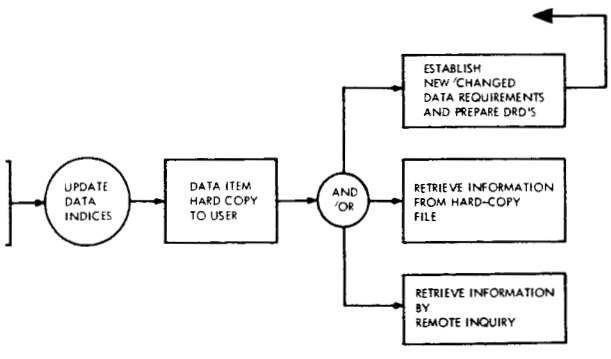
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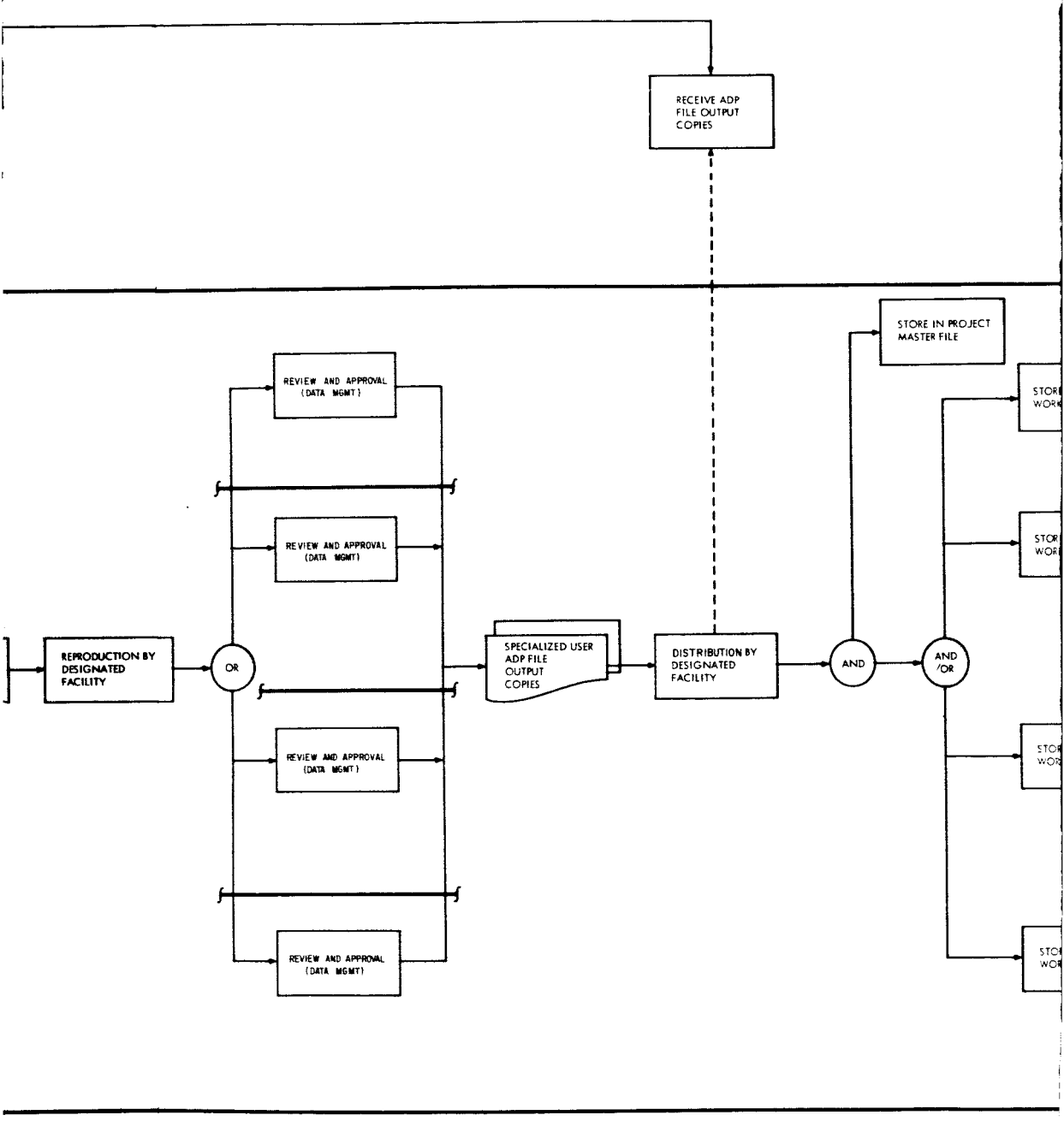
DATA HANDLING AND PROCESS



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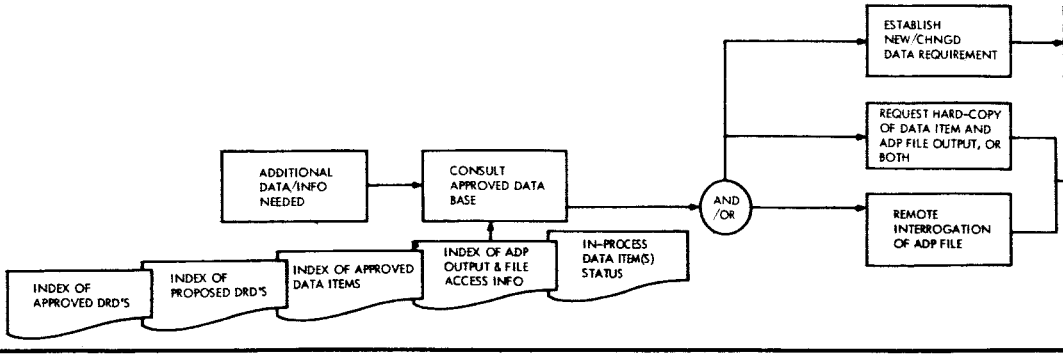

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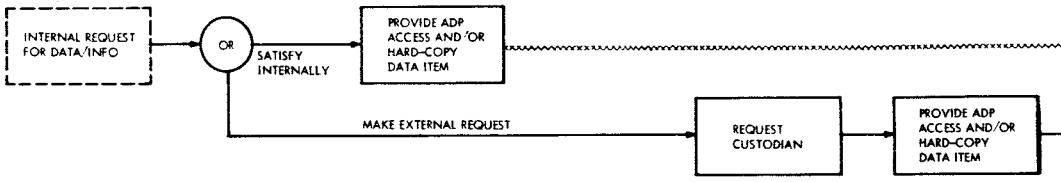

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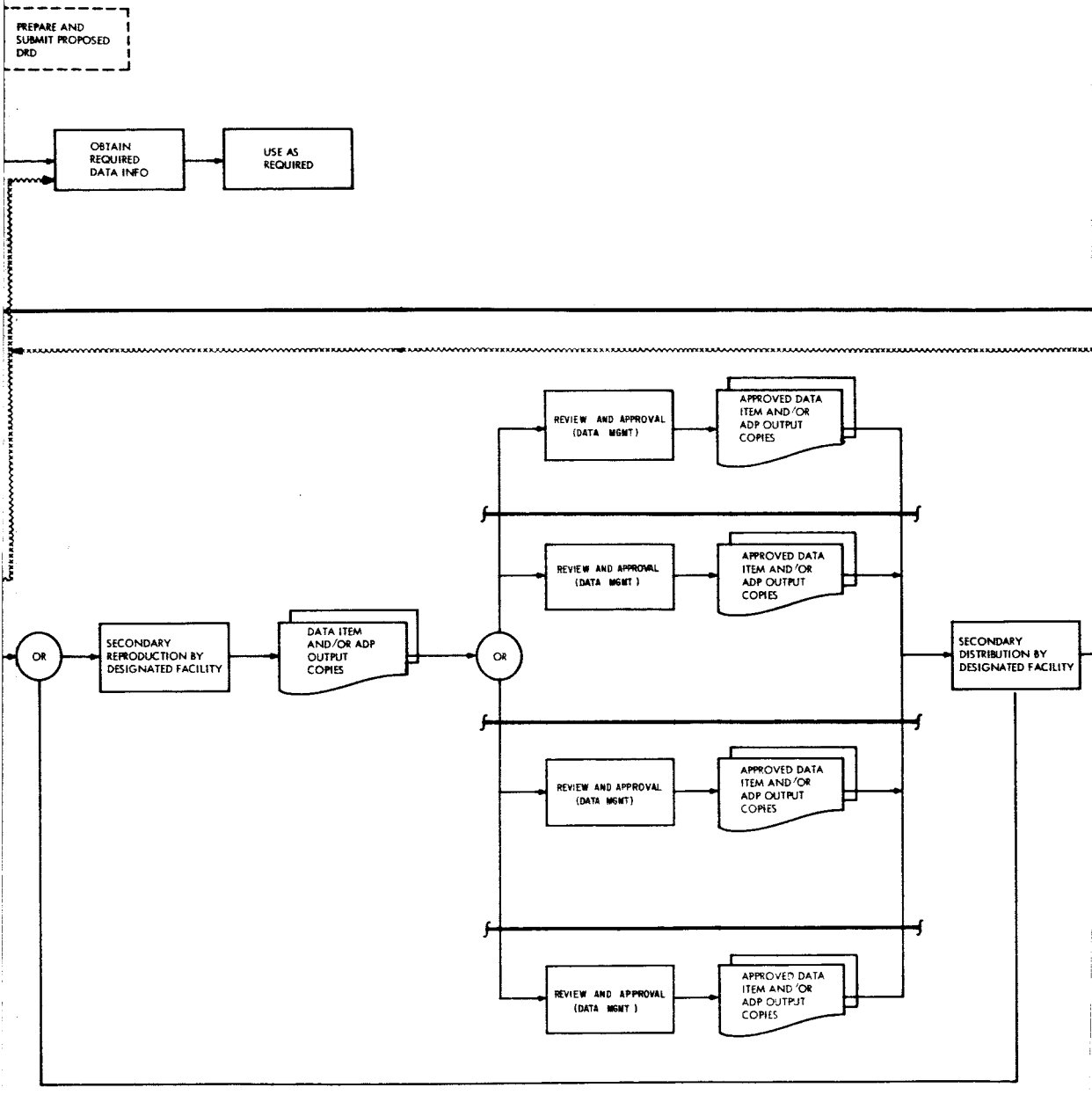


LEGEND:

EXCEPTION

INTERFACE

COMPUTER PROCESSING TO SUPPORT INFORMATION SYSTEM

FUNCTION OR ACTIVITY

DATA INFORMATION

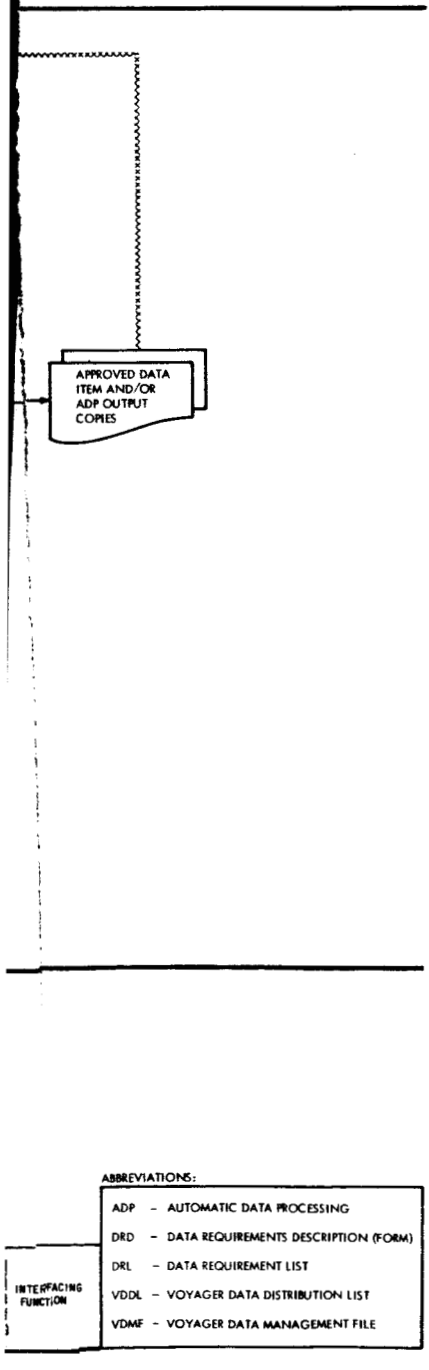


Figure 4-1. Voyager Data Management Program Summary Flow

Functions indicated in the summary flow diagram are repeated and amplified on the detailed flow diagrams.

4.3 SUMMARY SYSTEM DESCRIPTION

The Voyager Data Management System is described by examination of each of its three operational phases.

4.3.1 PHASE 1: ESTABLISHMENT OF DATA REQUIREMENTS

The key elements in this phase are the hierarchal establishment of data requirements by means of a data specification or Data Requirement Description (DRD) form prepared by the user. The approval of these DRD's by the Project Data Review Board and the establishment of a data management file provide wide capability for tracking and retrieving data.

Data requirements are established in the following sequence:

a. A project-level data call, initiated by the Voyager Project Manager, is conducted to establish and document the data requirements of the project-level functional management offices.

b. The proposed project-level DRD's are reviewed and approved by the Project Data Review Board. The applicable DRD's are then provided to the system-level offices to conduct that level's data call.

c. The proposed system-level DRD's are then reviewed and approved by the Project Data Review Board. Applicable DRD's are then provided to the contractor (Request for Proposal) to conduct that level's data call. This data call results in the following outputs:

    1. Proposed DRD's to be imposed on subcontractors and vendors

    2. Proposed DRD's to be placed on functional offices within the contractor's organization

    3. Proposed revisions to system-level DRD's.

d. The proposed contractor and subcontractor DRD's are submitted to the system level for review and then subsequently to the Project Data Review Board for final approval.

e. The applicable approved DRD's are then included in the contract for negotiation with the contractor (and subcontractor).

4.3.2 PHASE 2: DATA PREPARATION AND PUBLICATION

Key elements in this phase are: the preparation of the data items in response to the DRD's; the review and approval of the data items by technical and data management (in accordance with the DRD); the reproduction, distribution and storage of data item copies; and the application of sufficient planning and controls to assure the timely availability of accurate data.

Highlights of this phase are as follows:

a. Approval of the DRD (for project and system levels) and incorporation of the approved DRD into the Work Statement (for contractor and subcontractor levels) represents authorization to initiate the data item response.

b. The DRD indicates the disposition of each produced data item by specifying the review and approval hierarchy, which may be at the level at which the data item is prepared or at a higher level. (The highest level for approval of subcontractor produced data items is the contractor. Subcontractor-produced data is included in contractor data items where higher level approval is required.) Review will normally be required of both technical and data management personnel, to a degree that depends upon the nature of the data item.

c. The DRD specifies the project element responsible for performing reproduction activities (which is not necessarily the element that prepared the data item), the number of copies to be made and the subsequent review and approval requirements. Review and approval activities applicable to data item copies shall involve checks for form, format, legibility, etc., as opposed to checks for technical accuracy (which were accomplished during the preparation cycle).

d. Distribution of data item copies is accomplished by the project element designated on the DRD (normally the element that reproduced the data item). Copies shall be disseminated in accordance with the applicable data distribution list. Distribution shall be made to the project master file, data item users and the custodian. (The custodian is designated on the DRD and is responsible for data item storage).

4.3.3 PHASE 3: DATA HANDLING AND PROCESSING

This phase of the Voyager Data Management System deals with the conversion of selected data item information to machine-sensible form for updating of Automatic Data Processing (ADP) files and subsequent generation of "specialized user" information. Also shown are the functions necessary to satisfy those additional user requirements that will occur during the operational phases of the Voyager Project such as reproducing and distributing additionally required data item copies and establishing new requirements to satisfy new user needs. Highlights of this phase are as follows:

a. As required, the designated project element performs the functions necessary to establish or update Automatic Data Processing (ADP) files that can be manipulated to provide reports, listings and statistical tabulations necessary to satisfy requirements of specialized user information systems. Depending on the requirements of the specialized user information system, outputs may be in the form of batch reports emanating from computer processing and printed on peripheral devices, or quick-look summaries resulting from remote interrogation of the ADP file(s).

b. As a user establishes additional needs for data or information, he will determine the availability of such by examining the various data item and requirement indices resulting from data management file processing. He then obtains the data from his own internal working library maintained by his cognizant data management office, or, if need be, the custodian is requested to provide such. If his is a new data requirement, a proposed DRD is prepared and submitted for necessary review(s) and subsequent Project Data Review Board approval.

c. The custodian maintains an adequate stockpile of data item copies to satisfy as-required requests. As specified on the Voyager data distribtion list, the data item distribution may be open or limited, thus, secondary distribution is made accordingly.

d. All activities performed by the custodian to satisfy external requests are considered secondary activities since they are accomplished over and above those activities specifically indicated on the DRD. However, the review and approval activities governing the activity conducted to satisfy the DRD also apply to the results of secondary activities. For example, the DRD may specify a data management review/approval of reproduced copies prior to distribution. This review/approval then also applies to supplemental reproduction performed to satisfy needs as required.

4.4 SYSTEMS ANALYSIS

Key features of the Voyager Data Management System that are vital to its successful project-wide application include:

a. User establishment of data requirements

b. Requirement/response relationship

c. Data Review Board and data management office activity within organization levels

d. Emphasis on communication of information through effective data management

e. Recognition of specialized user systems and integration of such into overall system

f. Custodian maintenance of data item and ADP files

g. Voyager data management file for generation of project DRD and data item indexes

h. Application of systems, records and controls during establishment or requirements and DRD response activities to provide data item tracking capability

i. Providing traceability capability of data items (and certain data elements) as to generator, related hardware item, contract, etc.

SECTION 5

CONTRACTOR DATA REQUIREMENTS STUDY-PHASE II

5.1 INTRODUCTION

The Contractor Data Requirements Study had the dual objective of:

a. Developing an approach (including tools) for conducting a contractor-level data call, and

b. Identifying the data that a typical spacecraft contractor would manage during Phases C and D of the Voyager Program.

To accomplish this, an actual data call was conducted within the General Electric Voyager Project organization at the Valley Forge Space Technology Center. (This organization contained approximately 120 senior professional personnel at the time of the data call.)

Although this data call was a hybrid in that it developed a complete contractor data base in one cycle (rather than responding to system office imposed data requirements as would be normal during actual program implementation), the tools and approach developed - as well as the data base - are considered basically applicable for use on Voyager Phases C and D.

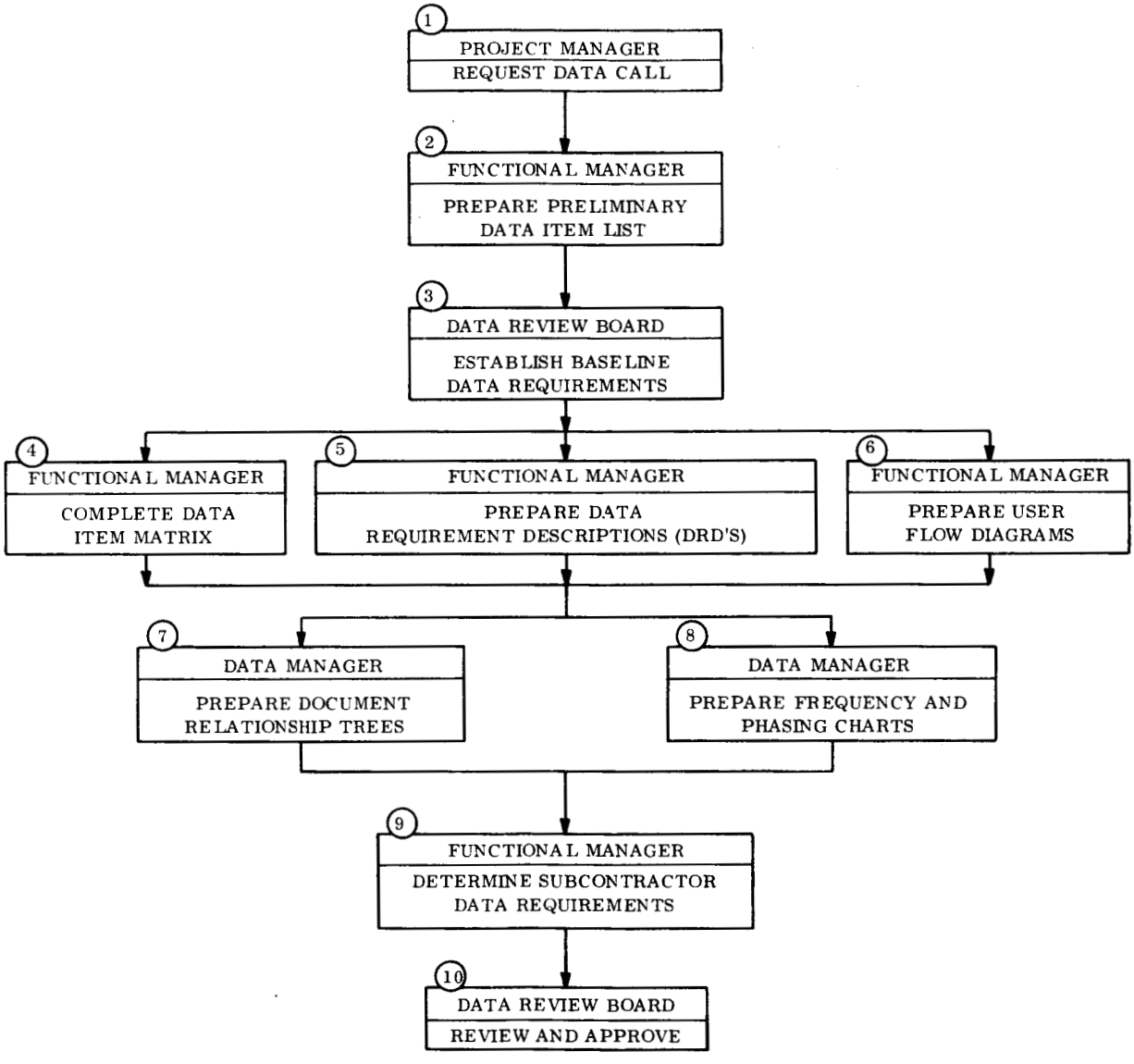
5.2 DATA CALL STUDY

As a result of the data call conducted within the GE Voyager organization, a recommended approach toward determining data requirements has been established and is summarized in Figure 5-1. A brief description of each step, with illustrations of the tools developed follows:

5.2.1 STEP 1: DATA CALL REQUEST BY PROJECT MANAGER

The initiation of the data call requires four actions by the Project Manager:

a. Assignment of responsibility for each data Functional Management Category to the senior member of his staff responsible for that area of activity. As the data Functional Management Categories have been established by NASA, and modified by the Voyager Project data management office, to be irrespective of organization, the



NOTE: CONTINUOUS INTEGRATION, REVIEW, AND SUPPORT BY THE CONTRACTOR'S DATA MANAGEMENT OFFICE (NOT SHOWN) IS REQUIRED THROUGHOUT THE DATA CALL.

Figure 5-1. Key Activities - Contractor Data Call

Project Manager must determine the closest match of responsibility between his particular organizational structure and the respective functional manager categories. The two areas in which this was found to be a problem were in the Engineering and Project Control Integration areas. In the case of Engineering, it was found necessary to assign integration responsibility for Technical Description and System Engineering (SE) to one of the Engineering Managers reporting to the Project Manager; in the case of the various categories which make up Project Control and Integration, it was necessary to separate the Procurement and Contracting Categories (PC) into a Procurement Category (P̲C) and a Contracting Category (P̲C).

b. Establishment of a Data Review Board. (The makeup and function of the Data Review Board is further discussed in Step 3, Section 5.2.3.)

c. Establishment of the project baseline to be utilized for the planning of data requirements for completion of the data call. For the study conducted, previously developed Voyager 1971 plans, as modified by preliminary plans for Voyager 1973, were established as the baseline. Detailed functional plans previously prepared for Voyager 1971 were to be utilized as a baseline in the data call. These plans are discussed in Step No. 2.

d. Establishment of a schedule for completion of the data call. (A detailed milestone schedule for accomplishment of the data call is prepared by the Data Manager and is used by the Project Manager along with the data call to assure accomplishment of all functional and integration activities.)

Figure 5-2 represents the Functional Management Categories for which data was developed during this study, the organizational title of the functional manager who prepared the data requirements, data requirement descriptions, and user flow diagrams for that category.

5.2.2 STEP 2: PREPARATION OF PRELIMINARY DATA ITEM LIST BY FUNCTIONAL MANAGER

As an a priori requirement for the establishment of data requirements is a functional plan, the GE-VFSTC managers used their Voyager 1971 plans for determining data requirements. These plans had been developed during prior contract and pre-proposal phases.

Different approaches were tried to determine an optimum approach to assist the functional manager in determining his requirements. One approach that was found to be particularly helpful was the categorization of data items by data types as shown in Figure 5-3.

DATA FUNCTIONAL MANAGEMENT CATEGORY	RESPONSIBLE FUNCTIONAL MANAGER
Technical Description and System Engineering	Manager, Engineering Mechanics
Planetary Quarantine	Manager, Planetary Quarantine
Manufacturing	Manager, Manufacturing
Configuration Management	Manager, Configuration Management
Quality Assurance	Manager, Quality Assurance
Test	Manager, Test and Operations
Reliability Assurance	Manager, Reliability Assurance
Logistics and Support	Manager, Logistics
Overall Management	Manager, Project Control and Integration
Scheduling	Manager, Project Engineering
Procurement and Contracting	Manager, Contracts/Manager, Subcontractor Control and Integration
Manning and Financial	Manager, Finance
Mission Operations	Manager, Mission Operations
Data Management	Manager, Data Management

Figure 5-2. Assignment of Data Requirement Responsibility

- DESIGN REPORTS
- DIRECTIVES
- DRAWINGS
- GUIDELINES
- HANDBOOKS
- INSTRUCTIONS
- INTEGRATION REPORTS
- LISTS
- LOGS
- MANUALS
- MINUTES
- PLANS
- PROCEDURES
- RECORDS
- REPORTS
- REQUESTS
- SCHEDULES
- SPECIFICATIONS
- STANDARDS

Figure 5-3. Data Types

A questionnaire initially used was subsequently replaced by a preliminary data item list, which is shown in Figure 5-4. This preliminary data item list is prepared by the functional manager and contains the most critical information regarding the data item to permit subsequent review by the Data Review Board.

During the preparation of this preliminary data item list, data management personnel work with the functional managers primarily to assure consistency between management categories.

The preparation of User Flow Diagrams, which relate data items to project activities, could be prepared during this period; from a contractor's viewpoint, however, it is felt that the previously prepared functional plans provide adequate bases to permit an early as possible review of the data requirements by the Data Review Board.

Guidelines to the functional manager at this point, prepared by the Data Manager, advise the inclusion of all "key data needed to do your job."

5.2.3 STEP 3: ESTABLISHMENT OF DATA REQUIREMENTS BASELINE BY DATA REVIEW BOARD

A permanent GE-Voyager Data Review Board was established, composed of:

Chairman:	Voyager Project Manager
Members:	Deputy Project Manager
	Manager - Systems Engineering
	Manager - Project Control and Integration
	Manager - Contracts Administration
	Manager - Pasadena Engineering Operation
	Data Manager

The Data Manager has the responsibility of preparing procedures, agenda items, and reports; the Manager, Contracts assures compliance with customer commitments; the Manager,

SHEET _____ of _____

DATE: _____

PRELIMINARY DATA ITEM LIST

FUNCTIONAL MANAGEMENT CATEGORY _____ PREPARED BY: _____

ITEM NO.	PROPOSED TITLE	DATA ITEM DESCRIPTION	PROJECT PHASE ISSUED	FREQ. OF ISSUE	QUAN.	APPROV. BY

PROJECT PHASES: SDR, PDR, HDR, CDR, FACI, MAR, J FACT

FREQUENCY: OT-Onetime, U/X-Update Freq, W-Weekly, M-Monthly, EM-Mi-Mo, Q-Quarterly, AR-As Required, NA Not Applicable

Figure 5-4. Sample Format - Preliminary Data Item List

Pasadena Engineering Operation represents the customer; the remaining members represent their internal Voyager function.

The review board was expanded on an ex-officio basis to include the functional manager of the category under review and managers of respective interacting categories.

During the study, each proposed data item was presented, discussed, and approved by the Data Review Board, chaired by the GE-Voyager Project Manager.

The Data Review Board also undertook the responsibility for distinguishing between formal data items (those which would be managed within the Voyager Project Data Management System) and key informal data items (those which would be managed by the spacecraft contractor).

As it was found that the Data Review Board filled an essential function in verifying data requirements, particularly those which interface with the customer (and across categories) it is recommended that their detailed review of the information contained in Figure 5-4 be conducted as early as feasible in the cycle, and that, if possible, it be held in continuous session to review all categories consecutively.

5.2.4 STEP 4: COMPLETION OF DATA ITEM LIST/USER MATRIX BY FUNCTIONAL MANAGERS

In order to relate data item users, reviewers, and approvers, a series of matrixes such as the one shown in Figure 5-5 are filled out by the responsible functional managers. A double iteration is involved in that each functional manager reviews the entire list to determine whether he is the final approver (A), in-line reviewer (R) or a prime user (U) of each data item. Following this, the functional manager responsible for that data item either concurs with the A, U or R entries or negotiates with the appropriate manager.

The Data Manager integrates this type of review and where conflicts exist, obtains resolution by the Data Review Board.

DATA ITEM LIST/USER MATRIX

PAGE NO 1 of 7

DATA ITEM NUMBER	1 of 7 DATA ITEM	DESCRIPTION	APPLICABILITY TO FUNCTIONAL USERS AT CONTRACTOR LEVEL																				APPLICABILITY AT SUBCONTRACTOR/VENDOR/SUPPLIER LEVELS						APPLICABILITY TO PROJECT BOARDS										
			SE	PQ	MG	CM	QA	TE	RA	LS	MA	SC	PC	MF	MP	DM	FA	SA	AL	SI	RP	AM	PRINCIPAL SUBCONTRACTORS	MAJOR SUBCONTRACTORS	KEY SUBCON. AND VENDORS	OTHER VENDORS	KEY SUPPLIERS	KEY SUBSUPPLIERS	CONFIGURATION CONTROL	CONFIGURATION MANAGEMENT	DATA REVIEW	DESIGN REVIEW	FAILURE MGT.	INTEGRATED SAFETY	INTEGRATED TEST	MAKE OR BUY	MATERIAL REVIEW	SOURCE EVALUATION	SOURCE SELECTION
	TECHNICAL DESCRIPTION AND SYSTEM ENGINEERING																																					
	PLANS																																					
SE-001	Plan, System Development	Defines the system analysis, design, test, integration and control activities in developing the spacecraft system and the relationship between subsystem development plans and integration and control plans.	R	U	U	U	U	U	R	U	PM	U	U	-	U	-	U	U	U	U	-	U	NA	NA	NA	NA	NA	NA	U	U	-	U	-	-	U	-	-	-	-
SE-002	Plan, Interface Integration	Defines the analysis, integration and control activities required to interface the spacecraft with the capsule, shroud, etc.	R	U	U	U	U	U	U	U	PM	U	U	-	U	-	U	U	U	U	-	U	NA	NA	NA	NA	NA	NA	U	U	-	U	-	-	U	-	-	-	-
SE-003	Plan, Subsystem Development	Defines the analyses, tests and design to be performed in developing the subsystem and its components. Each plan references or incorporates the pertinent provisions of the various integration and control plans.	R	U	U	U	U	U	R	U	PM	U	U	-	-	-	U	U	-	U	-	U	S	(S)	(S)	NA	(S)	NA	U	U	-	U	-	-	U	-	-	-	-
SE-004	Plan, Magnetic Cleanliness Control	Covers the approach for implementing appropriate general engineering specifications, which, in turn, are incorporated into hardware specifications.	A	-	R	-	U	U	U	-	U	-	-	-	-	-	U	U	-	U	-	U	C/S	C/S	C/S	NA	C/S	NA	U	U	-	U	-	-	U	-	-	-	-
SE-005	PLAN, ELECTROMAGNETIC COMPATIBILITY CONTROL	COVERS THE APPROACH FOR IMPLEMENTING APPROPRIATE GENERAL ENGINEERING SPECIFICATIONS, WHICH, IN TURN, ARE INCORPORATED INTO HARDWARE SPECIFICATIONS.	A	-	R	-	U	U	U	-	U	-	-	-	-	-	U	U	-	U	-	-	C/S	C/S	C/S	NA	C/S	NA	U	U	-	U	-	-	U	-	-	-	-
SE-006	Plan, Cleanliness Control	Covers the approach for implementing appropriate general engineering specifications, which, in turn, are incorporated into hardware specifications.	A	R	R	-	R	U	U	U	U	-	-	-	-	-	U	U	-	U	-	U	C/S	C/S	C/S	NA	C/S	C/S	U	U	-	U	-	-	U	-	-	-	-
SE-007	Plan, Mass Properties Control	Covers the approach for implementing appropriate general engineering specifications, which, in turn, are incorporated into hardware specifications.	A	-	U	-	U	U	-	-	U	-	-	-	-	-	-	U	-	U	-	U	(S)	NA	NA	NA	(S)	NA	U	U	-	U	-	-	U	-	-	-	-
	SPECIFICATIONS																																					
SE-008	Specification, System Performance/Design Requirements	Defines system configuration and performance, allocates performance and design requirements to each subsystem including OSE, and defines system constraints and interfaces.	R	U	U	U	U	U	R	U	PM	U	U	-	U	-	U	U	U	U	-	U	NA	NA	NA	NA	NA	NA	U	U	-	U	-	-	U	-	-	-	-
SE-009	Specification, Subsystem Design Requirements	Defines the subsystem configuration, allocates performance and design requirements to each component, including OSE. Not used for procurement.	A	U	U	U	U	U	R	-	R	-	-	-	-	-	U	U	U	U	-	U	(C)	(C)	NA	NA	(C)	NA	U	U	-	U	-	-	U	-	-	-	-
SE-010	Contract End Item (CEI) Detail Specification (Prime Equipment) Part I (Requirements)	Specifies performance and design requirements of a contract end item (flight hardware or operational support equipment).	A	-	U	U	R	U	R	U	R	-	-	-	-	-	U	U	U	U	-	U	C/S	C/S	(C)	NA	(C)	NA	U	U	-	U	-	-	U	-	U	-	-
SE-011	Contract End Item (CEI) Detail Specification (Prime Equipment) Part II	Specifies configuration details for procurement of a contract end item (including acceptance testing).	A	-	U	U	R	U	R	U	R	-	U	-	U	-	U	U	U	U	-	U	S	S	(S)	NA	(S)	NA	U	U	-	U	-	-	U	-	U	-	-

* KEY INFORMAL DATA

U - USE R - REVIEW AUTHORITY A - APPROVAL AUTHORITY PM - PROJECT MANAGER APPROVAL C - PREPARED BY CONTRACTOR S - PREPARED BY SUBCONTRACTOR/VENDOR/SUPPLIER ( ) - OPTIONAL APPLICATION NA - NOT APPLICABLE

Figure 5-5. Excerpt From Data Item List/User Matrix

During this cycle the Manager, Project Control and Integration, indicates for the Overall Management (MA) Category, those data items which he believes should be approved by the Project Manager. This is then verified by the Project Manager. As may be seen on the matrix, the major project boards are also indicated; the chairman of each board is assigned responsibility for reviewing data applicability for his board.

Entries for subcontractors are not included at this stage, but are subsequently added (See Step No. 9, Section 5.2.9).

Initial formats of this matrix also included identifying applicability (R's, A's and U's) for the proposed GE Voyager organization. These have been eliminated from the final matrixes included in Appendixes A through K, in order to indicate maximum applicability to other contractor organizations.

Completed Data Item List/User Matrixes are included in Appendixes A through Q for their respective function management categories.

5.2.5 STEP 5: PREPARATION OF (DRD's BY FUNCTIONAL MANAGERS

During this study, emphasis was placed upon the completion by the functional manager of the following elements of the DRD's (Figures 5-6 and 5-7):

a. Outline of contents

b. Use of document

c. Interrelationship with other data requirements

d. Final approval authority

e. Reference documents.

During subsequent steps in the study, the Data Manager also identified the following on the DRD's:

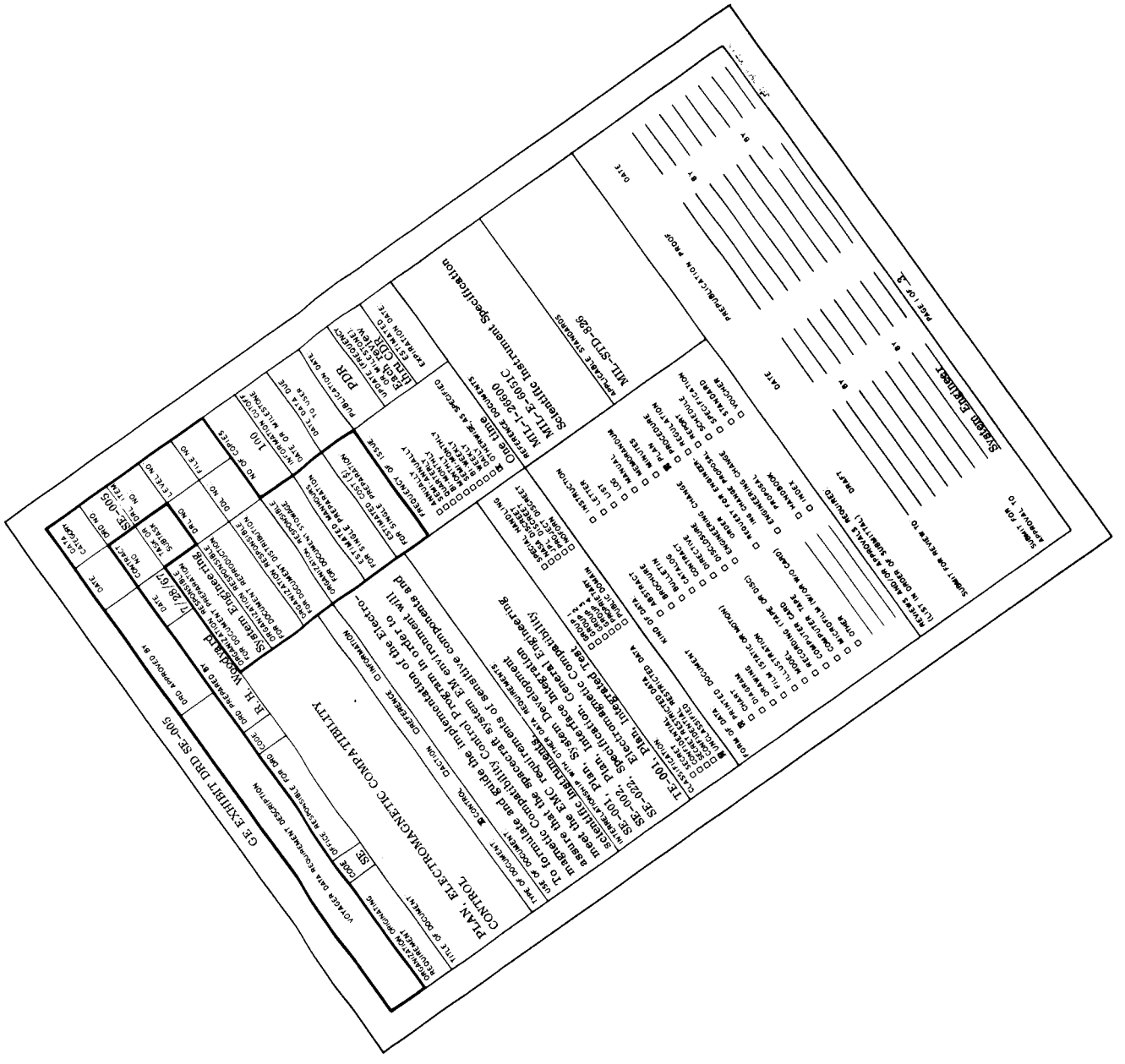


Figure 5-6. GE Exhibit DRD (SE-005, Page 1)

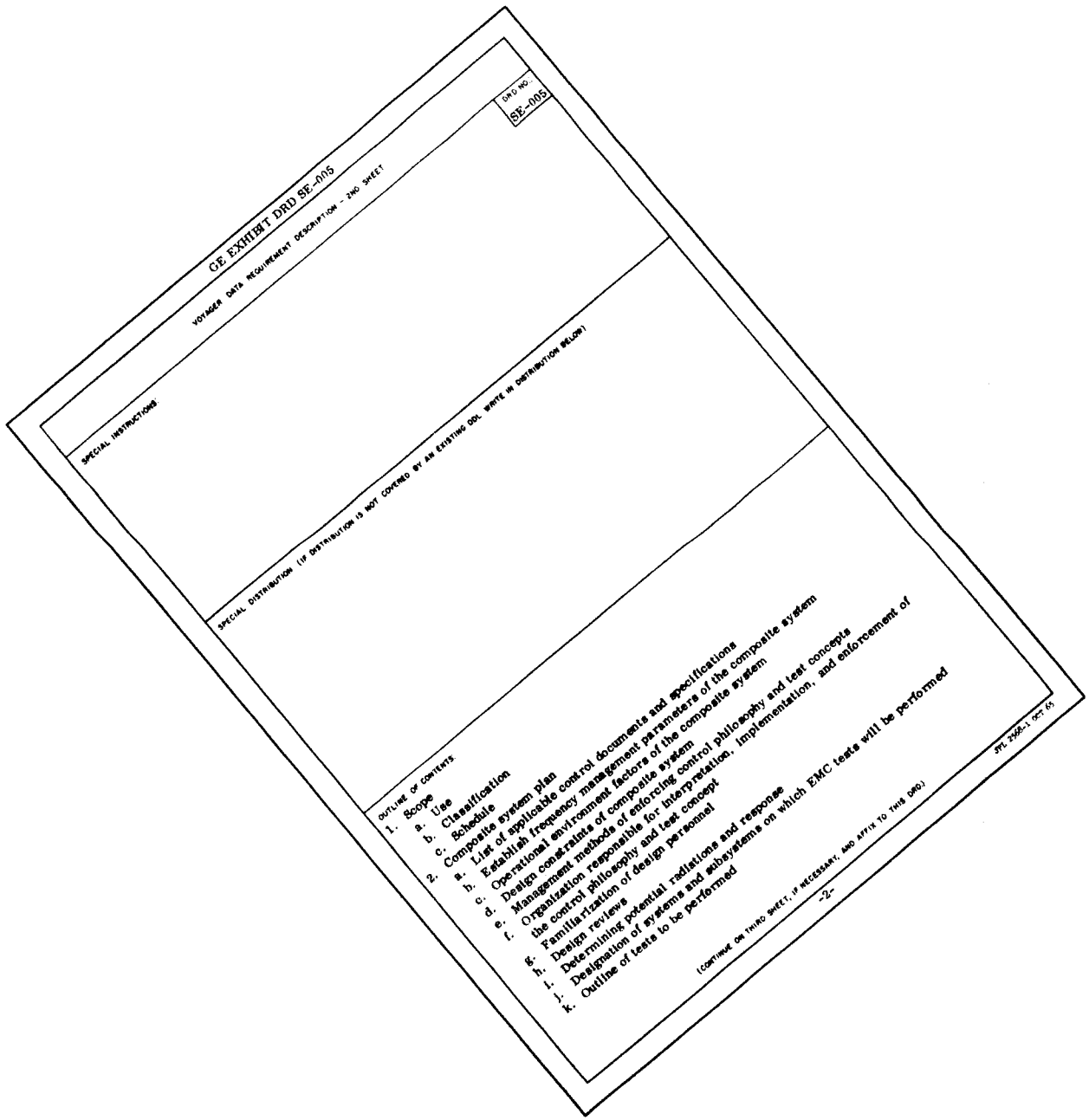


Figure 5- 7. GE Exhibit DRD (SE-005, Page 2)

a. Type of document

b. Classification

c. Form and kind of data

d. Frequency of issue

e. Number of contractor copies

f. Publication date by project phase.

Certain DRD's, upon the recommendation of the Data Manager, were reviewed by the Project Manager. In addition, the Data Manager was responsible for consistency of format.

Completed Data Requirement Descriptions (DRD's) are included in Appendixes A through K for their respective functional management categories.

5.2.6 STEP 6: PREPARATION OF USER FLOW DIAGRAMS BY USER MANAGERS

In order to fully integrate data requirements with project activities, User Flow Diagrams were prepared for the following areas by responsible functional managers:

a. Engineering (includes Test and Planetary Quarantine)

b. Manufacturing

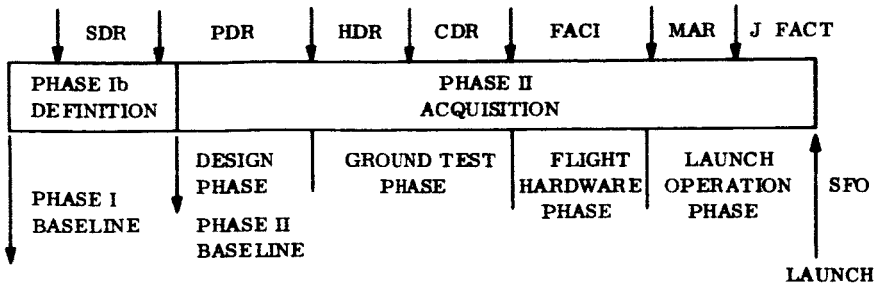
c. Quality Assurance

d. Logistics

e. Project Control

f. Reliability

The format adopted for the User Flow Diagrams used the project baseline with its major design reviews as the horizontal axis, and project elements as the vertical axis. The following was utilized as the project baseline:



DEFINITIONS

SDR = SYSTEM DESIGN REVIEW
PDR = PRELIMINARY DESIGN REVIEW
HDR = HARD DESIGN REVIEW
CDR = CRITICAL DESIGN REVIEW
FACI = FIRST ARTICLE CONFIGURATION INSPECTION
MAR = MISSION ACCEPTANCE REVIEW
J FACT = JOINT FLIGHT ACCEPTANCE COMPOSITE TEST

Project elements identified to form the vertical axis are:

a. System Office

b. Contractor Functions (e.g., Systems Engineering, Subsystems Engineering and Manufacturing Planning)

In addition, an excerpt of a User Flow Diagram is shown in Figure 5-8. These diagrams are prepared independent of Functional Management Category and are intended to include all data items necessary to perform the designated function. Where the data items are formal or key informal data items, the respective DRD numbers are shown on the diagram. Other data items contained therein are informal data items.

The User Flow Diagrams, in addition to identifying the basic flow of information within a function, provide a basis for the Document Relationship Trees and the Frequency and Phasing charts prepared in subsequent Steps 7 and 8.

Complete User Flow Diagrams are included in Appendixes A through K for their respective Functional Management Categories.

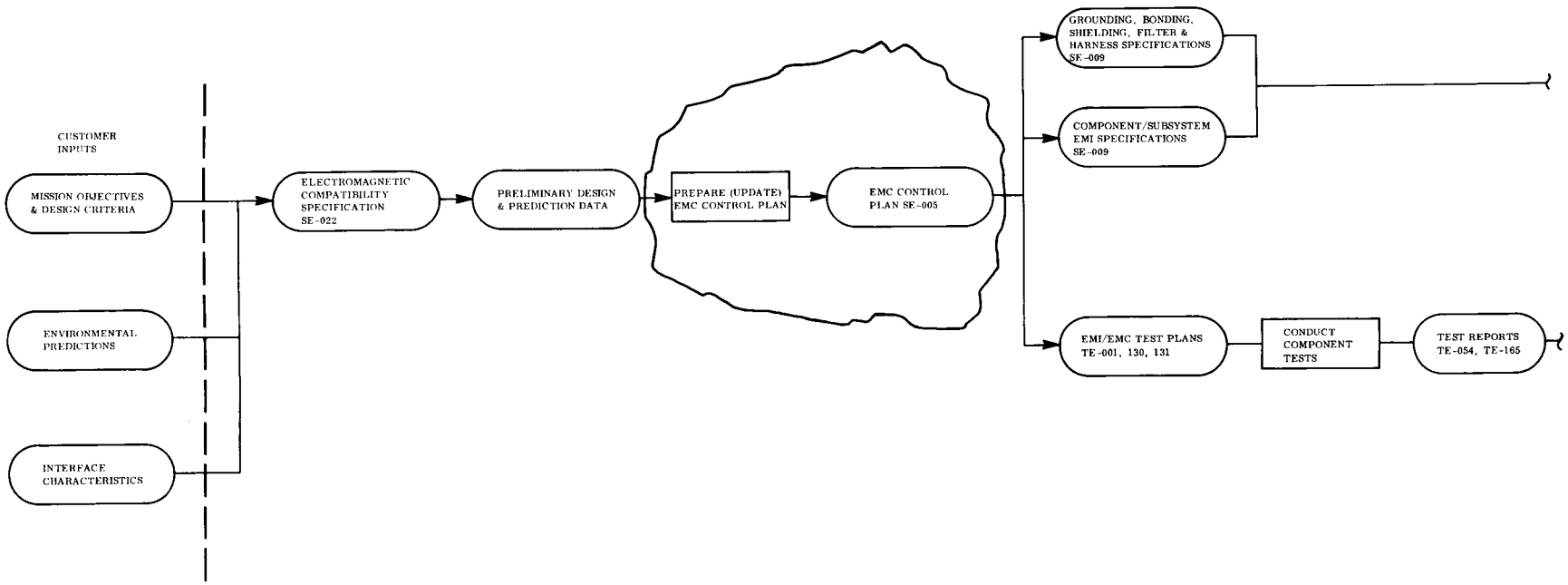


Figure 5-8. Excerpt From Engineering User Flow Diagram

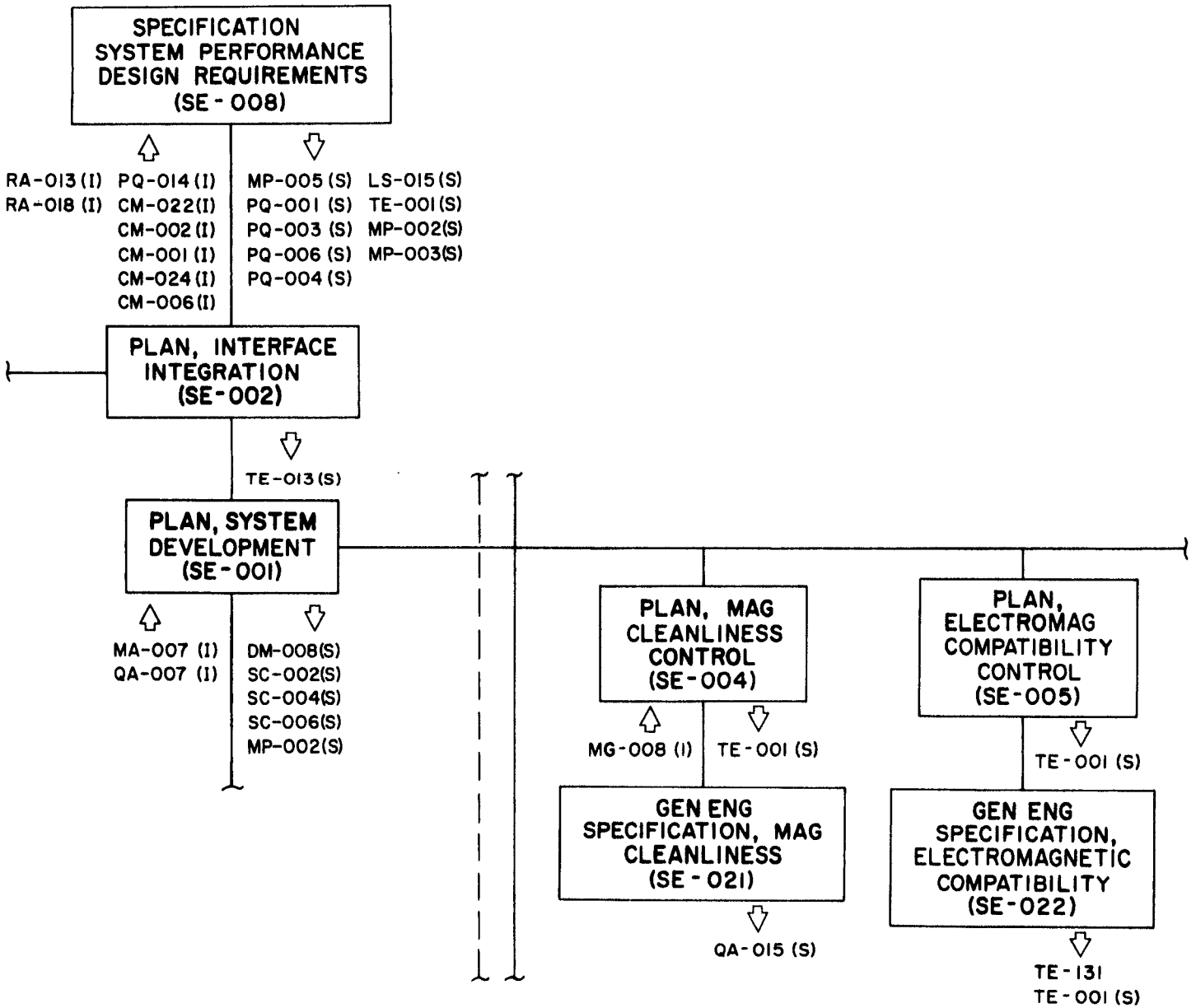


Figure 5-9. Typical Document Relationship Tree

5.2.7 STEP 7: PREPARATION OF DOCUMENT RELATIONSHIP TREES BY DATA MANAGER

In order to fully establish the relationship of data items, Data Relationship Trees were prepared by the Data Manager for each Functional Management Category. Figure 5-9 represents a typical tree. The direct relationship between data items in a particular category is shown as well as interrelationships with documents in other categories (both input and output).

These interrelationships are subsequently incorporated into the DRD's by the Data Manager.

Complete Document Relationship Trees are included in Appendixes A through K for their respective Functional Management Categories.

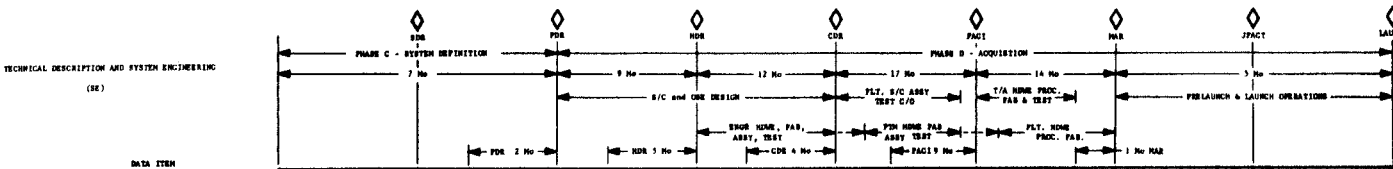
5.2.8 STEP 8: PREPARATION OF PHASING AND FREQUENCY CHARTS BY DATA MANAGER

In order to develop methods and media for the effective flow of the data that have been established in the DRD's and User Flow Diagrams, Phasing and Frequency Charts are prepared by the Data Manager.

These charts, an example of which is shown in Figure 5-10, locate the data item in the initial project phase in which it appears, and then indicate subsequent quantities (initial issue or update of the data item). These entries, which are based upon the User Flow Diagrams, are verified with the responsible functional manager. During this step, the functional manager also indicates the anticipated quantities which compose each data item; e.g., for example 225 different test reports actually comprise the test report data item "TE 165."

Upon the completion of the Phasing and Frequency Charts, the Data Manager prepares graphical summaries such as those shown in Figure 5-11, to provide an overview of the anticipated loadings of data items during phases of the project.

CompletePhasing and Frequency Charts and graphical summaries are included in Appendixes A through K for their respective Functional Management Categories.



TECHNICAL DESCRIPTION AND SYSTEM ENGINEERING (SE)

DATA ITEM TITLE	QUANTITY	FREQUENCY	TOTAL	QUANTITY	FREQUENCY	TOTAL	QUANTITY	FREQUENCY	TOTAL	QUANTITY	FREQUENCY	TOTAL	QUANTITY	FREQUENCY	TOTAL	QUANTITY	FREQUENCY	TOTAL	QUANTITY	FREQUENCY	TOTAL	QUANTITY	FREQUENCY	TOTAL	TOTALS	NOTES AND ASSUMPTIONS
PLANS																										
SE-001 Plan, System Development	1	1	1	1	U	1																			2	
SE-002 Plan, Interface Integration	1	1	1	1	U	1	1	U	1	1	U	1	1	U	1	1	U	1							6	
SE-003 Plan, Subsystem Development	15	1	15	15	U	15	15	U	15																45	
SE-004 Plan, Magnetic Cleanliness Control				1	1	1	1	U	1	1	U	1	1	U	1										4	
SE-005 PLAN, ELECTROMAG COMP. CONTROL				1	I	1	1	U	1	1	U	1	1	U	1										4	
SE-006 Plan, Cleanliness Control				1	I	1	1	U	1																3	
SE-007 Plan, Mass Properties Control				1	I	1	1	U	1	1	U	1													3	
SPECIFICATIONS																										
SE-008 Specification, Sys. Perf/Design Rqts.	1	1	1	2	1/U	2	1	U	1																4	
SE-009 Specification, Sub-Sys Design Rqts.				15	1	15	15	U	15																30	Based on Est. No. of S/C Sub-Systems
SE-010 Contract End Item (CEI) Detail Spec. (Prime Equipment Part I)				64	1	64	64	D	64																128	Totals Include Part II's & Part III's (RE-DITS & SE-DITS) Based on Est. of Prime Equip. (2) 's S/C & ORE
SE-011 Contract End Item (CEI) Detail Spec. (Prime Equipment Part II)										64	1	64	64	U	64											Based on Est. of Prime Equip. (2)'s S/C & ORE
SE-012 Detail Specification (Eng. Crit. Comp.)							103	1	103	50	U	50	53	U	53										206	Based on Est. of No. of Eng. Crit. Components
SE-013 Contract End Item (CEI) Detail Spec. (Identification Item)							171	1	171	100	U	100	71	U	71										342	Based On Est. of Ident. Items and Includes ORE
SE-014 Contract End Item (CEI) Detail Spec. (Requirement Item)							14	O/T	14																14	CPE etc.
SE-015 Specification, Part ( )				200	1	200	200	U	200	200	U	200													600	Excludes Company STD's
SE-016 Specification, Material				50	O/T	50	100	O/T	100	50	U	50													200	Excludes Mil Specs. Etc.
SE-017 Specification, Process				50	O/T	50																			50	Excludes Company & Mil. Processes
SE-018 Spec., Experiment & Planetary Scan Platform Interfaces							10	O/T	10	10	U	10													20	
SE-019 Document, Interface Control				10	O/T	10																			10	HGA, Boler Array, Capsule, LV, Science + 10
SE-020 Criteria, Structural Design							1	1	1	1	U	1													2	
SE-021 General Eng. Spec., Magnetic Cleanliness				1	O/U	2	1	U	1																3	
SE-022 General Eng. Spec., Electromagnetic Compt.				1	O/U	2	1	U	1																3	
SE-023 General Eng. Spec., Cleanliness				1	1	1	1	U	1																2	
SE-024 General Eng. Specification Design				10	1	10	10	U	10																20	
SE-025 General Eng. Specification, Test & Evaluation (Mil's, Parts, Processes)							150	O/T	150	150	O/T	150													300	Per each type, part or material to be tested

*Key Informal Data

A	Annual	O/T	One Time	I	Initial	CDR	Critical Design Review
B/A	Semi-Annual	A/R	As Required	F	Final	FACI	First Article Configuration Inspection
WK	Weekly	U	Update	N/R	New and Revised	MAR	Mission Acceptance Review
MO	Monthly	I/U	One Update	SDR	System Design Review	J FACT	Joint Flight Acceptance Composite Testing
B/W	Bi-Weekly	DA	Daily	PDR	Preliminary Design Review		
B/M	Bi-Monthly	Q	Quarterly	HDR	Hard Design Review		

Figure 5-10. Typical Phasing and Frequency Chart

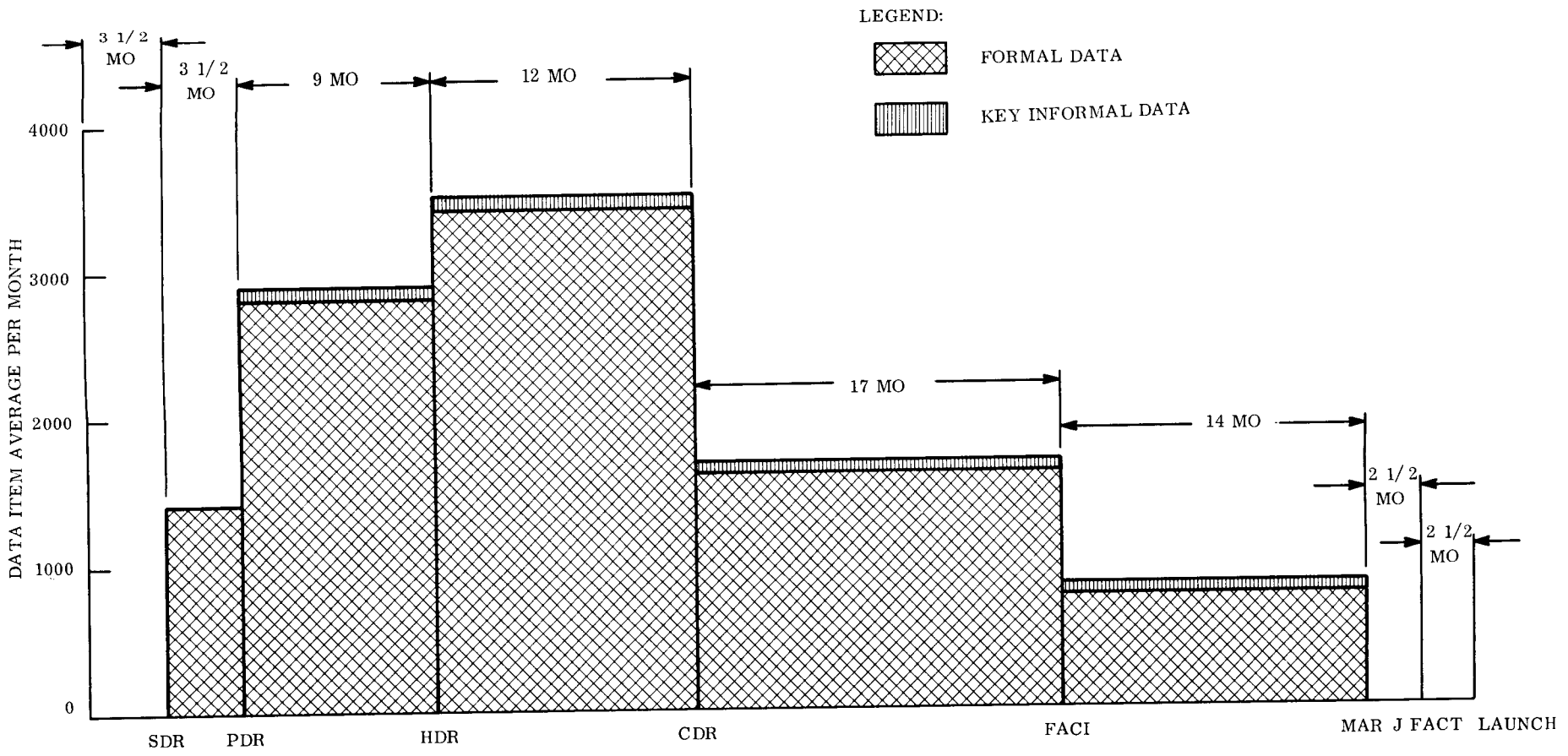


Figure 5-11. Typical Data Item Density Graphical Summary

5.2.9 STEP 9: DETERMINATION OF SUBCONTRACTOR DATA REQUIREMENTS BY FUNCTIONAL MANAGERS

The subcontractor level data base was divided into six classifications as shown in Figure 5-12 to accommodate the different levels of control required between the prime contractor and its subcontractors, vendors and subsuppliers. These classifications and definitions are:

a. Principal Subcontractor - A major subcontractor (first tier) whose contribution will substantially augment contractor capability.

b. Major Subcontractor - A subcontractor (first tier) whose participation in Phase C work will exceed a total of $100,000 or whose participation in Phase D work involves the design and/or delivery of a vital or pacing item regardless of the value of the subcontract or purchase order, but who is less than a principal subcontractor.

c. Key Subcontractor or Vendor - A subcontractor or vendor (first tier) whose participation in Phase D work involves the design and/or delivery of a vital or pacing item regardless of the value of the subcontract or purchase order but who is less than a major subcontractor.

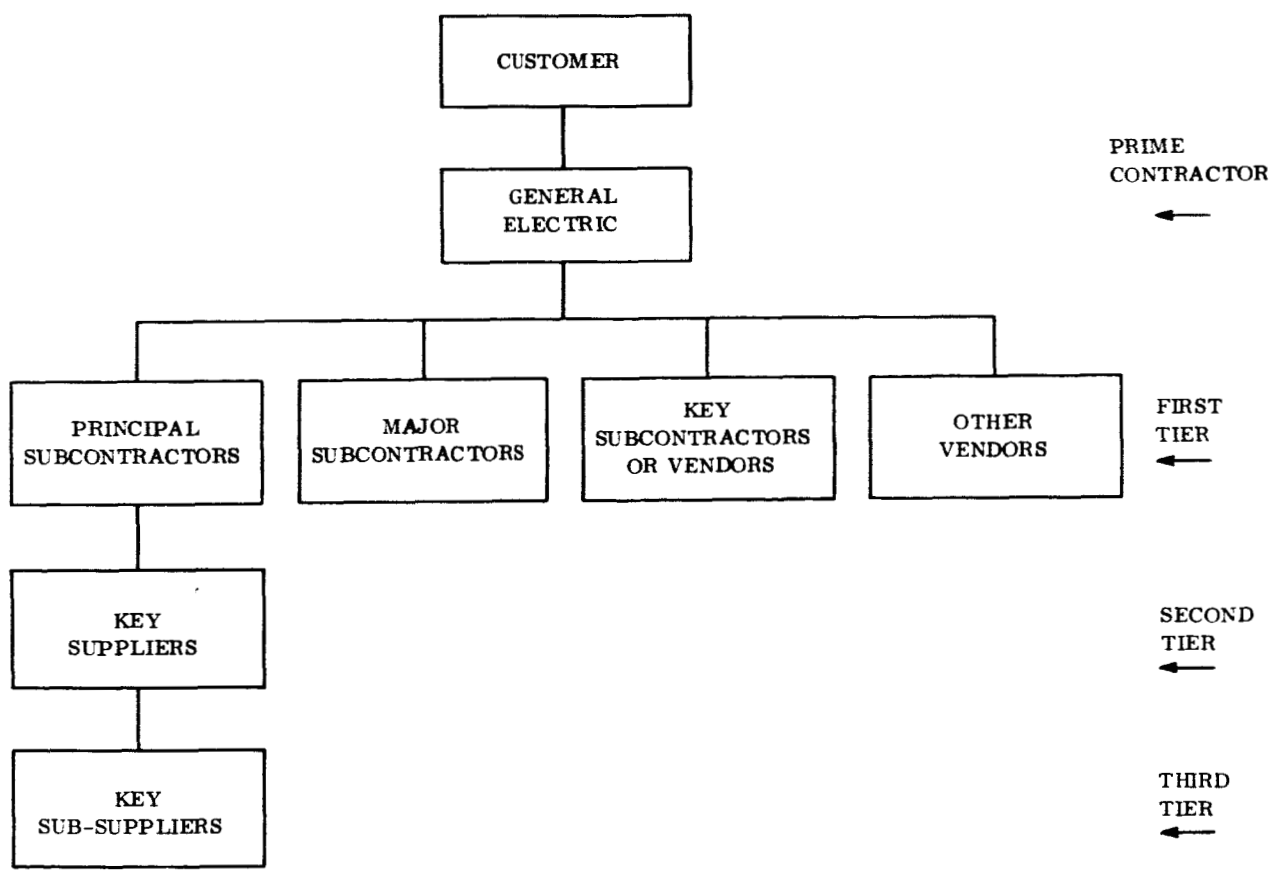


Figure 5-12. Subcontractor/Contractor Relationship

d. Other Vendor - A vendor (first tier) participating in Phase D work who would furnish primarily raw materials, stock or shelf components. No development is involved in these products.

e. Key Supplier - A supplier whose participation in Phase D work involves the design and/or delivery of a vital or pacing item. This is a second tier subcontractor or vendor, whose participation is directed by a first tier subcontractor.

f. Key Subsupplier - A supplier whose participation in Phase D work involves the design and/or delivery of a vital or pacing item. This is a third tier subcontractor or vendor, whose participation is directed by a second tier subcontractor or vendor.

In order to develop data requirements for these levels, GE subcontract managers responsible for planned subcontracts (e. g., radio command, propulsion) were assigned responsibility for reviewing the entire Data Item List and identifying the pertinency of contractor level data items to their subcontractor. Where the contractor was required to provide the data item to the subcontractor, this was to be noted by a C; where the subcontractor was to provide a comparable data item to the contractor, this was to be designated by an S.

These individual assessments were compiled by the Data Manager and integrated into a Preliminary Subcontractor Level Data Item List, which was then reviewed by the managers responsible as functional managers, to obtain their concurrence.

The final iteration of these requirements are shown in the subcontractor columns of the Data Item List/User Matrix in Figure 5-5.

As will be subsequently described under Section 5.4 (Subcontractor Data Requirements Study) this list was then iterated by direct review with selected potential subcontractors.

Complete subcontractor data requirements are included in the data item matrixes of Appendixes A through K for their respective Functional Management Categories.

5.2.10 STEP 10: REVIEW AND APPROVAL BY DATA REVIEW BOARD

Following the completion of the data call, a final meeting of the Data Review Board was called to verify the complete package.

At this meeting, presentation was made by the Data Manager of overall results, such as a comparison of in-house subsystem data requirements with subcontracted subsystem data requirements. Exceptions and significant changes since prior meetings of the Data Review Board were identified and any items still requiring resolution were noted.

Buyoff of the Data Review Board at this point primarily verified that the Data Manager had fully integrated the data requirements activities, and that there were no substantial changes from the original baseline list which had not been approved by the Data Review Board.

5.3 CONTRACTOR DATA REQUIREMENTS STUDY

Both formal data items (those managed within the scope of the Voyager Project Data Management System) and key informal data items (those managed within the contractor's organization) have been identified by functional managers using the process described in Section 5.2.

Detailed descriptions of these data items are contained in Appendixes A through K of this report; Figure 5-13, however, represents a listing of these data items by data item type. Three-hundred and forty-five data items are included in this list and are summarized in Table 5-1.

Table 5-1. Functional Category Summary

Functional Category	Functional Symbol	Total Number of Data Items
Technical Description and System Engineering	SE	65
Planetary Quarantine	PQ	14
Manufacturing	MG	21
Configuration Management	CM	45
Quality Assurance	QA	31
Test	TE	29
Mission Operations	MP	5
Reliability Assurance	RA	19
Logistics and Support	LS	23
Overall Management	MA	25
Scheduling	SC	14
Manning and Financial	MF	6
Procurement and Contracting	PC	8
Procurement and Contracting	PC	17
Data Management	DM	23
		345

	Data Item Title	Totals
DIRECTIVES (11)		
CM-001	Engineering Change Proposal (ECP)	2,000
CM-002	Specification Change Notice (SCN)	2,000
CM-003	Change Notice	145,000
MA-001	*Project Change Notice	295
MA-002	*Project Funding Instruction (PFI)	4,150
MA-003	Project Policies, Procedures, and Directives	261
MA-004	*Department Policies, Procedures, and Directives	261
PC-006	*Requisition and Instruction Sheet	8
PC-011	*Project Procurement Policies and Procedures	170
RA-001	*Reliability Action Directives	1,335
SC-001	*Schedule Change Request/Notice	285
DRAWINGS (10)		
MG-001	Drawings, Interface Tools, Jigs and Fixtures	185
MG-002	*Drawings, Tools, Jigs and Fixtures	4,100
SE-056	Drawings (Category A) for Design Evaluation	25,960
SE-057	Drawings (Category B) for Interface Control	4,700
SE-058	Drawings (Category C) for Test	6,300
SE-059	Drawings (Category E) for Manufacture and Procurement of Prime Hardware	63,950
SE-060	Drawings for Mock Ups	1,470
SE-061	*Drawings for Printed Wiring Boards and Assemblies	1,600
SE-062	Drawings for Test Models	3,180
SE-063	Drawings, Spacecraft Interconnections	1,600
GUIDELINES (2)		
PQ-001	Guidelines, System Operating Procedures for Planetary Quarantine	3
PQ-002	Guidelines, Equipment Design for Planetary Quarantine	3
HANDBOOKS (2)		
MP-001	Handbook, System Performance	7
SE-064	Handbook, Materials	2
INSTRUCTIONS (1)		
PC-012	*Instruction Subcontract Proposal Preparation	460
LISTS (34)		
CM-004	Approved Change Proposal (ECP), Contract End Item (CEI)	57
CM-005	Index, Contract End Item Approved Configuration	7,818
CM-006	Index, Specification Identification	1,225
CM-007	Index, System/Equipment Contract End Item Requirements	1
CM-008	List, Approved Changes per Equipment Echelon	227
CM-009	List, "As Designed" Parts Usage	52
CM-010	List, Hardware Incorporated Changes	145
CM-011	List, Indented Breakdown of Parts	57
CM-012	List, "As Built" Indented Configuration	115
CM-013	List, "As Built" Parts Usage	135
CM-014	Index, Drawing	87
CM-015	Index, Specification	242

	Data Item Title	Totals
CM-016	List, Deviations and Waivers	227
CM-017	List, Special Test Equipment, Tools, Fixtures, etc.	29
CM-018	List, Specification Status/ Release	242
CM-019	List, Break of Inspection, Per Contract End Item	135
DM-001	*Index, Contractor Data Submittal Information	64
DM-002	Index, Formal Data Items	277
DM-003	Index, Informal Data Items	277
DM-004	Index, Special Purpose	277
DM-005	List, Contact Report	277
DM-006	List, Document Distribution	63
LS-001	*List, Long Lead Items	4
LS-002	List, Priced Spares	43
LS-003	List, Spares	43
MA-005	List, Priority Action Items	64
MA-006	*List, Action Items	277
PC-013	List, Bidder	7
PQ-003	List, Sterilizable Parts, General Engineering	6
RA-002	List, Critical and Limited Life Item	2
RA-003	List, Failure Rate Data	2
RA-004	List, Flight Critical Processes and Practices	2
RA-005	List, Parts Application Data	2
LOGS (6)		
CM-020	Log, Contract End Item Assignment Number	1
CM-021	Log, Engineering Change Proposal (ECP) Number Sequence Assignment	1
CM-022	Log, Specification Change	1,184
CM-023	Log, Specification Distribution	1
CM-024	Log, Specification Identification Number Assignment	1
RA-006	Log, Problem/Failure Summary	23
MANUALS (16)		
CM-025	Manual, Configuration Management Procedure	6
LS-004	Manual, Assembly, Handling and Shipping Equipment (AHSE) Description/ Operation and Maintenance	3
LS-005	Manual, Launch Complex Equipment (LCE) Description	3
LS-006	Manual, Launch Complex Equipment (LCE) Description Operation and Maintenance	3
LS-007	Manual, Mission Dependent Equipment (MDE) Installation	3
LS-008	Manual, Mission Dependent Equipment (MDE) Description/Operation and Maintenance	3
LS-009	Manual, System Test Complex (STC) Installation	3
LS-010	Manual, System Test Complex (STC) Description/Operation and Maintenance	3
MG-005	*Manual, Certification and Training	55
MG-006	*Manual, Hardware Handling	55
PC-014	*Manual, Project Subcontractor Management	7
QA-003	Manual, Instrument Calibration and Maintenance	60
QA-004	Manual, Quality Assurance Operating Procedure	61
QA-005	Manual, Special Test Equipment, Component	38
QA-006	Manual, Workmanship Standards	41
TE-025	Manual, Test Facilities Description and Capabilities	11
MINUTES (4)		
DM-007	*Minutes, Data Review Board Meetings	20
QA-007	Minutes, Material Review Board	262
RA-007	*Minutes, Failure Analysis Review Board (FARB)	242
TE-024	*Minutes, Integrated Test Board (ITB)	263

* Key Informal Data

Figure 5-13. Data Item List (Sheet 1 of 4)

	Data Item Title	Totals
PLANS (25)		
CM-026	Plan, Configuration Management	1
DM-008	Plan, Contractor Data Acquisition Flow	3
DM-009	Plan, Data Management (Contractor)	3
LS-012	Plan, Logistics Support	1
LS-013	Plan, Field Communications	1
LS-014	Plan, Provisioning	2
LS-015	Plan, Packaging	2
LS-016	Plan, Site Support	1
LS-017	Plan, Transportation and Handling	2
LS-018	Plan, Field Storage	2
MA-007	Plan, Project Implementation	5
MA-008	Plan, Project Control	5
MA-009	Plan, Organization	5
MA-010	Plan, Project Communications	5
MA-011	Plan, Security	5
MA-012	Plan, Facility	5
MA-025	Plan, Contingency Operation	5
MG-009	Plan, Manufacturing	2
MG-010	Plan, Storage	3
MG-011	Plan, Manufacturing Detailed Flow and Inspection (Assembly Diagram)	5
MP-002	Plan, Mission Operations Support Spacecraft	2
MP-005	Plan, Flight Operation Diagnostic Computation	2
PC-015	Plan, Project Procurement	3
PC-016	*Plan, Project Subcontract Negotiation	460
PC-017	Plan, Subcontractor's Management	3
PQ-004	Plan, Planetary Quarantine, Spacecraft	2
PW-005	Plan, Planetary Quarantine, Planetary Vehicle Test	5
QA-008	Plan, Inspection	50
QA-009	Plan, Quality Assurance Program	4
QA-010	Plan, Sampling	80
QA-011	Plan, Test and Operating, for Special Test Equipment (STE) Component	421
RA-008	Plan, Reliability Assessment	2
RA-009	Plan, Reliability Program	2
RA-010	Plan, Parts Control Program	2
SE-001	Plan, System Development	2
SE-002	Plan, Interface Integration	6
SE-003	Plan, Subsystem Development	45
SE-004	Plan, Magnetic Cleanliness Control	4
SE-005	Plan, Electromagnetic Compatibility Control	4
SE-006	Plan, Cleanliness Control	2
SE-007	Plan, Mass Properties Control	3
TE-001	Plan, Integrated Test	24
TE-130	Plan, General Test	120
TE-131	Plan, Detailed Test	185
TE-112	Plan, Spacecraft Mission Operation Test	7
TE-013	Plan, Interface Test	36
TE-018	Plan, Operational Support Equipment (OSE) Certification	2
TE-123	Plan, Special Test Equipment (STE) Verification Tests	3
TE-157	Plan, Facilities Certification	2
TE-158	Plan, Software Certification	3

* Key Informal Data

	Data Item Title	Totals
PROCEDURES (29)		
CM-027	Procedure, Change Control	1
CM-028	Procedure Configuration Control (Administrative	1
CM-029	Procedure, Configuration Management Data Processing	1
CM-030	Configuration Management Reviews	1
CM-031	Procedure, Engineering Configuration Identification Document Release System	1
CM-032	Instruction, Change Document Preparation	1
CM-033	Instruction, Change Submittal and Approval	1
DM-010	Procedure, Data Program Support	8
DM-011	Procedure, Data Systems, Controls and Records	8
DM-012	Procedure, Data Preparation, Submittal and Review	4
DM-014	Procedure, Establishment of Data Requirements	4
DM-024	Procedure, Data Program Training	4
LS-020	Instruction Modification Kit	1
LS-021	Procedure, Handling	1
LS-027	Procedure, Storage	1
MG-003	Procedures, Manufacturing Operation	725
MG-004	Manufacturing Standing Instructions (MSI's)	100
PQ-006	Procedure, Planetary Quarantine Operating	3
PQ-007	Procedure, Bio-Assy Test	6
QA-012	Procedure, Process Control	400
QA-013	Procedure, Test/Inspection	2,600
QA-014	Procedure, Rework	20
QA-015	Procedure, Area Control	20
RA-011	Procedure, Reliability Operating	2
TE-129	Procedure Equipment Calibration and Checkout	120
TE-030	Procedure, Test Operating	164
TE-125	Procedure, Facilities Operating	10
TE-159	Procedure, Equipment (Spacecraft and Operational Support) Assembly and Handling	40
TE-160	Procedure, Operating, Integrated Test Board (ITB)	2
PROPOSALS (3)		
PC-001	Contract Change Proposal	67
PC-018	Proposal, Subcontractors	460
PC-019	Proposal, Subcontract Change	1,480
RECORDS (21)		
CM-034	Chart, Congiguration	1,184
CM-035	Record, Drawing Approval	1
CM-036	Record, Drawing Release and Status	1
CM-037	Record, Installation	31
DM-023	*Project Information Request/Release	32,000
MG-007	Record, Methods and Tool Sheets	7,000
MG-008	Sheet, Planning, Fabrication/Assembly	18,000
PC-008	*Record of Contract Correspondence	64
QA-016	Record, Calibration	47,400
QA-017	Record, Shelf Life	31,000
QA-018	Record, Tool and Gauge Usage	68,500
QA-019	Record, Test (Materials, Parts, Sub-Assembly)	1,680,000
QA-001	Logbook, Component	24,500
QA-002	Logbook, Vehicle	5
RA-012	Card, Parts Data	40,000
RA-013	Chart, Reliability Assurance Control	42
SE-065	Logbook, Engineering	300

Figure 5-13. Data Item List (Sheet 2 of 4)

	Data Item Title	Totals
RECORDS (21) (Cont'd)		
TE-027	*Logbook, Test	205
TE-161	*Logbook, Cumulative Test Time	205
TE-028	Tape, Data Storage	110
TE-162	Film, Test Operation	110
REPORTS (34)		
CM-038	Report, Change Approved/Change Held	1,210
CM-039	Report, Configuration Management Activity	60
CM-040	Report, Configuration Management Audit	60
CM-041	Report, Contract Document Status	57
CM-042	Report, Hardware Status	135
CM-043	Report, Spares Status (Contract End Item)	19
CM-044	Report, Updating/Modification Status	57
DM-015	Report, Cost Accumulation Formal Data	19
DM-116	Report, Document Distribution Control	19
DM-017	Report, Facility Capability and Loading Data Reproduction, Processing and Dissemination	57
DM-018	Report, Informal Data Audit	57
DM-019	Report, Specialized User System Description	12
DM-020	Index, Documents Schedule and Status of Key Documents	57
LS-023	Report, Logistics Summary	1
LS-025	Report, Modification Kit Status	20
LS-026	Report, Provisioning Status	98
MA-013	Report, Final Project	1
MA-014	*Report, Project Review	61
MA-015	Report, Project Problem/Action (Red Flag)	128
MA-016	Report, Project Progress (Monthly)	64
MA-017	Report, Project Review Schedule and Agenda	65
MA-018	Report, Film	12
MA-019	Report, Quarterly, Written	21
MA-020	Report, Resources Requirements/ Availability	64
MA-021	Report, Weekly Activity	277
MA-022	Report, Schedule/Cost Coupling Summary Monthly	64
MA-023	*Report, Schedule/Cost Coupling	277
MA-024	Report, Contact	5,480
MF-001	*Report, Material Commitment	2,728
MF-002	Report, Contractor Financial Management Form 533	64
MF-003	Report, Overtime	2,728
MF-004	*Report, Vouchered Hours	2,216
MF-005	*Report, Project Financial Performance	508
MF-006	*Report, Manpower	2,728
MG-016	Report, Line of Balance	197
MG-017	*Report, Producibility	200
MG-018	*Report, Receiving	38,000
MG-019	*Report, Stock Inventory	206
MG-020	Report, Fabrication/Assembly	237
MG-021	Report, Hardware Status	237
MP-004	Report, Operational Design Description	2
PC-020	*Report, Subcontract Cost Analysis	1,940
PC-021	*Report, Subcontractor/Vendor Expenditure Analysis	17,410
PC-022	*Report, Subcontractor/Vendor Survey	140
PC-023	*Report, Subcontractor/Vendor Rating	140
PC-024	*Report, Subcontractor Proposal Evaluation	460
PC-002	Report, Contract Status	64
PC-003	*Report, Incentive Contract Analysis	22
PC-004	Report, New Technology	22
PC-005	Report, Shipping Document	1620
PC-007	Report, Status, Government Furnished Property (GEP)	22

	Data Item Title	Totals
PQ-008	Report, Bio-Assay Test	170
PQ-009	Report, Planetary Quarantine Analysis	18
PQ-010	Report, Planetary Quarantine Audit	4
PQ-011	Report, Planetary Quarantine, Planetary Vehicle (PV) Test	2
QA-020	*Report, Failure Analysis	9,756
QA-021	*Report, Nonconforming Material (NCMR)	49,380
QA-022	*Report, Process Trends	46
QA-023	*Report, Quality Audit	1,630
QA-024	*Report, Quality Status	64
QA-025	Report, Special Measurement and Test Equipment Evaluation (Component)	1
QA-026	Report, Quality Assurance Audit Summary	18
QA-027	Report, Quality Assurance Trend Summary	18
QA-028	Report, Break of Inspection	13,435
QA-029	*Report, Failure Categorization	48
QA-030	Report, Qualification Status	57
RA-015	Report, Failure Review	9,756
RA-016	Report, Summary, Audit and Appraisal	18
RA-017	Report, Design Review	594
RA-018	Report, Reliability Assessment	19
RA-019	Report, Reliability Program Status	5
SC-008	Report, Project Level PERT	137
SC-009	Report, Project Level Milestones	277
SC-010	Report, Task and Sub-Task Level PERT	137
SC-011	Report, Task and Sub-Task Level Milestones	137
SC-012	*Report, Detail PERT Fragnet Status	137
SC-013	*Report, Work Package and Account Level Milestones	137
SE-032	Report, Spacecraft System Description	1
SE-033	Report, System Analysis, General	2
SE-034	Report, System Analysis, Trajectories and Orbit	3
SE-035	Report, System Analysis, Magnetic Character	5
SE-038	Report, System Analysis, Reliability	16
SE-036	Report, Sequence of Events	18
SE-037	Report, Trade Studies	45
SE-039	Report, Dynamic Analysis	4
SE-040	Report, Structural Design Loads Analysis	4
SE-041	Report, Stress Analysis	4
SE-042	Report, Thermal Analysis	5
SE-043	Report, Deployment Analysis	2
SE-044	Report, Separation Analysis	2
SE-045	*Report, Engineering Development Discrepancy	2
TE-054	Report, Quick-Look Test	255
TE-165	Report, Test	255
TE-167	Report, Test Phase Summary	45
TE-046	Report, Cumulative Test Time	209
TE-056	Report, Daily Operations	1,265
TE-163	Report, Integrated Test Board (ITB) Actions Summary	63
TE-166	Report, Test Program Summary	3
DESIGN REPORTS (3)		
SE-046	Report, Component Design	440
SE-047	Report, Subsystem Design	120
SE-048	Report, Part, Material and Process Evaluation	4
INTEGRATION REPORTS (7)		
SE-049	Report, Circuit Data Sheet	7
SE-050	Report, Component Data Sheet	3
SE-051	Report, Mass Properties	4
SE-052	Report, Power Profile	18
SE-053	Report, Thermal Balance	9
SE-054	List Command	31
SE-055	Report, Instrumentation and Telemetry	34

* Key Informal Data

Figure 5-13. Data Item List (Sheet 3 of 4)

	Data Item Title	Totals
REQUESTS (6)		
CM-045	Request, Design Change	50,484
DM-021	Distribution Change Request	490
DM-022	DRD Change Request	93
MG-012	*Request, Manufacturing Planning	21,500
MG-013	*Request, Special Tool(s)	4,500
PC-025	*Request, Subcontract Proposal (S/C RFP)	450
SCHEDULES (9)		
MG-014	Schedule, Detail Assembly	850
MG-015	Schedule, Shop Loading	230
PC-026	*Schedule, Project Procurement	31
SC-002	Schedule, Project Level (PERT)	137
SC-003	Schedule, Project Level (Milestone)	21
SC-004	Schedule, Task and Sub-Task Level (PERT)	137
SC-005	Schedule, Task & Sub-Task Level (Milestone)	137
SC-006	*Schedule, Detail PERT Fragnets	137
SC-007	*Schedule, Work Package and Cost Account Level (Milestone)	277
SPECIFICATIONS (30)		
MP-003	Specification, Mission Dependent Equipment (MDE)	2
PQ-012	Specification, Bio-Assay Test Requirements	4
PQ-013	Specification, Facilities Requirements, Planetary Quarantine Design	2
PQ-014	Specification, General Engineering, Planetary Quarantine	2
QA-031	Specification, Special Test Equipment (STE), Component	421
SE-008	Specification, System Performance Requirements	4
SE-009	Specification, Subsystem Design Requirements	30
SE-010	Contract End Item (CEI) Detail Specification (Prime Equipment) Part I (Requirements)	128

	Data Item Title	Totals
SPECIFICATIONS (30) (Cont'd)		
SE-011	Contract End Item (CEI) Detail Specification (Prime Equipment) Part II	
SE-012	Detail Specification Engineering Critical Component	206
SE-013	Contract End Item (CEI) Detail Specification (Identication Item)	342
SE-014	Contract End Item (CEI) Detail Specification (Requirement Item)	14
SE-015	Specification, Part ( )	600
SE-016	Specification, Material	200
SE-017	Specification, Process	50
SE-018	Specification, Experiment and Planetary Scan Platform Interfaces	20
SE-019	Document, Interface Control	10
SE-020	Criteria, Structural Design	2
SE-021	General Engineering Specification, Magnetic Cleanliness	3
SE-022	General Engineering Specification, Electromagnetic Compatibility	3
SE-023	General Engineering Specification, Cleanliness	2
SE-024	General Engineering Specification Design	20
SE-025	General Engineering Specification, Test and Evaluation (Materials, Parts, Processes)	300
SE-026	Specification, Mock-ups	74
SE-027	Specification, Special Test Models	3
SE-028	List, Approved Materials	8
SE-029	List, Approved Parts	10
SE-030	List, Approved Processes	7
SE-031	List, Component Design Parameters	3
TE-164	Specification, Software Performance	40
TE-031	Specification, Special Test Equipment (STE) (System and Subsystem)	45
STANDARDS (1)		
RA-014	Standard, Rework	4
SUBCONTRACT (1)		
PC-027	Subcontract	460

* Key Informal Data

Figure 5-13. Data Item List (Sheet 4 of 4)

Of the 345 total data items, 52 (or approximately 15 percent)are key informal data items.

Technical and administrative proprietary data items prepared in response to the general provisions of the contract are not included in this list, but are itemized separately in Appendix J, which covers the Procurement and Contracting Functional Management Category. Data items shown on the General Provisions Data Item List have been included because they are specifically called out by NASA procurement regulations and are considered applicable to the Voyager spacecraft contractor. Those identified with an asterisk were identified by functional managers as necessary to perform their responsibilities prior to preparation of the General Provisions Data Item List and are also shown on the functional category data item lists.

Key references that formed the basis of generation of the data items were:

1. "Guidelines for the Voyager Spacecraft Contractor," Jet Propulsion Laboratory, MA002BB001-2A, November 12, 1965.

2. "Quality Program Provisions for Space System Contractors," National Aeronautics and Space Administration, NPC 200-2, April 20, 1962.

3. "Reliability Program Provisions for Space System Contractors," National Aeronautics and Space Administration, NPC 250-1, July 30, 1963.

4. General Electric Company Management Plans, Voyager Phase IB Proposal, e.g., "Preliminary Quality Program Plan," General Electric Missile and Space Division, CII VC110VP011, 31 January 1966.

A summary chart that reflects the combined total of all the data items in the 14 Functional Management Categories has been prepared and is shown in Figure 5-14, Voyager Project Data Items Density Profile (Summary).

Analysis of the chart reveals a uniform buildup and decline of requirements for preparation of both formal and key informal data items. Since preparation requirements for certain data items (CM-003, Alteration Notices; CM-045, Design Change Requests; RA-012, Parts Data Cards; and QA-019, Test Reports) were considerably in excess of other items, they were plotted separately to show their individual effect. (DM-023, Internal PIR's is not shown on this chart.)

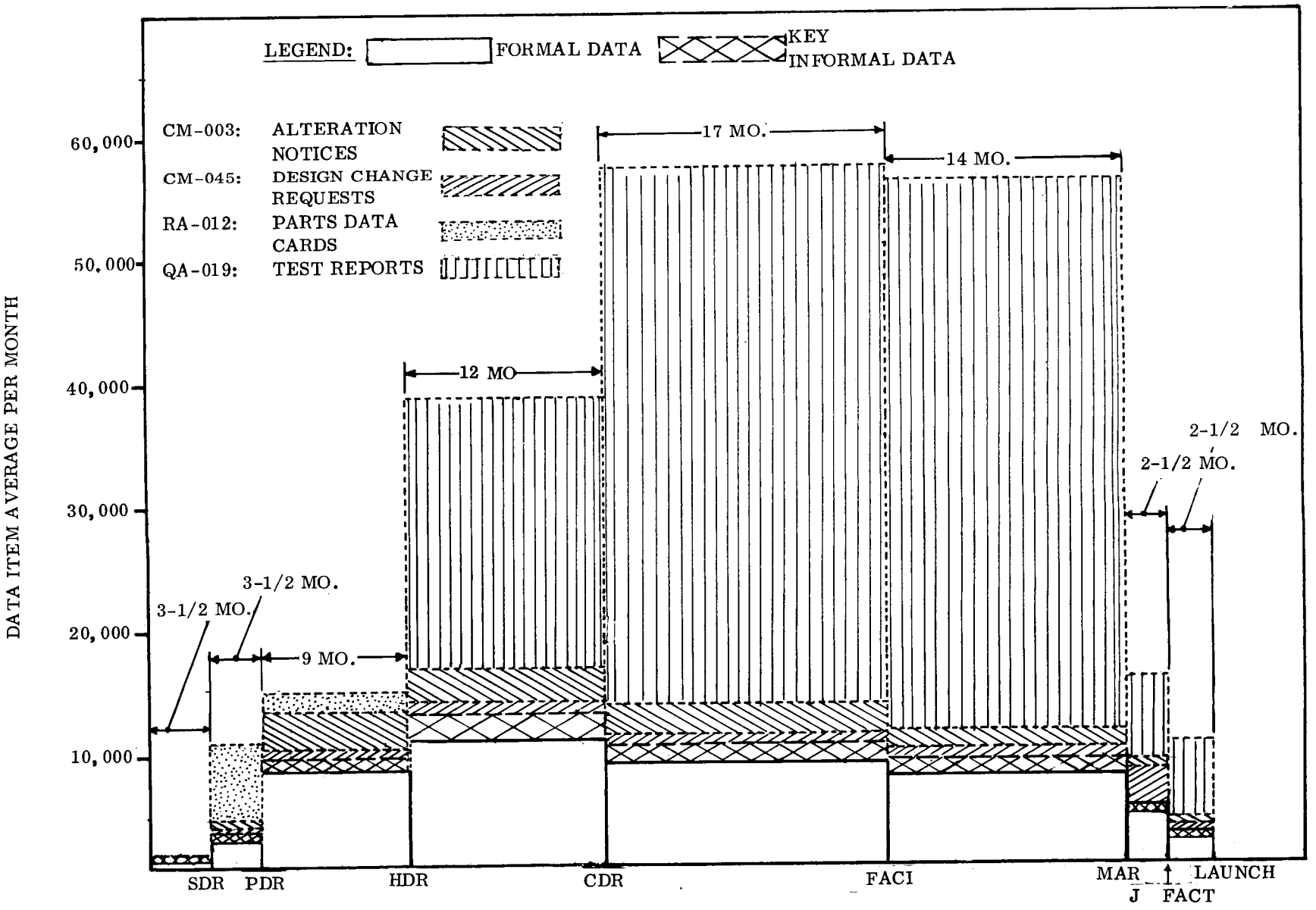


Figure 5-14. Voyager Project Data Items Density Profile (Summary)

A summary of baseline data requirements, derived from the frequency/quantity analyses and subsequently utilized in the Automatic Data Processing Plan (Section 6.3) is shown as Figure 5-15.

Following the formal data call, further analysis of the User Flow Diagrams and Automatic Data Processing Plan has indicated additional candidate data items, as shown in Figure 5-16. The Candidate Data Item List is not all-inclusive; rather, it is illustrative and has been included to show how new data items evolve as the subject is probed from additional perspectives.

5.4 SUBCONTRACTOR DATA REQUIREMENTS STUDY

As indicated in Step 9 (Section 5.2.9), initial estimates of subcontractor level data requirements were made by GE managers for four types of first tier subcontractors (principal subcontractors; major subcontractors; key subcontractors/vendors; and other vendors) and for second and third tier suppliers. In order to further develop this estimate, however, it was decided to work directly with selected potential subcontractors.

Consequently, a presentation highlighting the interaction of the subcontractor with the Voyager Data Management System was prepared, and a series of visits was initiated to:

a. Texas Instruments, Apparatus Division, Dallas, Texas

b. Motorola Semi-Conductor Division, Phoenix, Arizona

c. Rocket Research Corporation, Seattle, Washington

d. Aerojet-General, Sacramento, California

These subcontractors were requested to review the data items that would be imposed upon them by the spacecraft system contractor and classify them as follows:

a. Similar or identical to those currently in use (old):

   Group I - Data which is developed by persons whose services are covered by administrative overhead. (There is no direct charge to the customer for this service.)

PROJECT PARAMETERS	
Project Duration in Months (to Launch)	64
Spacecraft Contractor Personnel	2,000
Equivalent Number of Spacecraft	8
Equivalent Number of OSE Sets	2
COST AND SCHEDULE PARAMETERS	
Charge Numbers (Cost Account)	10,000
Task and Sub-task Milestones	75,000
Task and Sub-task PERT Events	5,000
HARDWARE PARAMETERS (PER VEHICLE)	
Spacecraft CEI and Engineering Critical Components	150
Spacecraft Subassemblies	2,500
Spacecraft Pieceparts	100,000
OSE, AHSE, MDE, CEI and Engineering Critical Components	190
OSE, AHSE, MDE Subassemblies	2,000
OSE, AHSE, MDE Pieceparts	70,000
DRAWINGS AND SPECIFICATIONS	
Spacecraft Drawings	20,000
Spacecraft Drawing Revisions	40,000
Spacecraft Specifications	600
Spacecraft Specification Revisions	600
OSE, AHSE, MDE Drawings	16,000
OSE, AHSE, MDE Drawing Revisions	32,000
OSE, AHSE, MDE Specifications	800
OSE, AHSE, MDE Specification Revisions	800
CHANGE DOCUMENTS	
Spacecraft Engineering Change Proposals	900
Spacecraft Specification Change Notices	900
Spacecraft Change Notices	80,000
OSE, AHSE, MDE Engineering Change Proposals	1,200
OSE, AHSE, MDE Specification Change Notices	1,200
OSE, AHSE, MDE Change Notices	65,000
PROJECT DOCUMENTATION	
Selected Formal and Informal Data (Excluding Drawings, Specifications and Related Documents)	225,000

Figure 5-15. Baseline Data Requirements (From Contractor Automatic Data Processing Plan)

Data Item	Description
CHARTS	
*Chart, Manpower (MF)	Line chart displaying Project manpower plan by fiscal week.
*Chart, Organization (MF)	Block type chart showing organizational structure with concise functional descriptions.
DIRECTIVES	
*Request, Material (M/R) (PC)	Provides the means for requesting and, after approval, obtaining materials and/or services from outside sources; the M/R file provides a record of such requests/approvals.
LISTS	
*List, Bonded Stock (MG)	Shows what materials, parts, and components have passed all inspections and tests and have been impounded for authorized use when needed.
*List, Buy (PC)	Shows materials, parts, and components which evaluations provided for by the Make or Buy Plan currently indicate should be bought.
*List Make (MG)	Shows materials, parts and components which evaluations provided for by the Make or Buy Plan currently indicate should be made in-house.
List, Telemetry (SE)	Includes channels, sensors, equipment performance and other parameters which enable access to vehicle performance data and its translation to usable form while the vehicle is in flight.
MANUALS	
Manual, Engineering Standards (SE)	Establishes engineering standards to be used in the design, procurement, fabrication and testing of Voyager spacecraft hardware and in the preparation of Project software.
PLANS	
*Plan, Contamination Control (MG)	A plan for achieving and maintaining Voyager cleanliness.
Plan, Cost Reduction (MA)	Provides details of contractor's cost reduction program and indicates specific

*Plan, Make or Buy (MG)	Covers the concepts, policies, and procedures used in determining which materials, parts, and components should be bought and which made in-house.
*Plan, Manufacturing Reliability (MG)	A plan for achieving the objectives of NPC 250-1 in manufacturing.
*Plan, Master Financial (MF)	Provides a graphic comparison at all work breakdown structure levels of cumulative actual and forecast costs versus value-of-work performed data.
Plan, New Technology (PC)	Demonstrates how the contractor and major subcontractors will implement provisions of the new technology clause (NASA PR 9.101.4).
Plan, Summary, Master Financial (MF)	Provides a graphic comparison at the overall contractor level of acumulative actual and forecast costs versus value-of-work performed data; shows number of months funding available.
PROCEDURES	
*Procedure, Data Item Audit (DM)	Details the steps taken in performing a data item audit.
RECORDS	
*Record, Personnel Qualification Status (QA)	Provides an updated file of personnel qualifications and training status.
*Report, Subcontractor Action Summary (PC)	Provides a weekly summary of subcontractor action item activities.
*Report, Subcontractor Value of Accomplishment (PC)	Shows value of work accomplished by subcontractors against an integrated base of cost, schedule and technical performance.
REPORTS	
*Report, Cleanliness (MG)	Summarizes cleanliness conditions of hardware and facilities.
*Report, Reliability Audit (RA)	Summarizes manufacturing performance from the standpoint of Reliability.
*Report, Status, Test Equipment (TE), Special Test Equipment (STE), and Special Tools and Fixtures (SC)	A weekly automatic data processing print-out showing status and whereabouts of contractual items. A supplement shows status of noncontractual items.

*Key Informal Data

Figure 5-16. Candidate Data Items

Group II - Data which is developed in the normal course of doing business and the customer will accept the present format or form. (Producer gets paid for reproduction services only.)

b. New data items/new format:

Group III - Data which is developed in the normal course of doing business but the customer requires additional effort to obtain the desired form or format. (Producer gets paid to convert and/or amplify, prepare, and reproduce this data.)

Group IV - Data which would not be developed in the normal course of doing business. (Producer gets paid to develop, prepare, and reproduce this data.)

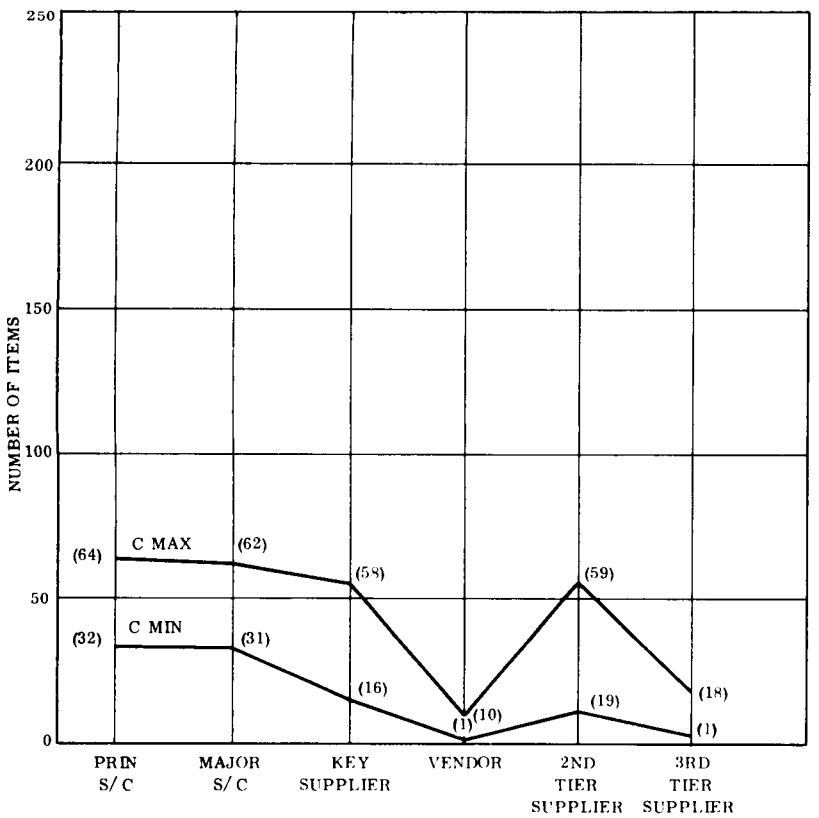
Group V - Unacceptable or not applicable.

Subcontractor responses to both classifications (i.e., contractor requirements imposed on subcontractors (C); and subcontractor internal requirements (S) are portrayed in Figure 5-17.

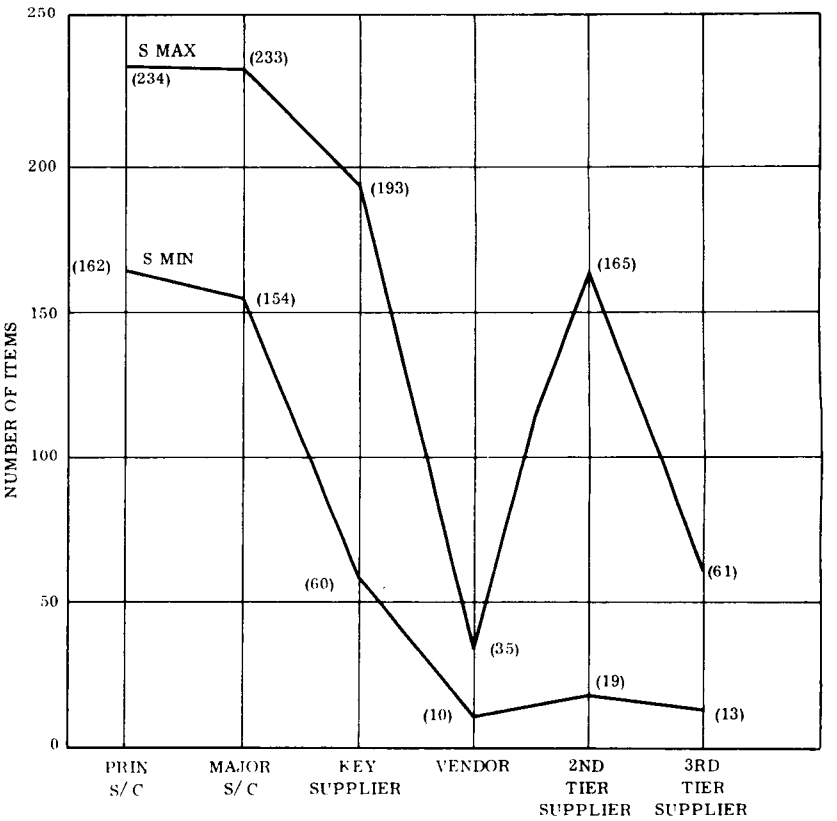
In addition, these subcontractors were requested to review the data item list for all items which they would impose on their second tier key suppliers. Based upon this review, the GE subcontract managers (and functional managers) subsequently revised the basic subcontractor level data item matrixes (reference Figure 5-5) which are included in Appendices A through K.

An analysis of subcontractor response follows: good correlation existed in the principal subcontractor category between the original and the revised Data Item List (234 of the previous 245 data items remain)... this tends to verify the basic validity of the original estimate. Good correlation also existed on the number of data items falling into the different cost group classifications between all four potential subcontractors queried. (See Figure 5-18).

Although the principal subcontractors and GE were in general agreement on data item requirements, almost half (47 percent) of the data items were new to the firms queried. This suggests that further refinement of the subcontractor level data item list may subsequently be desirable.



"C" DATA ITEM REQUIREMENTS -
CONTRACTOR FURNISHED TO SUBCONTRACTOR



"S" DATA ITEM REQUIREMENTS –
SUBCONTRACTOR FURNISHED TO CONTRACTOR

Figure 5-17. Subcontractor Level Data Requirements (Summary)

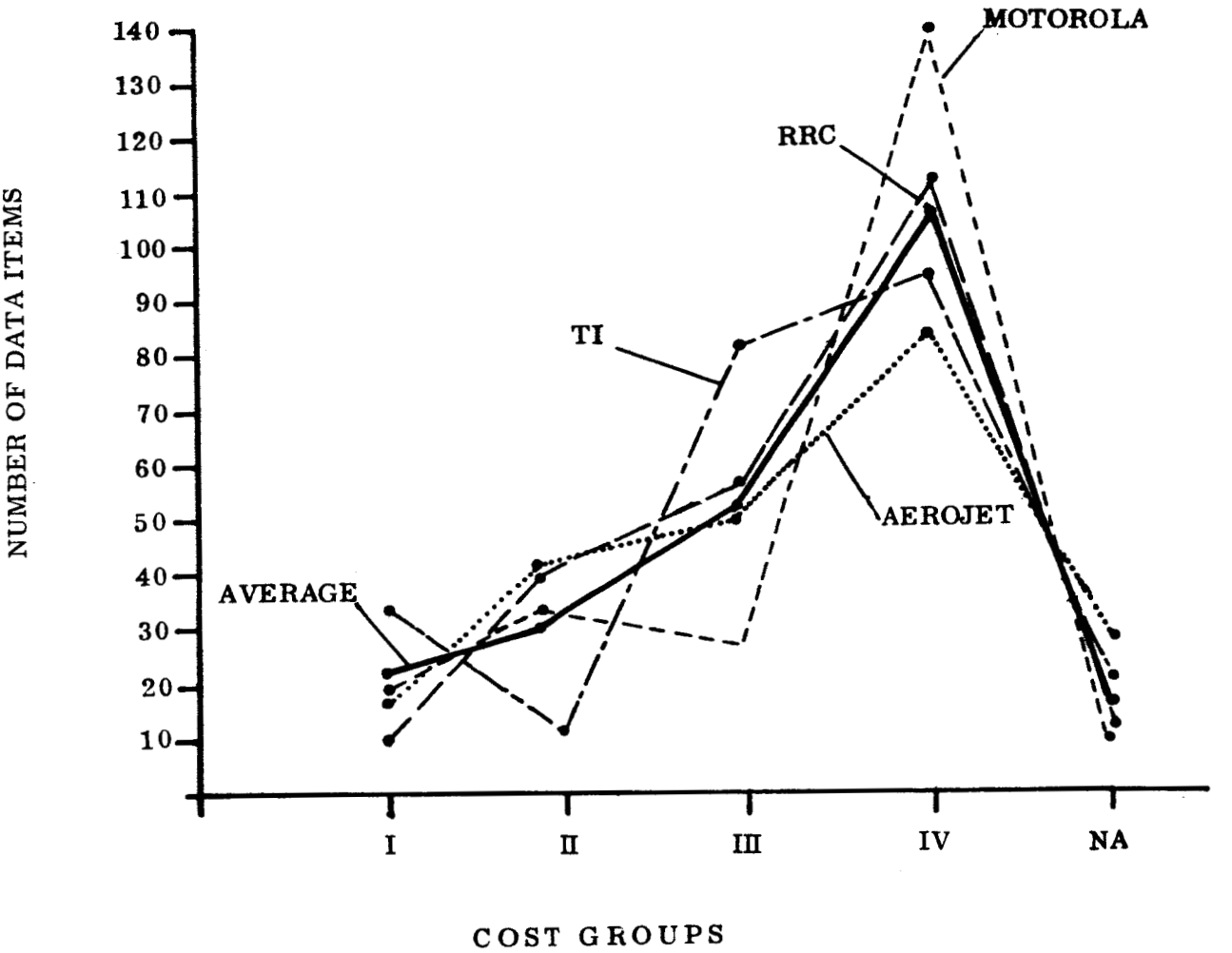


Figure 5-18. Principal Subcontractors

The quantity of key supplier data items (second tier subcontractors) increased significantly over the number estimated in the original Data Item List. (This indicates the need for additional review and potential creation of DRD's that delineate the portions of contractor and subcontractor data items that should be imposed on key suppliers.)

The computer and sequencer (an in-house developed subsystem) Data Item List diverges in specifics, but not in quantity, from the principal subcontractor list. This points out that although all subsystems do not have identical data items, a close correlation exists between the total requirements for both in-house and subcontracted data items.

SECTION 6

CONTRACTOR IMPLEMENTATION STUDIES - PHASE III

6.1 INTRODUCTION

The following studies were prepared during this phase to determine how the contractor would use the data management system delineated in Phase I to process the data developed in Phase II:

a. Information System Equipment Handbook and Microfilm Compendium

b. Automatic Data Processing Plan

c. Indentured Numbering System Study

d. Data Cost Study

Summary descriptions of the contents of these reports follow.

6.2 INFORMATION SYSTEM EQUIPMENT HANDBOOK AND MICROFILM COMPENDIUM

The Information System Equipment Handbook contains descriptions of the functional and performance characteristics of data processing and office equipment used in information systems work. Performance and cost trends are discussed for the classes of equipment described and typical applications are included.

The handbook was written to serve two purposes: First, it was intended as a tool for the information system designer to help him with preliminary system design and evaluation. Existing equipment capabilities and costs are made conveniently available so that proposes solutions to information system problems can be examined quickly from the standpoint of hardware capability and cost. Second, it was intended for use by the information system user as a guide to the capabilities and limitations of the equipment, thereby providing him with a better understanding of processing.

An effort was made in the handbook to identify the trends developing in various sectors of the equipment spectrum, to permit designing Voyager systems appropriate to the time period of their employment (1968-73).

Data is presented for the following classes of equipments used in information system work:

a. Medium and large-scale computers

b. Auxiliary data storage devices

c. Special input/output equipment

d. Unit record equipment

e. Telecommunications equipment

f. Reproduction and office copying equipment.

Each section contains a description of the equipment belonging to the class and the function it performs. Performance and cost data, such as that illustrated in Figures 6-1 and 6-2, are given, generally in the form of comparison tables. No evaluation of competing equipments has been attempted. Applications illustrative of the use to which a particular machine might be put are provided in a number of cases. In addition, a Microfilm Compendium identifying microfilm processes, systems, and equipment that could be used in the storage, retrieval, and dissemination of information by the document control centers concerned with Voyager data management was prepared.

6.3 AUTOMATIC DATA PROCESSING PLAN

This report describes a plan for an integrated automatic data processing (ADP) system for the Voyager spacecraft project. This automatic data processing system is to be used by the spacecraft contractor in the acquisition, storage, processing, and transmission of data required for management and technical control and support of the development, production, and test of the Voyager spacecraft.

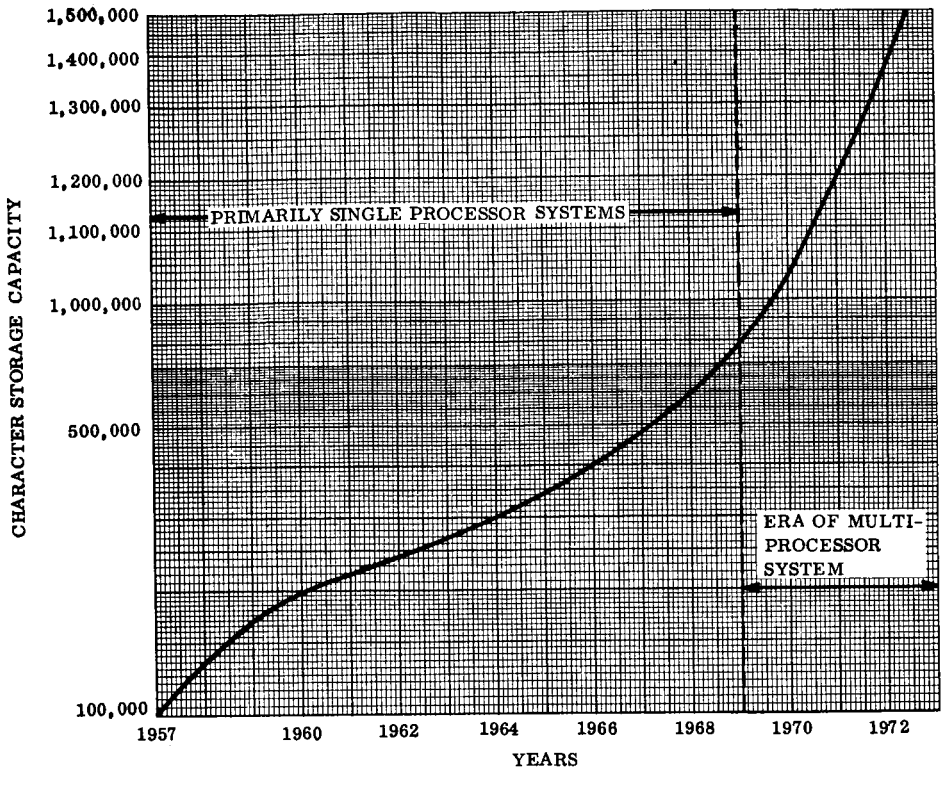
An ADP system is necessary for the following reasons: (1) criticality of schedule performance, (2) high spacecraft reliability demands, (3) length and continuity of the program, and (4) diverse locations and multiplicity of customer, prime contractor, and subcontractor interfaces.

Table 3-5. Medium-Scale Computer Specifications

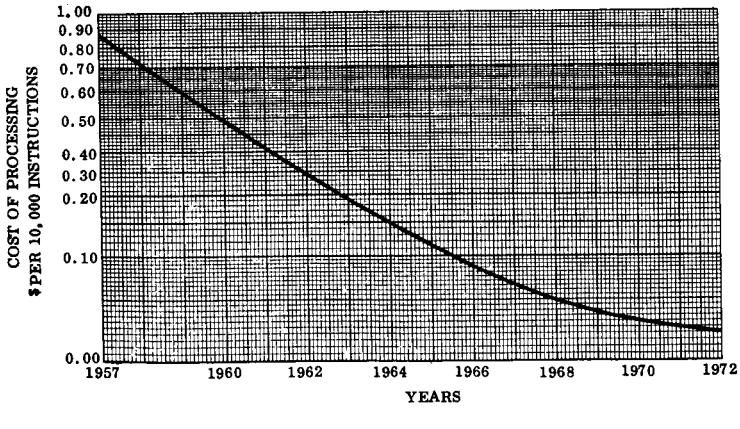
Manufacturer	Burroughs	CDC	CDC	GE	GE	Honeywell	Honeywell	IBM	IBM	RCA	SDS	Univac	Univac
Model/Type	5500	3200	3400	235	435	800	200 series 4200	360 series 40	360 series 50	Spectra 70 55	Sigma 7	491	492
Average system cost													
Monthly rental ($1000)	23.0	16.0	24.0	13.1	15.6	25.0	22.3	14.5	24.0	13.5	17.0	16.1	17.8
Purchase price (1,000,000)	1.0	0.8	11.0	0.7	0.9	1.2	1.1	0.69	1.3	0.67	0.57	0.715	0.785
Central processor													
Cycle time (microseconds)	2	2.5	2.6	12	8.8	24.0	9.4	11.9	4.0	2.3	2.0	4.8	4.8
Auto interrupt	X	X	X	X	X	X	X	X	X	X	X	X	X
Floating point	X	X	X	X	X	X	X	X	X	X	X	X	X
Memory protect	X				X		X	X	X	X	X	X	X
Indirect addressing	X				X	X	X				X		
Number of index registers		3	6	3	6	64	30	16	16	43	16	7	7
Internal storage													
Capacity: Words (1000)	4 to 32	4 to 32	16 to 32	4 to 16	4 to 32	4 to 28	65 to 524 ch	16 to 262 bytes	65 to 524 bytes	65 to 524 bytes	4 to 131	16 to 32	16 to 32
Characters (1000)	32 to 262	16 to 131	130 to 262	12 to 49	16+130	24 to 168	65 to 524 ch	16 to 262 bytes	65 to 524 bytes	65 to 524 bytes	16 to 524	80 to 163	80 to 163
Access time (microseconds)	2.0	1.25	1.5	6.0	2.7	6.0	0.75/4 ch	2.5	2.0	0.84/4 bytes	1.2	4.8	4.8
Word length (Bits)	48+parity	24+parity	48+parity	18+sign + parity	24+parity	48+parity	8+parity	1 byte = 8 bits	1 byte = 8 bits	1 byte = 8 bits	32	30	30
Other available storage and transfer rates													
Additional bulk core storage								X	X				
Drum	X	X			X			X	X	X		X	X
Disc	X	X		X	X	X	X	X	X	X	X		
Magnetic tape	X	X	X	X	X	X	X	X	X	X	X	X	X
Magnetic card					X					X			
Magnetic strip							X	X	X				
Input/output devices													
Typewriter consoles	X	X	X	X	X	X		X	X	X	X	X	X
Card readers (cpm)	800	1200	1200	900	900	650	800	1000	1000	1435	800	900	900
Card punches (cpm)	300	250	250	300	300	250	250	300	300	100	300	300	300
Printers (ch/l and lpm)	132/1040	132/1000	1000	120/1000	136/1200	900	950	132/1100	132/1100	160/1250	1000	922	922
Paper tape reader (ch/sec)	1000	1000	350	1000	500	1000	600	1000	1000	200	300	400	400
Paper tape punch (ch/sec)	100	110	110	110	110	110	110			100	120	110	110
Plotters		X	X	X	X								
Visual display							X	X	X	X			
Data communications													
Capability	X	X	X	X	X	X	X	X	X	X	X	X	X

Key: cpm = cards per minute; lpm = lines per minute; ch = characters; ch/l = characters per line

Figure 6-1. Excerpt from Information System Equipment Handbook



(a) Capacity Trend of On-line Storage



(b) Cost Trend of Processing

Figure 6-2. Cost Excerpt from Information System Equipment Handbook

Three conceptual approaches to ADP systems were considered: independent, centralized, and federated.

The independent and centralized approaches represent two extremes. The independent approach uses several independent functional systems, with the advantage of flexibility and the disadvantage of the absence of central coordination. The centralized approach uses one centralized integrated system, with the advantage of central coordination and the disadvantage of the lack of flexibility.

The federated approach is an intermediate one, with an optimal balance of the advantages and disadvantages of the independent and centralized approaches. This is the only one that simultaneously permits both the flexibility required in the developmental environment and the central coordination required for control of data to ensure accuracy and consistency.

The federated ADP system planned for use by the Voyager spacecraft contractor consists of seven functional information systems:

a. Project Control - Supports planning and control activities including costs, schedule, resource allocation, estimate and forecast data, subcontractor management and administrative reporting, and technical performances indexes.

b. Engineering Development - Provides a variety of data to engineering, management and customer personnel including on-line hardware design parameters, design and effectiveness optimization routines, and automated engineering graphics.

c. Configuration Management - Provides control of designed configuration data such as parts lists, drawing status and change notice status, and visibility of "as built" configuration.

d. Purchasing and Material Control - Supports the entire material procurement cycle from the consolidation of material requests through the withdrawal of material from stockrooms.

e. Fabrication, Assembly, and Test - Supports the contractor in-house production and test activities, including planning, production scheduling, and status reporting, shop loading, and labor cost accumulation.

f. Test and Environmental History Accounting - Provides an accounting of all equipment failures and tests, but is limited to ground test data at this time.

g. Document Management - Provides the means for monitoring the timely preparation of data in response to contractual obligations, document distribution control, and operation of the document retention center.

For each functional system, the following were considered: purpose and objectives, use of outputs, approach and general considerations, system particulars, loading estimates, equipment and manpower requirements, and implementation.

Figure 6-3 indicates a typical output information and documentation chart. Figure 6-4 illustrates a typical automatic data processing flow diagram.

For the overall federated ADP system, a number of computer and peripheral equipment systems were evaluated according to system hardware, computation load, availability, assignment, operating costs, and implementation requirements.

System hardware includes large-scale computer systems, medium-scale computer systems, remote input/output computers, remote-access, time-sharing computations, on-line file storage, unit-record and terminal equipment, and telecommunications channels.

Computation load, such as is shown in Figure 6-5, was determined according to base load and operating load. Availability was estimated with consideration of the scheduled work week, preventive-maintenance requirements, and malfunction downtime. Operating costs were estimated as were system-operating requirements. Implementation requirements reflected personnel and schedule requirements as indicated in Figure 6-6. The impelementation schedule is based on a contract award during first quarter of 1968 and a launch date of July 1973.

The federated ADP system was evaluated with respect to key system capabilities and the impact of the ADP system on the Voyager spacecraft program. Key system capabilities

Table 8-1. Output Information and Documentation, Test and Environmental History System

Subsystem	Output	User	Process Form	Frequency of Issue	Input		Purpose
					Source	By	
Failure Data	Failure Status Report (QA-029)*	Failure Analysis Review Board and Quality Assurance Engineering	Batch Reporting	Monthly	Failure Report	Inspector, FARB	To provide the "open/closed" status of each failure report
	Failure Summary Reports (RA-006)	Failure Analysis Review Board and Quality Assurance Engineering	Batch Reporting	Monthly	Failure Report	Inspector, FARB	To provide a tabulation of failure reports in sequence of, and summarized by failure code or organizations responsible for corrective action, within a hardware design or hardware type or CEI
Performance Data	Hardware Test Profile Report	Design, Reliability, and Quality Assurance Engineering	Batch Reporting	Weekly Activity Reporting	Performance Criteria	Reliability Engineering	To identify and provide selected results of each test affecting a specific hardware item. Also to provide the residual life of the specific hardware item.
					Data Sheet	Tester/ Inspector	Provides the overall test result history applicable to a specific hardware design. Also to provide the calculation of mean-time-between-failures
	Test Summary Report	Design, Reliability, and Quality Assurance Engineering	Batch Reporting	Monthly	Failure Report	Tester/ Inspector	
Configuration Experience	Configuration Experience Profile (Assembly)	Design, Reliability, and Quality Assurance Engineering	Remote Inquiry	As required	Performance Data File	Automatic Data Processing System	To provide a summation of the test results and failure history applicable to each hardware item included in a specific assembly, including CEI
					Failure Data File	Automatic Data Processing System	
	Configuration Experience Profile (Hardware Item)	Design, Reliability, and Quality Assurance Engineering	Remote Inquiry	As required	Performance Data File	Automatic Data Processing System	To provide, by audio response, a summation of the test results and failure history applicable to a specific hardware item
					Failure Data File	Automatic Data Processing System	

*Numbers shown in parentheses in the "Output" column indicate formal documents or key informal data. All other entries are contractor informal data.

Figure 6-3. Typical Output Information and Documentation Chart

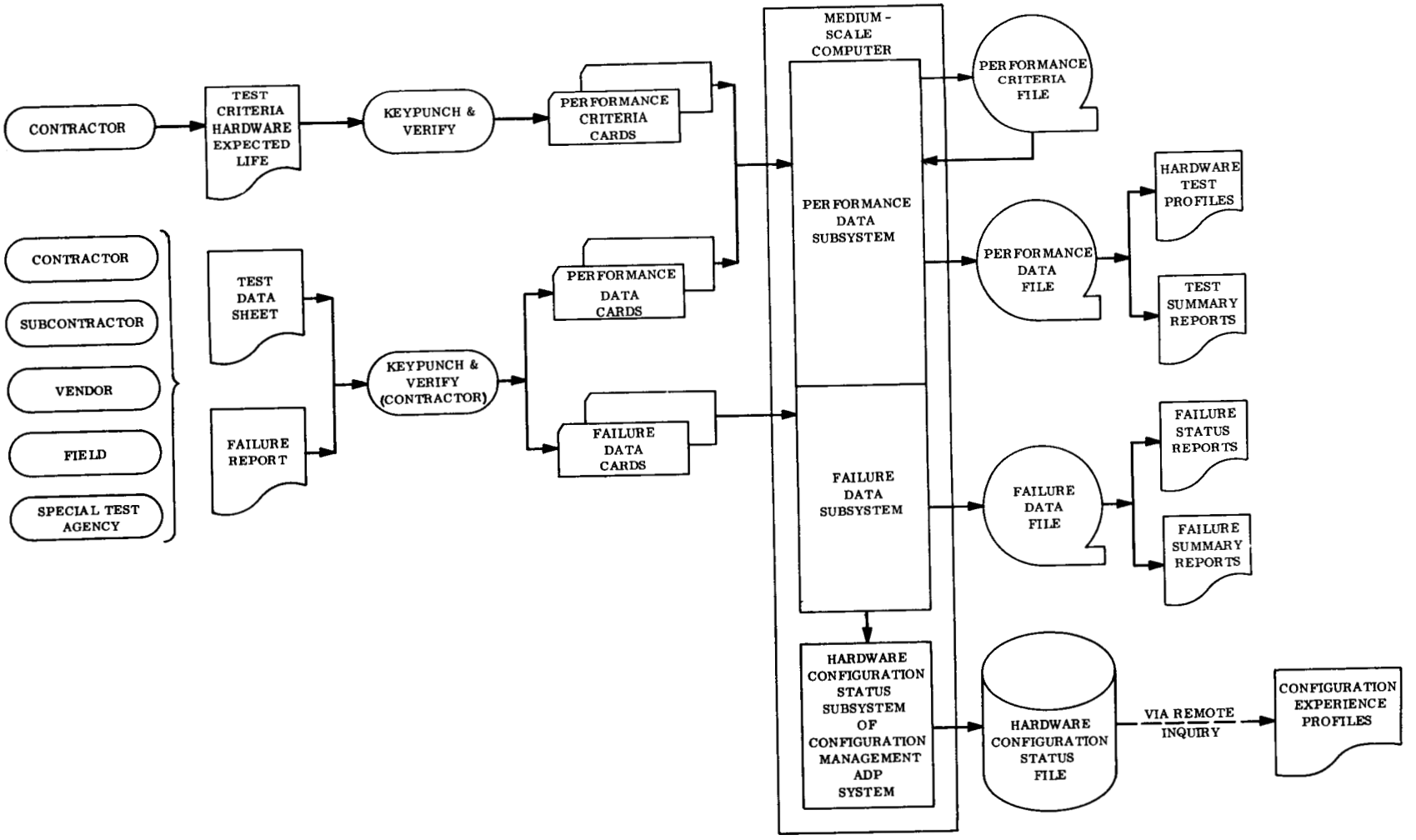


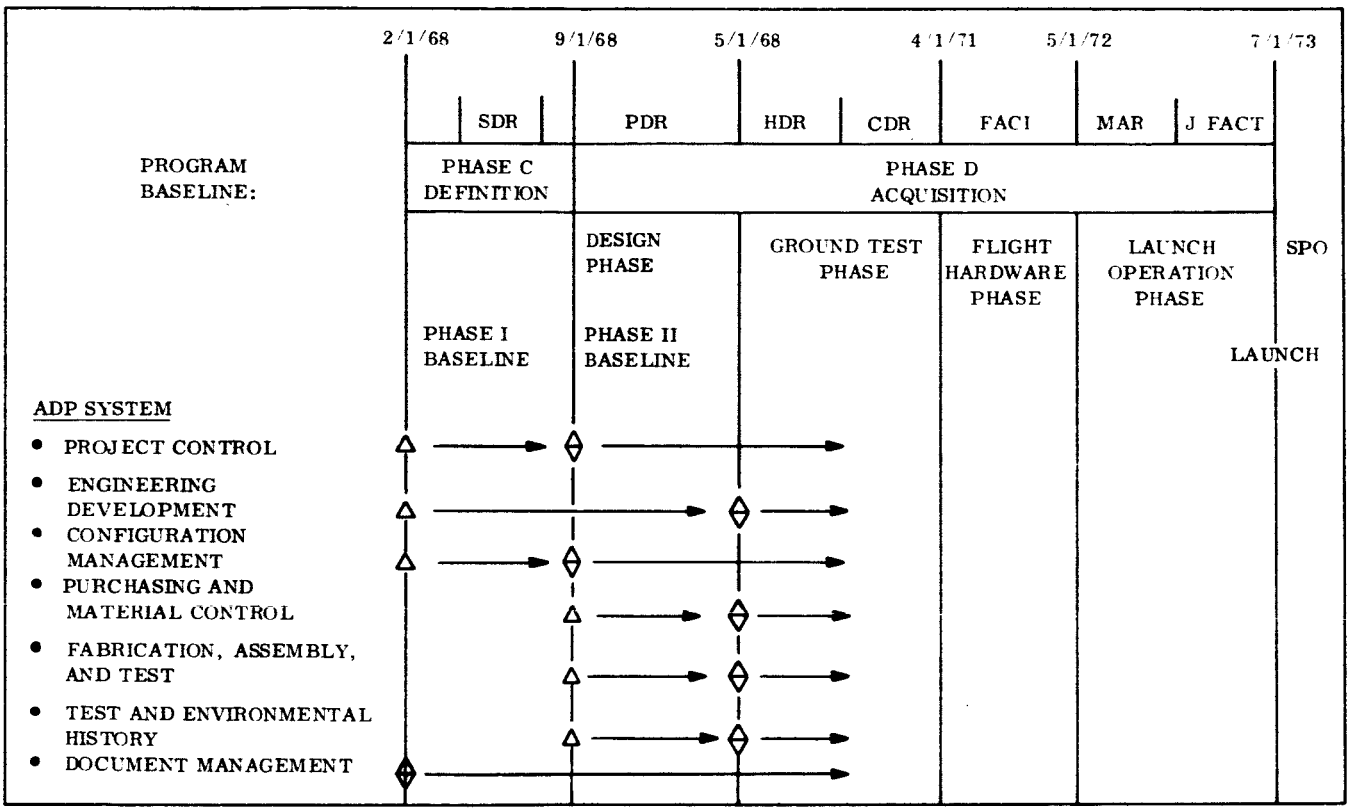
Figure 6-4. Typical ADP System Flow Diagram

Table 10-1. Equipment and Manpower Base Load Requirements

Resource	Year of Voyager Contract					
	1	2	3	4	5	Total
Large-Scale Batch Computers (hours)						
Project control	110	84	88	84	80	446
Engineering development	205	213	199	48	48	713
Configuration management	-	-	-	-	-	-
Purchasing and material control	-	-	-	-	-	-
Fabrication, assembly, and test	-	-	-	-	-	-
Test and environmental history	-	-	-	-	-	-
Document management	-	-	-	-	-	-
Total	315	297	287	132	128	1,159
Medium-Scale Computers (hours)						
Project control	384	384	384	384	384	1,920
Engineering development	470	546	638	336	216	2,206
Configuration management	313	1,338	1,762	1,923	2,706	8,042
Purchasing and material control (B)	380	495	450	415	155	1,895
Fabrication, assembly, and test	755	485	1,940	1,455	730	5,365
Test and environmental history	100	600	900	500	100	2,200
Document management (B)	201	748	921	777	230	2,877
Total	2,603	4,596	6,995	5,790	4,521	24,505
Remote Batch Processing (hours)						
Project control	-	-	-	-	-	-
Engineering development	-	-	-	-	-	-
Configuration management	-	-	-	-	-	-
Purchasing and material control	1,420	1,860	1,690	1,590	582	7,112
Fabrication, assembly and Test	84	105	420	315	160	1,084
Test and environmental history	-	-	-	-	-	-

Document management	-	-	-	-	-	-
Total	1,504	1,965	2,110	1,905	742	8,196
Remote Access Time Sharing (hours measured at terminal)						
Project control	2,000	2,400	3,000	2,800	2,600	12,800
Engineering development	3,800	2,900	1,800	1,300	600	10,400
Configuration management	367	763	1,238	1,554	2,325	6,247
Purchasing and material control	5,550	7,250	6,600	6,100	2,480	27,980
Fabrication, assembly, and test	5,300	6,500	7,300	6,100	2,200	27,400
Test and environmental history	200	1,300	1,900	1,400	400	5,200
Document management	1,232	4,576	5,632	4,752	1,408	17,600
Total	18,449	25,689	27,470	24,006	12,013	107,627
On-Line Storage (1000 characters)						
Project control	12,000	13,000	14,000	13,000	12,000	
Engineering development	18,000	26,000	34,000	42,000	42,000	
Configuration management	4,830	15,300	35,400	60,900	115,600	
Purchasing and material control	6,470	7,650	7,650	7,650	2,940	
Fabrication, assembly, and test	600	1,200	4,800	3,600	1,800	
Test and environmental history	1,360	8,500	12,580	9,180	2,380	
Document management	84	312	384	324	96	
Total	43,344	71,962	108,814	136,654	176,816	
Input Labor Hours (keypunch)						
Project control	800	480	600	600	600	3080
Engineering development	2,250	1,000	1,000	1,000	500	5750
Configuration management	1,111	3,910	4,379	3,325	5,960	18,685
Purchasing and material control	2,160	2,700	2,520	2,340	900	10,620
Fabrication, assembly and test	452	864	3,456	2,592	1,296	8,640
Test and environmental history	217	1,360	2,013	1,469	381	5,440
Document management	1,400	5,200	6,400	5,400	1,600	20,000
Total	8,370	15,514	20,368	16,726	11,237	72,215

Figure 6-5. Equipment and Manpower Base Load Requirements Summary



LEGEND:

◇ FULLY OPERATIONAL
△ PARTIALLY OPERATIONAL

DEFINITIONS

SDR	=	SYSTEM DESIGN REVIEW
PDR	=	PRELIMINARY DESIGN REVIEW
HDR	=	HARD DESIGN REVIEW
CDR	=	CRITICAL DESIGN REVIEW
FACI	=	FIRST ARTICLE CONFIGURATION INSPECTION
MAR	=	MISSION ACCEPTANCE REVIEW
J FACT	=	JOINT FLIGHT ACCEPTANCE COMPOSITE TEST

Figure 6-6. Automatic Data Processing (ADP) System Implementation Schedule

include recovery from machine failures, adaptability to information flow between contractors, file protection, capability of performance within limits imposed by hardware, file-data auditing, and hardware performance cycles.

Modification and extension of the ADP system were considered. Areas of investigation included changes in system scope, data-handling requirements and data processing hardware; cost and performance trends in hardware and telecommunication; and system shutdown for project completion.

Particular attention was paid to the establishment of a design data base for use in the engineering development phase of the program (see Figure 6-7).

6.4 DATA ITEM INDENTURED NUMBERING SYSTEM STUDY

The purpose of this study was to develop a unified numbering system that would relate hardware and software across all significant elements of the project and enable retrieval of documents and information concerning them. The following requirements were used as the basis for developing the numbering system:

a. Traceability between project activities and hardware must be maintained.

b. Traceability would include both formal and informal data items

c. The capability must exist for determining the data items composing or related to project functions, work packages, organizational outputs, or project phase

d. The capability must exist for document retrieval against request by document identification number, part number, project function, work package, and kind of document.

The following actions based on these requirements were taken:

a. Analysis of possible kinds of requests was made

b. Analysis of possible kinds of responses was made

c. The Data Item List was reviewed to determine kinds of documents to be considered

Subsystem	Output
Automatic Cross-Section Layout	Cross-sectional view drawings of completed spacecraft and its components
Mechanized Drafting	Mechanically produced engineering drawings, schematics, flow diagrams, and layout drawings
Energy Balance	Definition of power load requirements for each component by mission phase and power type
Flight Sequency of Events and Power Profile	Definition of mission events, time of event, command source and definitions, and power requirements by event and mission phase
Link Calculation	Definition of telemetry-data requirements for each phase of mission
Telemetry List	List of all telemetered data points and rates, including variable to be sampled, units, sampling rate, and data mode
Optimum Parts Selection	Selection of parts most suitable for a specified design application
Parts History of Reliability	Performance history, under varying environmental and functional conditions, for predetermined part types or criticality levels in hardware system
Qualification Status	Dynamic record of qualification status of components and other parts used in hardware system
System Reliability Analysis	System-level configuration definitions and reliability predictions for specified levels of systems and hardware
Reliability Assessment and Appraisal	Measurement and control data useful for reliability and maintainability surveillance of specified levels of systems and hardware
Structural/Dynamics Analysis	Analysis of structural design integrity, including dynamics and stress analysis, of hardware system
Thermal Analysis	Thermal maps for analysis of thermal design integrity, including thermal balance and control of hardware system

Figure 6-7. Outputs of Engineering Development Subsystem

d. Document numbering structuring patterns were reviewed and choices made

e. Work breakdown structure patterns were reviewed and choices made

f. A significant document coding was developed

g. Existing numbering systems used for retrieval were reviewed.

The recommended numbering system is a series of numbers and alpha codes constructed in a manner that enable formal and key informal data items to be identified and retrieved. The document identification number (DIN) assigned by the preparer and marked on the data item is the basis by which it is identified, filed and retrieved. In addition, the data item marking will include for:

a. Formal data items:

   1. Functional management category code

   2. DRD number

   3. Imposers code

   4. Response sequence number

   5. Responders code.

b. Informal data items:

   1. Functional management category

   2. Work Breakdown Structure (WBS) number

   3. Preparing organization code.

The series of numbers and codes also provides the capability of identification and retrieval of data items, when requested, against such subjects as:

a. Work Breakdown Structure (WBS) - which includes project, project phase, system/task, subsystem/sub-task and project activities.

b. Type and kind of data item - which allows identification and retrieval of groups of the same type/kind of data items. When requested in conjunction with the WBS segregater, those related to a specific subtask/task/function.

c. Preparing organization - which allows identification and retrieval of data items prepared by a specified organization element regardless of function or work task association.

d. Hardware identification - which establishes by identification of part numbers and their defining data items the relationship of hardware to specified functions and work packages.

e. Contractual response - which includes the identification of the Data Requirements List (DRL) line item and its associated Data Requirements Description (DRD) against which the response is made.

6.5 DATA COST STUDY

This study was conducted to develop the following contractor-level techniques for estimating monitoring the cost of data produced by a contractor for the Voyager Project:

a. Preparation of estimates of the price of data items on the Contractor Data Requirements List (DD Form 1423)

b. Accumulation, monitoring, and control of the overall costs of formal and informal data

c. Accumulation, monitoring, and control of the individual cost of selected formal and informal data items.

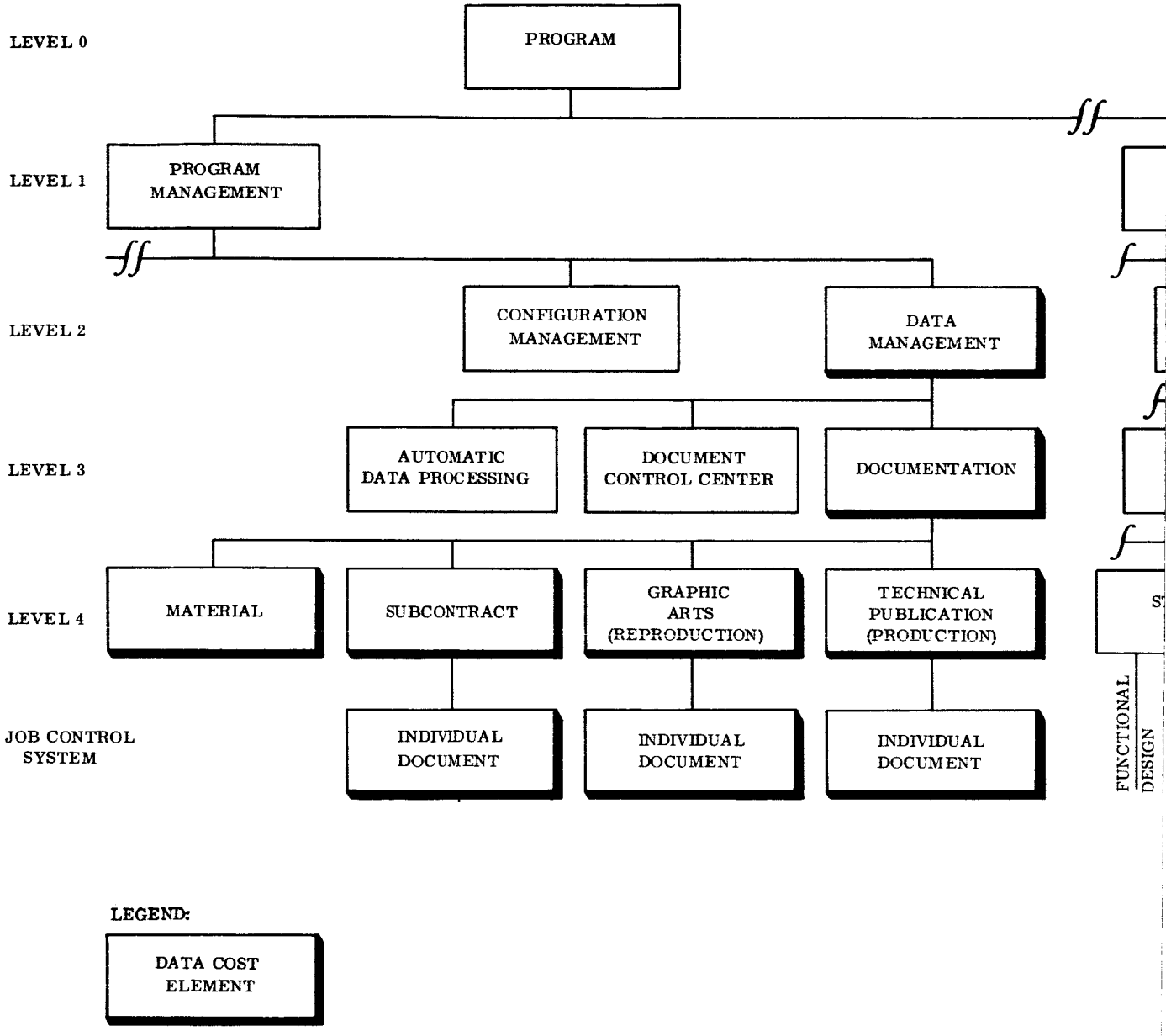
The basic approach recommended was that all data activities would be organized in a contractor Work Breakdown Structure similar to that shown in Figure 6-8. This is proposed as a five-level breakdown, which is assumed as a minimum for the Voyager Project. Three principles are involved:

a. The generation and preparation of data for each formal data item would be included, either as a separate work package or as a specified subtask in a larger work package. For example, preparation of a group of technical manuals, meeting the criteria for a separate work package would be identified as a separate work package; preparation of a single report, not meeting the criteria for a separate work package, would be identified as part of a larger work package for which it would be a logical output.

b. The production and reproduction of all contractor-generated data items would be included in a single work package. An additional level of breakdown is required for this work package to account for individual data items. This is the job control system referenced in Figure 6-8.

c. Other data activities related to the overall performance of the data management function would be grouped and included as separate work packages, as desired, for effective management.

Data item cost and price estimates normally would include only production and reproduction costs. Generation and preparation costs would be included only when an integrated data activity can be established as a separate work package.



LEGEND:

DATA COST ELEMENT

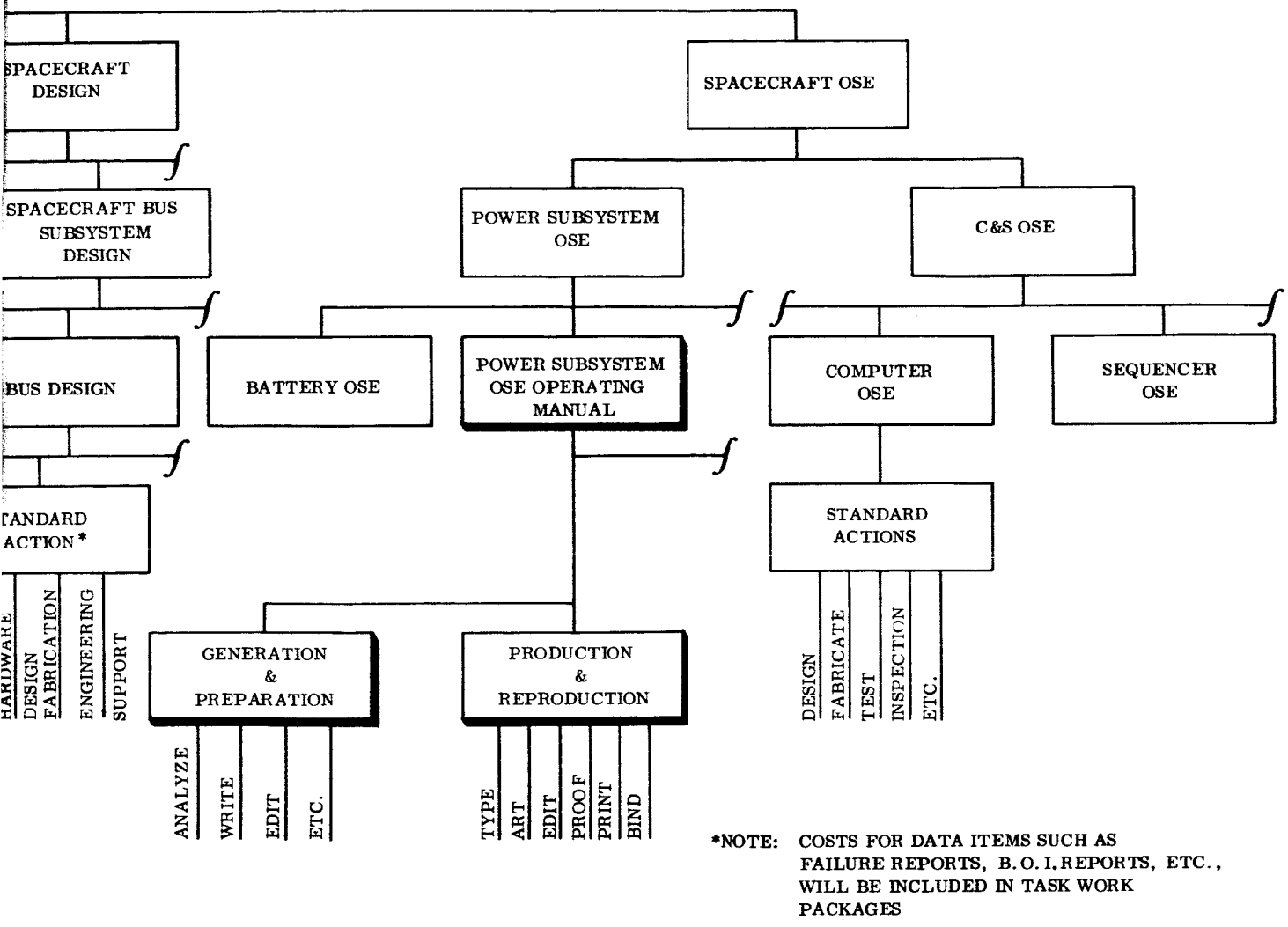


Figure 6-8. Illustrative Work Breakdown Structure for Data Cost Accumulation

SECTION 7

CONTRACTOR MANAGEMENT INFORMATION STUDY - PHASE IV

7.1 INTRODUCTION

The Voyager Project has several fundamental requirements that demand particularly tight control of the project. Launch window constraints make performance within planned schedules most critical. The number and geographic dispersion of subcontractor and customer offices, of associate contractor and contractor locations require a complex multipath communications network. A large amount of data is generated. The major project control task therefore, is the accumulation, selection, calculation, and analysis in response to the large volume of data and recommendation and follow-up to assure action.

The critical question is finding a means to communicate to program management the vital project control data needed, the analysis and basic conclusions to be drawn from the data, alternative courses of action and the action recommendations and follow-up.

The development of management information data requirements and flow channels was conducted through a series of related activities, as indicated below:

a. Formal Data Requirements - These include the Data Item Matrices, the Data Requirement Descriptions, and the User Flow Diagrams that are included in Appendix G.

b. Automatic Data Processing System for Project Control - Development of an automatic data processing system to handle management data is included in the Automatic Data Processing Plan and summarized in Section 7.2.

c. Technical Performance Monitoring Study - An approach toward the monitoring of technical performance for the Voyager Project has been developed and issued in a technical report. This approach is summarized in Section 7.3.

d. Project Control Room Study - A Project Control Room Study has been conducted and described in a technical report that is summarized in Section 7.4.

7.2 AUTOMATIC DATA PROCESSING SYSTEM FOR PROJECT CONTROL

The subsystems that make up the automatic data processing system for project control have six broad aims:

a. To establish, record, and maintain plans for financial, schedule, and resource (i.e., manpower and material) plans

b. To provide a method of updating those plans and for recording and measuring actual performance against them

c. To facilitate projections and forecasts of performance based on the analysis of actual versus planned performance

d. To generate resource support information such as personnel lists and organization charts

e. To provide a method of producing the various reports needed to satisfy customer data requirements, subcontract management needs, and internal management and functional use

f. To provide total visibility and downward traceability to the Program Manager and the customer, including the deviations from plan, the trends, and/or predictions which represent problem areas (current and/or future) that require his attention due to the level of decision and/or customer involvement.

To accomplish this, seven subsystems have been identified in the automatic data processing system for project control.

7.2.1 COST AND SCHEDULE SUBSYSTEM

Project control uses this subsystem to determine project costs, budgets, schedules, resource utilization, and projections. It determines project status in terms of "Value of Accomplishment," technical progress, and cost expenditures. ("Value of Accomplishment" is a calculated index that establishes a dollar equivalence for technical accomplishment as measured by the number of milestones completed.) Further, it identifies where management action needs to be taken. The subsystem provides many of the financial and schedule reports required internally and by the customer. At any time the file can be remotely interrogated for financial-schedule data.

7.2.2 OPERATIONS ANALYSIS SUBSYSTEM

This subsystem gives project control access to status information contained in the other systems of the Automatic Data Processing Plan. This is a real-time subsystem which provides the Project Control Room with the capability to gather data of particular interest, to ascertain its significance to project performance, and to initiate action based on the analysis of the data. Use of this subsystem is on an "as-needed" basis. It is employed by all levels of management. Critical milestone and action item status are automatically annotated by the subsystem.

7.2.3 CONTRACT/ACTION ITEM SUBSYSTEM

This subsystem provides a means of collecting total project external contact information and action item requirements and status. The subsystem automatically prints out daily action item lists at the responsible operational remote terminal and demands from them current updating of action item status. Project control is made aware of the status of the critical and dormant action items automatically.

7.2.4 FACILITIES SUBSYSTEM

This subsystem provides project control with project level information relative to space requirements, equipment needs, and associated activities.

7.2.5 SUBCONTRACT PROCUREMENT SUBSYSTEM

Subcontract management uses this subsystem to help control subcontractor activity. The information utilized is held in the Cost and Schedule Subsystem and the Contact/Action Item Subsystem as an integral part of the total project status. Subcontract procurement status is extracted from those systems as required. Data on subcontractor costs, schedules, and action items is normally received monthly in the form of punched cards or magnetic tape. However, provisions are made in this subsystem to input data by remote terminals. Both critical subcontractor milestone and action item status are maintained in this manner.

7.2.6 RESOURCE SUPPORT SUBSYSTEM

This subsystem generates administrative support data such as personnel lists, telephone directories, organization charts, and similar items.

7.2.7 PROJECT CONTROL ROOM SUBSYSTEM

The Project Control Room Subsystem provides uniform data for baseline analyses, displays, and reports for direct use by project management, project control, functional management and customer personnel.

Project control personnel are provided with timely and accurate information that is made available through a variety of techniques, including microfilm projectors, automatic graph preparation, and audio-computer response. Cathode-ray tubes and teletype terminals enable project control personnel to have access to computer data banks and to perform analyses, simulations and tradeoff studies, as appropriate.

A summary of the output information of the Project Control Room Subsystem is presented in Figure 7-1.

7.3 TECHNICAL PERFORMANCE MONITORING STUDY

This report presents an approach to provide "monitoring" of technical performance for the Voyager Project.

In the context of this study, "monitoring" is considered to involve analysis by project management of available data to determine:

a. Conformance with established technical requirements

b. Required action to solve indicated problems and prevent potential problems.

Engineering approaches to assure design adequacy and management approaches to assure application of long-life spacecraft project practices are not included within the scope of this study.

The approach recommended for Voyager is to incorporate three essentially complementary viewpoints to establish a realistic Technical Performance Monitoring System.

Table 3-2. Output Information and Documentation, and Project Control System

Subsystem	Output	User	Process Form	Frequency of Issue	Input		Purpose
					Source	By	
Cost and Schedule	Project Level Report (SC008)*	Customer and Project Control	Batch Reporting	Biweekly	Operation Schedules	Project Engineers	To provide status of PERT activities at project level
	Task and Subtask Report (SC010)	Project Control	Batch	Biweekly	Operation	Project	To provide status of PERT at task and subtask level
	Detail Fragnet Status (SC012)	Project Control and Operations	Batch Reporting	Biweekly	Operation Schedules	Project Engineers	To provide status of PERT at component level
	Project Level Schedule (SC002)	Customer and Project Control	Batch Reporting	Biweekly	Operation Schedules	Project Engineers	Network showing key milestones - for planning purposes
	Task and Subtask Schedule (SC004)	Project Control	Batch Reporting	Biweekly	Operation Schedules	Project Engineers	To provide detail of interfaces with customer
	Detail Fragnet Schedule (SC006)	Project Control and Operation	Batch Reporting	Biweekly	Operation Schedules	Project Engineers	To provide details of interrelationship of activities necessary to complete task
	PERT Network graphs	Project Control	Batch Reporting	Biweekly	Operation Schedules	Project Engineers	To provide graphic portrayal of networks at task level
	Resource Profiles	Project Control and Operation	Batch Reporting	Monthly	Resource Estimates	Project Engineers	To provide resource profiles by shoporder, performing organization, resource type
	Staffing Profiles	Project Control and Operation	Batch Reporting	Monthly	Resource Estimates	Project Engineers	To provide smoothed man-load by project, task, and operation
	Applied Time Profiles	Project Control and Operation	Batch Reporting	Monthly	Resource Estimates	Project Engineers	To provide applied time plan by organization and task
	Overtime Profiles	Project Control and Operation	Batch Reporting	Monthly	Resource Estimates	Project Engineers	To provide overtime activity plan by organization and task
	UPAL Forecasts	Project Control and Operation	Batch Reporting	Monthly	Resource Estimates	Project Engineers	To provide forecast of unapplied, potentially applied labor
	Total Manpower Required	Project Control and Operation	Batch Reporting	Monthly	Resource Estimates	Project Engineers	To provide total manpower requirements, including support staff
	Total Resource Utilization	Project Control and Operation	Batch Reporting	Monthly	Resource Estimates	Project Engineers	To provide total resource utilization estimates and predictions
	Shop Order Projection	Project Control and Cost	Batch Reporting	Monthly	Resource Estimates	Project Engineers	Optimized resource plan by shop order - ready to be costed

		Project Funding Instructions (MA002)	Project Control Finance Operation	Batch Reporting	Monthly	Resource Estimates	Project Engineers	To provide funding documentation. and authorization at various levels
		Direct Cost Estimates	Project Control and Cost Estimating	Batch Reporting	Monthly	Resource Estimates	Project Engineers	Report showing labor and material cost estimate by S.O., task, operation and project
		Direct Cost through Overhead Estimates	Project Control and Cost Estimating	Batch Reporting	Monthly	Resource Estimates	Project Engineers	Report which adds overhead adders to direct costs
		Direct Cost through G&A Estimates	Project Control and Cost Estimating	Batch Reporting	Monthly	Resource Estimates	Project Engineers	Report which adds G&A adders to direct costs and overhead
		Cost at completion reports	Project Control and Operation	Batch Reporting	Weekly	Resource Estimates	Project Engineers	To provide estimates of cost at completion by S.O., task, project based on ITD estimates
		Manpower Utilization Reports	Project Control and Operations	Batch Reporting	Weekly	Cost Accumulation	Finance	To show manpower utilization by S.O., organization, task, and project
		Cost Expenditure Reports	Project Control Operations	Batch Reporting	Weekly	Cost Accumulation	Finance	To show cost expenditures at summary and detail level by S.O., organization, test and project
		Contractor Financial Management Report (MF002)	Customer	Batch Reporting	Monthly	Cost Accumulation	Finance	533 Report of Contract Costs
		Project Financial Performance Report (MF005)	Customer-Project Control	Batch Reporting	Monthly	Cost Accumulation	Finance	To provide internal financial performance information
		Manpower Report (MF006)	Customer	Batch Reporting	Monthly	Cost Accumulation	Finance	Utilization reports for customer
		Contract Status Report (PC002)	Project Control Customer	Batch Reporting	Monthly	Cost Accumulation	Finance	Report of contract status showing total funds and CCN status
	Cost and Schedule	Overtime Report (MF003)	Project Control Customer	Batch Reporting	Monthly	Cost Accumulation	Finance	Report of overtime activity by S.O., organization, task and project
		Vouchered Hours Report	Project Control Operations	Batch Reporting	Weekly	Cost Accumulation	Finance	Report of vouchered hours charged by S.O., organization

(MF004)						task and project
Milestone Status Report	Project Control and Cost Estimating	Batch Reporting	Weekly	Project Schedules	Project Engineering and Operation Management	Internal report of status showing planned, actual and revised completion date
Project Level Reports (SC009)	Cost and Project Control	Batch Reporting	Weekly	Project Schedules	Project Engineering and Operation	Report on status of key milestones
Task and Subtask Report (SC011)	Project Control and Operation	Batch Reporting	Weekly	Project Schedules	Project Engineering and Operation Management	Report on task and subtask level milestone status
Work Package and Cost Account Schedule	Operations	Batch Reporting	Biweekly	Project Schedules	Project Engineering and Operation Management	Report on milestone status at S.O. level
Project Level Schedule (SC003)	Customer and Project Control	Batch Reporting	Quarterly	Project Schedules	Project Engineering and Operation Management	Bar chart of key system and interface milestones
Task and Subtask Level Schedules (SC005)	Project Control	Batch Reporting	Biweekly	Project Schedules	Project Engineering and Operation Management	To provide details of customer interface milestones
Work Package and Cost Account Schedule (SC007)	Project Control and Cost Operation	Batch Reporting	Weekly	Project Schedules	Project Engineering and Operation Management	To provide details of internal milestones
Special Schedule Printout (SC014)	Operations	Batch Reporting	Weekly	Project Schedules	Project Engineering and Operation Management	Special purpose schedules, e.g., engineering releases, procurement, tests, etc.
Schedule/Cost Coupling Summary Report (MA022)	Customer and Project Control	Batch Reporting	Monthly	PERT Schedules, Cost Expenditures	Project Engineering and Finance	Summary report at task/subtask level
Schedule/Cost Coupling Report (MA023)	Project Control Operation	Batch Reporting	Weekly	PERT Schedules, Cost Expenditures	Project Engineering and Finance	Internal detail report at work package and cost account levels
Out of Control Report	Project Control Operation	Batch Reporting	Weekly	PERT Schedules, Cost Expenditures	Project Engineering and Finance	Report showing VA calculations which exceed control criteria.

Facilities	GE Furnished Property Status	Project Cost	Batch Reporting	Monthly	Operation Records	Operation Administrator	ing location, condition, person responsible, etc.
	Government Furnished Property Status Report (PC007)	Project Control and Customer	Batch Reporting	Monthly	Operation Records	Operation Administrator	Report on Government Furnished Property showing location, condition, person responsible, etc.
	Space Requirement Report	Project Control	Batch Reporting	Monthly	Operations Records	Operation Administrator	Report showing accumulation of project space requirements
	Equipment Requirement Report	Project Control	Batch Reporting	Monthly	Operation Records	Operation Administrator	Report showing accumulation of project equipment requirements
	Resource Requirement Availability Report (MA020)	Customer and Project Control	Batch Reporting	Monthly	Operation Records	Operation Administrator	Report showing resource requirements versus availability
	Major Facility Schedules	Project Control	Batch Reporting	Monthly	Division Facility Schedule	Facility Management	To integrate major facility schedules based on PERT requirements
Contact/Action Item	Contact Status	Project Control	Remote Inquiry	As required	Operation Records and Schedules	Operation Management and Review Boards	To provide real-time remote access to Contact Status Information
	Priority Action Item List (MA005)	Customer Project Control	Remote Inquiry	As required	Operation Records and Schedules	Operation Management and Review Boards	Lists GE/Customer priority action items
Contact/Action Item	Action Item List (MA006)	Project Control Operation	Remote Inquiry	Weekly	Operation Records and Schedules	Operation Management and Review Boards	To provide details about action items required to meet subtask milestones
	Action Summary (MA021)	Project Control	Remote Inquiry	Weekly	Operation Records and Schedules	Operation Management and Review Boards	Report showing weeks activity-opened, closed, action, person responsible, etc.
	Action Item Tabulation	Operation	Remote Inquiry	Daily	Operation Records and Schedules	Operation Management and Review Boards	To provide daily identification of action items at responsible location
Resource Support	Interdepartment Charge Reports	Project Control Operation	Batch Reporting	Weekly	Accounting	Cost Accounting	Report shows interdepartment charges by organization, responsibilities, and key people
	Organization	Project Control	Batch	Monthly	Project Plan	Project Manage-	To provide internal organization

	Charts and Lists		Reporting			ment	Information
	Personnel Lists	Project Control Operation	Batch Reporting	Monthly	Resource Plan	Project Control	Internal personnel lists by organizations, alpha lists, etc.
	Telephone and Space Directory	Project Control Operation	Batch Reporting	Monthly	Resource Plan	Project Control	Directory of people indicating phone numbers, location, and functional responsibility
Subcontract Procurement	Subcontract/ Vendor Expenditure Analysis Report (PC021)	Project Control and Subcontract Management	Batch Reporting	Monthly	Subcontract Schedule and Expenditure Records	Subcontractor Submittal	To provide financial analysis of subcontractor actual versus estimated costs
	Subcontract Management Summary Reports	Subcontract Management and Project Control	Batch Reporting	Monthly	Subcontract Schedule and Expenditure Records	Subcontractor Submittal	Report of subcontractor activity by subcontractor, task, and organization
	Subcontractor Value of Accomplishment Report	Project Control and Subcontract Management	Batch Reporting	Monthly	Subcontract Schedule and Expenditure Records	Subcontractor Submittal	To show value of accomplishment for subcontractor activity
	Subcontractor Activity Reports	Material Control	Batch Reporting	Monthly	Subcontract Schedule and Expenditure Records	Subcontractor Submittal	To provide efficiency rating for inputs to Material Control System
	Subcontractor Action Items	Subcontractors and Project Control	Batch Reporting	Daily	Subcontractor A/I Status Reports	Subcontractor Submittal	To provide daily identification of subcontractor action item at his location
	Subcontractor Action Summary Reports	Contractor and Subcontractor Management	Batch Reporting	Weekly	Subcontractor A/I Status Reports	Subcontractor Submittal	To provide weekly summaries of subcontractor action item activity
	Subcontractor Summary Report	Subcontractor	Batch Reporting	Monthly	Subcontractor A/I Status Reports	Subcontractor Submittal	Report to subcontractor of his action item activity

*Numbers shown in parentheses in the "Output" column indicate formal documents or key informal data. All other entries are contractor informal data.

Figure 7-1. Project Control from ADP

The viewpoint of technical management, reinforced as required by external experts, is obtained through the Design Review mechanism at discrete points.

The viewpoint of the Cognizant (or Lead) Engineer is obtained through the Technical Adequacy Report at regular (bi-weekly) periods.

The viewpoint of the performing functional organizations is obtained through their regular assessment of technical status by reporting milestones completed (or percent of completion) into a Schedule-Cost Coupling System.

The recommended system, summarized below, is consistent with existing and planned management systems for Voyager, and is composed of three major elements, described in the following paragraphs, which are all utilized throughout the analysis, development, test, and operational phases of the program.

7.3.1 TECHNICAL ADEQUACY SYSTEM

A Technical Adequacy System, which provides for assessment by the cognizant engineer of status and trend with respect to selected system and subsystem parameters would be implemented as follows:

a. By negotiation (between the customer system office and the contractor) critical system and subsystem parameters would be selected for reporting.

b. System and subsystem engineers would determine probabilistic specification or allocation requirements for the selected parameters.

c. System and subsystem engineers would report technical status with respect to these parameters on a standard form at regular (bi-weekly) intervals.

d. Contractor management would analyze these reports and forward them, together with their analysis, to the system office.

A detailed description of this system, including potential subsystems parameters, reporting format, and a statistical technique for status assessment is presented in the report.

7.3.2 DESIGN REVIEW DATA SYSTEM

A Design Review Data System would provide management with information concerning the technical design at discrete time periods. Inasmuch as Design Reviews are a proven technique, further development during this study was concentrated upon the data requirements and data flow associated with these reviews.

The data requirements and flow for major project reviews and typical intermediate-level reviews are presented in the report. Figure 7-2 represents an excerpt from the report showing a portion of the Data Package for the Preliminary design review.

7.3.3 SCHEDULE-COST COUPLING SYSTEM

A Schedule-Cost Coupling System would provide management with real-time assessment of the relation between technical status and schedules and costs.

During the early phase of this study, an analysis was conducted of Schedule/Cost Coupling Systems and their potential application to Voyager. (Schedule/Cost Coupling Systems are techniques for determining "real" overrun/underrun status by comparing actual value of work performed with the planned cost for performing that work.)

Because of the obvious relationship of schedule/cost coupling to technical performance monitoring (technical problems invariably translate into schedule and cost problems) further activity during this study was concentrated upon identifying means to enhance their effectiveness in highlighting technical problems.

As a result of this study, it was determined that the addition of the following features would make a schedule/cost coupling system a more effective technical performance monitoring tool:

a. Direct communication - both input and feedback - between the technical performer and the "system"

b. Selection and highlighting of milestones with technical significance

Preliminary Design Review (PDR) marks the completion of all requirements and performance specifications (Part I of the CEI Specifications)

SE 001	Plan, System Development
SE 002	Plan, Interface Integration
SE 003	Plan, Subsystem Development
SE 004	Plan, Magnetic Cleanliness Control
SE 005	Plan, Electromagnetic Compatibility Control
SE 006	Plan, Cleanliness Control
SE 007	Plan, Mass Properties Control
SE 008	Specification, System Performance/Design Requirements
SE 009	Specification Subsystem Design Requirements
SE 010	Contract End Item (CEI) Detail Specification (Prime Equipment) Part I (Requirements)
SE 015	Specification, Part
SE 016	Specification, Material
SE 017	Specification, Process
SE 019	Document, Interface Control
SE 021	General Engineering Specification, Magnetic Cleanliness
SE 022	General Engineering Specification,Electromagnetic Compatibility
SE 023	General Engineering Specification, Cleanliness
SE 024	General Engineering Specification, Design
SE 026	Specification, Mockups
SE 028	List, Approved Materials
SE 029	List, Approved Parts
SE 030	List, Approved Processes
SE 033	Report, System Analysis, General
SE 034	Report, System Analysis, Trajectories and Orbit
SE 035	Report, System Analysis, Magnetic Characteristics
SE 036	Report, Sequence of Events
SE 037	Report, Trade Studies
SE 038	Report, System Analysis, Reliabilities
SE 042	Report, Thermal Analysis
SE 046	Report, Component Design
SE 047	Report, Subsystem Design
SE 052	Report, Power Profile
SE 056	Drawings (Category A) for Design Evaluation
SE 057	Drawings (Category B) for Interface Control
TE 001	Plan, Integrated Test
TE 024	Minutes, Integrated Test Board
TE 025	Manual, Test Facilities Description and Capabilities
TE 027	Logbook, Test
TE 031	Specification, Special Test Equipment (STE) (System and Subsystem)
TE 046	Report, Cumulative Test Time

(cont'd)

(Excerpt from Technical Performance Monitoring Report)

Figure 7-2. Data Package (Partial List) for Preliminary Design Review (PDR)

c. Summarization by technical craft, e.g., thermal analysis

d. Trend reporting and graphical displays

e. Flexibility to utilize "% Complete" estimates during the development phase.

Addition of these features indicated the desirability of not only computerizing the entire system but providing for direct inputting and readout capability, both tabular and graphic, for technical performers (desk-side computers in a time-sharing mode.)

Coincident with the Voyager-oriented study, both the Re-entry Systems Department (RSD) and the Manned Orbiting Laboratory (MOL) Department concluded that it was desirable to mechanize their schedule/cost coupling systems; consequently a description of the MOL system, which is typical of a Voyager system, was included in the report. Additionally, typical outputs of a real-time system were developed and included.

7.4 PROJECT CONTROL ROOM STUDY

The study as described in the Project Control Room Report identified the key characteristics of a successful project control room. These included the capability of: (1) highlighting the exceptions, (2) identifying the information from which conclusions were drawn, (3) having available the broad-based background information that makes the exceptions understandable and permits the Program Manager to be fully informed, and (4) assessing the impact of changes on meeting the fixed launch data.

To attain these essential characteristics, four major requirements were established:

a. Visibility, which includes the top-down work-breakdown relationship, maintenance of baselines, tie between schedules and costs, action-item tracking, alternate plans, and currency of information.

b. Communicability, which includes use of uniform baselines, mechanisms for communicating baselines, and quick-acting display techniques.

c. Dependability, which includes the requirements for comprehensiveness, information authentication, single-input sources, remote interrogation, and security.

d. Usability, which includes economy, timeliness, operational use, growth, and flexibility to accommodate change.

Within this framework, the Work Breakdown Structure was selected as the primary tool for ensuring the continuity and traceability of project control room data, for the following reasons:

a. The Work Breakdown Structure serves as common basis for structuring the technical plan, estimating costs, establishing schedules and manpower plans.

b. Allocation of resources are correlated to all program effort, across all contract phases, via the Work Breakdown Structure.

c. The Work Breakdown Structure facilitates correlation of schedules with cost, with technical progress as required contractually for reporting, and also provides the basis for future cost estimates.

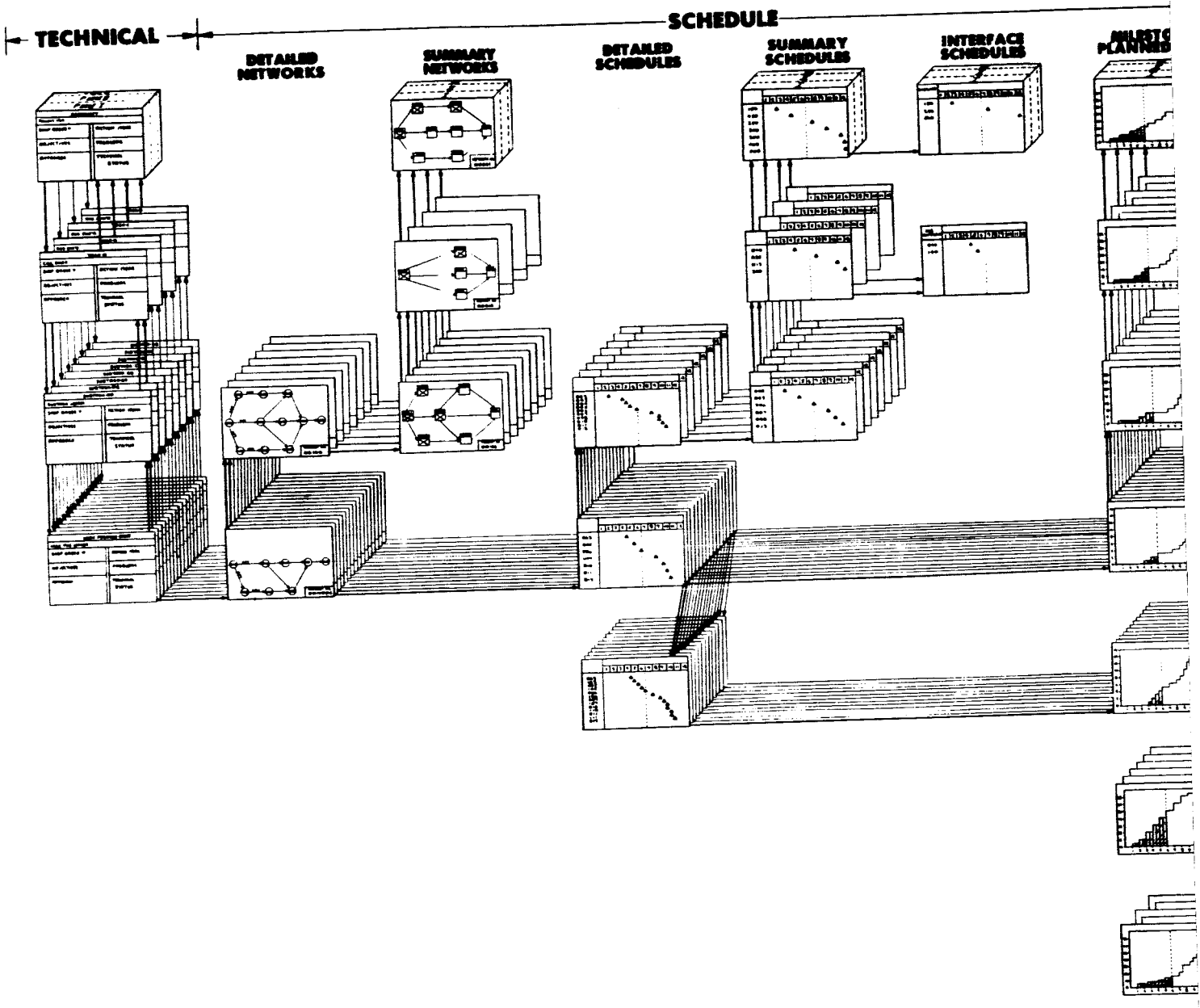
d. The Work Breakdown Structure provides the medium for communicating the coding structure necessary to identify program milestones, PERT network development, interfacing, and correlation with all task levels, and identification of responsibilities within the System Contractors Organization.

e. The Work Breakdown Structure identifies the program level where resources are authorized for expenditure/consumption for the current and near-term program phases (at the bottom-tier work package or standard action) and the higher task levels where remaining resources are allocated in accordance with the total Program Plan.

Data displays were developed from the Work Breakdown Structure utilizing the approach symbolized in Figure 7-3, which identifies the type of plan/status data to be maintained at each level and indicates the data selected for display. This figure also illustrates the interrelationships that exist between the various elements of each type of data, and between the various levels of data.

Directional arrows indicate the interrelationships that exist between the various data. Schedule data may be traced vertically from the detailed work package fragnets and schedules to the project-summary network and milestone schedule or horizontally to the charts which depict milestones met vs.milestones planned.

DATA MATE


TECHNICAL
SCHEDULE
DETAILED NETWORKS
SUMMARY NETWORKS
DETAILED SCHEDULES
SUMMARY SCHEDULES
INTERFACE SCHEDULES

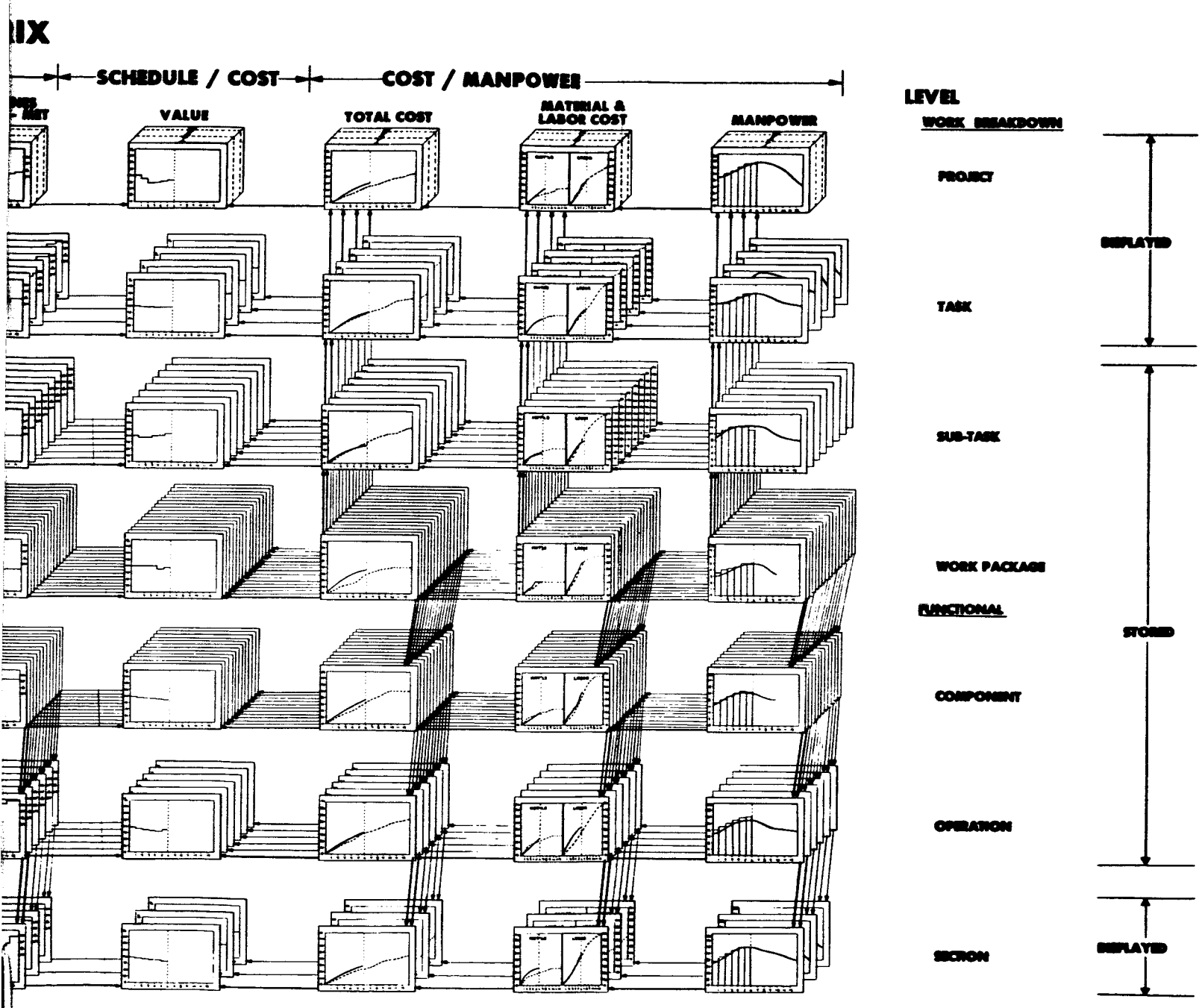


Figure 7-3. Data Matrix

Included in the report are comparative data on representative operating project control rooms, analysis of user requirements, design of the project control room, and sample operating procedures.

Typical display charts for the following types of information are included:

1. Facilities utilization schedules
2. Major hardware utilization schedules

Plan/Status Data

3. Summary networks at subtask, task, and project level
4. Detailed schedules of activities by subtask and functional component
5. Summary schedules at subtask, task, and project level
6. Interface event schedules - customer/contractor; contractor/subcontractor
7. Special event schedules, e.g., all Proof Test Model components complete.
8. Total cost curves by work breakdown level and functional level and by standard action.
9. Labor cost curves by work breakdown level and functional level and by standard action
10. Material cost curves by work breakdown level and functional level and by standard action
11. Total manpower curves by work breakdown level and functional level
12. Categorized manpower curves by work breakdown levels and functional level
13. Technical requirements/status at subtask, task and project levels, unresolved problem lists
14. Detailed networks of special and topical subtask activities.

Measurement Data

1. Value curves by work breakdown level (work package, subtask, and task project) and by functional level (component, operation, section, and department)

2. Planned time versus actual time by activity

3. Planned cost versus actual cost by work package.

Special Data

1. Open action items lists

2. Superseded revisions of all schedule, cost, and manpower plans

3. Work breakdown structure by customer, contractor, and subcontractors

4. Organization interface

5. Overtime control.

SECTION 8

BIBLIOGRAPHY

The following Technical Reports (TR's) and Technical Memos (TM's) were issued during the study:

Report Number	Issue Date	Title/Author
VOY-C4-TR-01	10/31/66	Preliminary Report Number 1 Contractor Data Requirements H. C. Thomas/J. E. Nitsche/A. W. Morris
VOY-C4-TR-01	10/31/66	Preliminary Report Number 1 Appendix 2A - GE Exhibit DRD's (Preliminary) Technical Description and System Engineering (SE) W. E. Johnston/D. D. Rosard/L. T. Seaman/ B. C. Daniels/L. M. Bergere
VOY-C4-TR-01	10/31/66	Preliminary Report Number 1 Appendix 2B - GE Exhibit DRD's (Preliminary) Configuration Management (CM) A. W. Morris
VOY-C4-TR-01	10/31/66	Preliminary Report Number 1 Appendix 2C - GE Exhibit DRD's (Preliminary) Quality Assurance (QA) T. F. Smyth/J. R. Gottshall
VOY-C4-TR-01	10/31/66	Preliminary Report Number 1 Appendix 2D - GE Exhibit DRD's (Preliminary) Reliability Assurance (RA) J. B. Silverwood/K. R. Thomas
VOY-C4-TR-01	10/31/66	Preliminary Report Number 1 Appendix 2E - GE Exhibit DRD's (Preliminary) Partial Sets - 10 Categories Functional Management/Voyager Spacecraft System Project
VOY-C4-TR-01	10/31/66	Preliminary Report Number 1 Appendix 3A - Contractor User Flow Diagrams Engineering D. D. Rosard/C. C. Clark/L. T. Seaman/ K. R. Thomas

Report Number	Issue Date	Title/Author
VOY-C4-TR-01	10/31/66	Preliminary Report Number 1 Appendix 3B - Project Control and Integration C.H. Sells/F.J. Reynolds/F. J. Ginett/ F. W. Pfluger
VOY-C4-TR-02	11/18/66	Microfilm Compendium F. J. Ginett/Information Systems and Computer Centers Section
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VOY-C4-TR-12	4/26/67	Project Control Room Report E. A. Bage/B.R. Boodoian/R.G. Hannye/ C. E. Kohler, Jr./A.J. Rothstein
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