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SPACECRAFT DESIGN DATA INFORMATION SYSTEM
FINAL REPORT

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ASTRO-ELECTRONICS DIVISION
DEFENSE ELECTRONIC PRODUCTS
RADIO CORPORATION OF AMERICA
PRINCETON, NEW JERSEY

AED R-2946

Issued: April 15, 1966

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PREFACE

Under Contract No. 951335 to the Jet Propulsion Laboratory of the California Institute of Technology, the Astro-Electronics Division of RCA has undertaken a study to determine the feasibility of implementing a Spacecraft Design Data Information System (SDDIS) that would serve as a guide and point of departure for defining advanced concepts for future space missions. This Final Report describes the work performed and results obtained in the performance of that contract. Principal authors of this report are Messrs. L. Rosenberg, R. Morton, and R. Morgan.

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SECTION I
INTRODUCTION AND SUMMARY

A. INTRODUCTION

Mission planning and spacecraft design functions can be greatly assisted by considering the experience gained in performing prior spacecraft projects having similar mission goals or profiles. However, the number of spacecraft projects performed to date and the large number of documents describing project and spacecraft performance severely limit the individual's ability to retrieve information pertinent to all projects that may be of interest to him. In fact, in some cases, the individual may not be aware of all projects which are of interest to him. The SDDIS (Spacecraft Design Data Information System) is intended to simplify the individual's access to data on prior programs by summarizing, in a single set of looseleaf binders, design and management information for virtually all of the spacecraft projects performed in the United States. Separate summaries, or "data sheets", would be included for each spacecraft, as well as for each subsystem comprising that spacecraft, thus providing a convenient source of both system and subsystem reference information.

In its largest sense, the SDDIS is intended as a solution to the problems posed by the ever-increasing size of our technical libraries, as it condenses the thousands of documents describing each project into perhaps one hundred pages of pertinent information, preselecting information of interest on the basis of known and anticipated user requirements. Thus, the SDDIS will facilitate reference to specific design and project characteristics and, perhaps more important, will provide an unprecedented capability for conveniently surveying design, performance, and management characteristics of all spacecraft projects. At the very least, the SDDIS will allow the interested user to precisely determine what projects, and what subsystems, are of interest to the mission he is considering.

B. PROJECT OBJECTIVES

The overall objective of the SDDIS is to provide a source of system-level and subsystem-level design data that will serve as a "guide and point of departure for defining advanced concepts for future space missions." The general objective of the effort reported on here was to demonstrate the feasibility of such a system. Specific tasks associated with this study were to:

(1) Define the format and content requirements for an SDDIS;

(2) Define the overall book configuration and methods of indexing;

(3) Accumulate source data for preparing TIROS, Nimbus, and OGO data sheets;

(4) Prepare TIROS, Nimbus, and OGO data sheets as required to prove feasibility of a recommended SDDIS and provide a preprototype of that system;

(5) Accumulate source data for an additional 31 programs* as required to ensure a smooth transition between this (Phase 1) definition and any subsequent (Phase 2) implementation efforts; and

(6) Prepare a development plan detailing costs, schedules, and procedures required to fully define and implement the recommended SDDIS.

All of the major project objectives were attained. Format and content requirements as defined during this study (Task 1) are summarized by the system and subsystem abstracting instructions included as Exhibits A and B of this report. Although some of the effort originally intended for index development was diverted to increase the effort applied to the data collection tasks (3 and 5), indices and book configuration have been defined to the level of detail required to define a workable system. (Gross characteristics of the recommended loose-leaf binders are defined by a sample binder submitted under separate cover.)

Complete data were retrieved from NASA sources for preparing TIROS, Nimbus, and OGO data sheets. TIROS data were abstracted and data sheets prepared as required to refine the format and content requirements; Nimbus data sheets were prepared to the final Phase 1 format and serve as preprototype of the recommended system. (Typical data sheets are included as Exhibits C and D of this report. Complete sets of data sheets are submitted under separate cover.) OGO data were abstracted to the final format. Although some difficulty was experienced in obtaining data required to fulfill the requirements of Task 5, a basic library of data was developed and sufficient data are on hand to provide smooth transition into a Phase 2 effort. Specific procedures for effecting this transition are presented in the SDDIS development plan, submitted under separate cover.

C. GENERAL APPROACH

In order to place in context the efforts performed under this contract, it is important to realize that the basic approach was an iterative one. That is, all procedures relating to data retrieval, format and content definition, etc., were successively refined by actual experience with the prototype programs—first TIROS, then Nimbus, and then OGO. This prevented efforts from being wasted through "making the same mistake twice." This approach was particularly important in the data collection process, for which no adequate precedent existed.

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* Defined in Exhibit A of the Work Statement and as subsequently revised. (See Section II of this report.)

D. SYSTEM SUMMARY

The Spacecraft Design Data Information System (SDDIS) as presently envisioned would consist of some eleven separate looseleaf volumes, each containing a different kind of information. There would be four volumes containing system-level data, with the volumes defined in terms of four general types of spacecraft missions:

- Observatories and Meteorological Missions;
- Lunar and Planetary Probes;
- Communications and Navigational Missions; and
- General Experimental.

A typical volume would contain perhaps 150 pages describing some ten spacecraft programs, at the system level. The manner of presentation would be the same for all system-level data sheets, with a rigidly defined format allowing convenient reference to specific units of data. "Browsing" through this restricted volume of data could be effected quite easily, even though the data are quite literally representative of <u>all</u> systems similar to that being considered. Browsing is, in fact, encouraged by several factors:

(1) As the volumes are organized functionally, all of the data presented are (presumably) pertinent to the user's field of interest.

(2) The graphic quality of the data sheets will be high, and the number of pages limited.

(3) The consistency of format, style, and manner of presentation increases the effective intelligibility — and reading effectiveness will increase with use.

Subsystem data will also be organized functionally, and will be presented in seven volumes representative of the basic types of subsystems considered generally applicable to all spacecraft:

- Power;
- Data Transmission and Reception;
- Guidance, Propulsion, and Stabilization;
- Command, Control, and Telemetry;
- Structure and Thermal Control;

- Optical and Infrared Imaging*; and
- Experiments, General.

Although the ability to browse through the SDDIS volumes may prove to be an important benefit, it is obviously not the primary purpose of the SDDIS. The important capability provided is that for responding to specific data requirements — whether for performance parameters or for information regarding "management approach." Such information are useful not only in their own right; the tabulation of data for all programs may provide "trend" information that will suggest correlations useful in planning advanced missions. Perhaps the most single aspect of the system is that it is virtually unprecedented, and the assemblage of such an accumulation of data may provide new insights into old information. Just as the system concept must be refined as data are actually introduced into the system, so must the system functions be refined through use. And, for systems of this type, the serendipitous capabilities, in time, often prove more important than those the system was designed to provide.

E. ORGANIZATION OF THIS REPORT

Sections II through V of this report outline the efforts performed on each of the major project tasks:

II. Development of Data Sources;

III. Development of the SDDIS Book Format and Indexing System;

IV. Preparation of TIROS, Nimbus, and OGO Data Sheets;

V. System Development.

Conclusions and Recommendations are presented in Section VI and are further amplified by the project development plan, submitted under separate cover.

The output of the project is further defined by the exhibits to this report, which contain sample formats for system and subsystem data sheets, as well as actual data sheets prepared for the Nimbus Program. (All data sheets prepared for the SDDIS project are included in a separate supplement to this report.)

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* Although the optical and infrared imaging subsystems are really considered as "experiments" (i.e., not fundamental to the spacecraft design) the relative importance of such subsystems, and the large number of subsystems already developed, suggests interest and importance sufficient to warrant a separate volume.

SECTION II
DEVELOPMENT OF DATA SOURCES

It was the original intent of the project to perform the data collection effort in four steps:

(1) Obtain bibliographies listing all reports issued for each project of interest;

(2) Review bibliography entries to assess the potential utility of each document;

(3) Select and procure the requisite documents; and

(4) Verify the sufficiency of the documents obtained.

The first three steps were to be performed for all programs to be included in the SDDIS (see Table 2-1); the fourth step, verifying sufficiency of the documents obtained, was to be performed only for the TIROS, Nimbus, and OGO Projects. However, as the project progressed, it became obvious that bibliographies obtained from such central information agencies as STIF were grossly lacking in the sources required for the abstraction of design data. Thus, the nature of the data-collection effort changed from simply requesting specific documents from government and industrial sources to personally visiting and hand-selecting documents from among those available at the various agencies.

A. OBTAINING BIBLIOGRAPHIES

At the start of the project, it appeared that the requisite source data would be available through NASA STIF (Scientific and Technical Information Facility) for NASA Programs and through the DDC (Defense Documentation Center) for DOD Programs. Thus, the first step in the data collection process involved ordering bibliographies (machine searches) from STIF for the three prototype projects—TIROS, Nimbus, and OGO.

The cognizant NASA agencies were simultaneously interrogated, either to cross-check information to be supplied by STIF, or to serve as sources of the basic bibliographies. However, it became apparent that neither STIF nor the cognizant agencies could supply such data. STIF bibliographies, both by project name and by contract number, consisted primarily of references to journal articles and other information in the public domain. Very few of the significant technical reports appeared in the STIF bibliographies. Even for TIROS, a project that started six years ago, the significant reports, such as final technical reports and flight evaluation reports, were not yet in STIF. Letter requests to cognizant agencies produced return letters referring the inquiries to STIF. Telephone follow-ups of the letters yielded no additional information, and it appeared that, for the most part, even the individual project offices within NASA do not have comprehensive bibliographies of the required reports.

TABLE 2-1. PROGRAMS SELECTED FOR INCLUSION IN SDDIS

SDDIS Library Catalog Code	Project	SDDIS Library Catalog Code	Project
10	TIROS	34	Early Bird
11	Nimbus	35	OAO
12	OGO	36	BIOS
20	GEOS	37	Surveyor
21	SERT 1	38	ATS
22	Explorer (IMP 1, 2)	39	Transit
23	Mariner 1, 2, 3, 4	40	LOPC (Lunar Orbiter)
24	NUDETS	41	ASSET
25	Ranger 6, 7, 8, 9	42	RAO
26	Pegasus 1, 2	43	SATAR
27	Relay 1	44	Scanner
28	SYNCOM 1, 2, 3	45	MILCOM
29	Telstar 1, 2	46	TRS
30	OSO 1, 2	47	SMS
31	Pioneer 1	48	COMSAT
32	IMP 3	49	NOMSS
33	SECOR 2, 3	50	Apollo (subsystems)

B. DEVELOPMENT OF A DATA COLLECTION PROCEDURE

As soon as it became apparent that bibliographies were not available for the projects of interest, emphasis shifted to developing an alternate method of data collection. The only reasonable alternative involved personal contacts at the project office. To this end, RCA representatives visted the TIROS, Nimbus, and OGO project offices at NASA Headquarters and at NASA/GSFC. The result was most encouraging. In contrast to the lack of response to letter and telephone communications, all parties contacted actively supported the project efforts and complete data were subsequently retrieved. Data retrieval was particularly simple for TIROS and Nimbus, as there were central project libraries established within GSFC. However, there was no such library established for OGO at GSFC and, although OGO personnel were cooperative, the bulk of the technical information was simply not available at the headquarters and GSFC locations. Therefore, the OGO Project Office referred the problem to the NASA officer at TRW, the OGO prime contractor. As travel to TRW was not authorized under the contract, RCA personnel reviewed TRW monthly progress reports to obtain a condensed bibliography of technical documents, and then requested specific documents from the NASA officer at TRW. The data retrieval effort was subsequently completed by a JPL representative, who visited TRW to pick up the documents selected.

On the basis of TIROS, Nimbus, and OGO experience, a detailed data-collection procedure was developed. Basically, this procedure involves three phases: (1) initial requests of STIF (or DDC), letter and telephone requests to Public Information Officers at agencies and contractors, and letter and telephone requests to headquarters and agency project offices; (2) personal visits to headquarters project offices, agency project offices, and in some cases, contractor facilities; and (3) follow-up visits to government facilities for re-retrieval of information. (See Figure 2-1.) Only the first of these efforts was fully authorized under the Phase 1 contract; however, available project funds were diverted as far as possible to support the second to the level required to ensure a smooth transition between Phase 1 and Phase 2. The third step was performed only for Nimbus, as it did not appear necessary for TIROS, and there was not sufficient time to evaluate the OGO data and consider re-retrieval of information.

- PRE-CONTRACT ASSURANCES FROM NASA/STIF
- STIF INTERROGATIONS
- REVIEW STIF BIBLIOGRAPHIES
- INTERROGATIONS OF PUBLIC INFORMATION OFFICERS
- QUERY NASA HEADQUARTERS AND AGENCY LIBRARIES
- REQUEST STIF DOCUMENTS
- PMO INTERROGATIONS AT HEADQUARTERS
- PMO INTERROGATIONS AT AGENCIES
- PERSONAL VISITS TO STIF
- PERSONAL VISITS TO HEADQUARTERS
- JPL/HEADQUARTERS AUTHORIZATIONS
- PERSONAL VISITS TO AGENCIES

Nimbus and TIROS only:
- DATA ABSTRACTION
- RE-RETRIEVE FROM AGENCIES

Figure 2-1. Phases of the Data Collection Task as Performed During the Phase 1 Effort

A detailed summary of the data collection steps performed during Phase 1 is presented in Table 2-2*.

C. TYPES OF DOCUMENTS REQUESTED

As the project progressed, it became possible to categorize the types of documents that are of interest to the SDDIS effort. Thus, specific requests to the project offices were made for the documents of the types listed in Table 2-3.

D. STATUS OF THE DATA-COLLECTION EFFORT

As shown in Figure 2-2, the first phase of the data-collection process was performed for effectively all of the programs noted in Table 2-1, and personal visits have been made to several of the project offices, particularly at NASA Headquarters. Where personal contacts were made, the individuals contacted have been most cooperative in all cases except one. However, even for the one exception, there is no reason to expect that the difficulty is insurmountable. (In fact, the primary objection offered in this one instance was not to the nature of the SDDIS; rather, the individual contacted was reluctant to offer information which he felt would soon be generally available (June 1966) in NASA-issued reports.)

The status of the data-collection task as it relates to the primary purpose of the Phase 1 effort, ensuring a smooth transition between the Phase 1 and Phase 2 efforts is summarized in Table 2-4. This figure lists the programs for which "complete" documentation has been collected, where complete (100-percent) collection is defined as collection to a level such that preparation of data sheets can be started immediately and not seriously delayed because of missing data. (Collection of complete documentation is considered to be required for only 10 programs, as the work statement requires that Phase 2 efforts be considered in terms of 10-program lots.)

E. GENERAL RESULTS OF THE DATA-COLLECTION TASK

In the course of Phase 1 of the SDDIS Project, several significant conclusions were made affecting the nature of the data-collection effort. These are outlined in the following.

1. Development of Requisite Data Sources

As stated previously, collection of 30 document types was attempted for each program to be included in the SDDIS. Based on the results of data-sheet preparation for the three initial programs (TIROS, NIMBUS, OGO), 10 document types have been

*Typical letters sent as part of the data-collection effort are shown in Exhibit F of this report.

TABLE 2-2. SUMMARY OF DATA-COLLECTION STEPS

A. NASA PROGRAMS

Item	TIROS	Nimbus	OGO	GEOS	SERT	IMP	Mariner	Ranger	Pegasus	Relay	SYNCOM
1. Interrogate STIF-Project Name	X	X	X	X	X	X	X	X	X	X	X
2. Interrogate STIF-Contact Nos.	X	X	X	X	X	X	X	X	X	X	X
3. Evaluate Bibs (1 & 2)	X	X	X	X	X	X	X	X	X	X	X
4. Order Documents from STIF	X	X	X	X	X	X	X	X	X	X	X
5. Interrogate Contractor PIO	X	X	X	X	X	X	X	X	X	X	X
6. Interrogate Agency PIO	X	X	X	None	X	X	X	X	X	X	X
7. HQ Library and Routine (Incl. PIO)	X	X	X	X	X	X			X	X	X
8. RCA Letter to HQ Prog. Mgr.			X	X	X	X	JPL	JPL	X	X	X
9. RCA Letter to Agency Prog. Mgr.			X	None	X	X	JPL	JPL	X	X	X
10. Follow-up Telcons where Useful	X	X	X	X	X				X	X	X
11. Personal contacts at HQ Level	X	X	X	X	X	X			X	X	X
12. Personal Contacts at Agency Level	X	X	X	None	X	X			X	X	X
13. Request PDP from JPL	X	X	X	X	X	X	X	X	X	X	X

TABLE 2-2. SUMMARY OF DATA-COLLECTION STEPS (Continued)

A. NASA PROGRAMS

Item	Telstar	OSO	Pioneer	LO	Early Bird	OAO	BIOS	Surveyor	ATS	(RAE) RAO	Scanner
1. Interrogate STIF-Project Name	X	X	X	X	X	X	X	X	X	X	X
2. Interrogate STIF-Contact Nos.	X	X	X	X	X	X	X	X	X	X	X
3. Evaluate Bibs (1 & 2)	X	X	X	X	X	X	X	X	X	X	X
4. Order Documents from STIF	X	X	X	X	X	X	X	X	X	X	X
5. Interrogate Contractor PIO	X	X	X	X	X	X	X	X	X	X	X
6. Interrogate Agency PIO	X	X	X	X	X	X	X	X	X	X	X
7. HQ Library & Routine (Incl. PIO)	X	X	X	X							
8. RCA Letter to HQ Prog. Mgr.	X	X	X	X	X	X	X	X	X	X	X
9. RCA Letter to Agency Prog. Mgr.	X + Bell Labs	X	X	X	X	X	X	X	X	X	X
10. Follow-up Telcons where Useful	X	X	X	X							
11. Personal contacts at HQ Level	X	X	X	X							
12. Personal Contacts at Agency Level	X	X	X	X							
13. Request PDP from JPL	N/A	X	X	X	N/A	X	X	X	X	X	X

TABLE 2-2. SUMMARY OF DATA-COLLECTION STEPS (Continued)

A. NASA PROGRAMS

Item	SMS	COMSAT	NOMSS	Apollo
1. Interrogate STIF-Project Name	X	X	X	X
2. Interrogate STIF-Contact Nos.	X	X	None	X
3. Evaluate Bibs (1 & 2)	X			
4. Order Documents from STIF	X			
5. Interrogate Contractor PIO	X	X	N/A	X
6. Interrogate Agency PIO	X	X		X
7. HQ Library and Routine (Incl. PIO)	X			
8. RCA Letter to HQ Prog. Mgr.		X		X
9. RCA Letter to Agency Prog. Mgr.		X		X
10. Follow-up Telcons where Useful				
11. Personal contacts at HQ Level				
12. Personal Contacts at Agency Level	L			
13. Request PDP from JPL	X	N/A	X	X

TABLE 2-2. SUMMARY OF DATA-COLLECTION STEPS (Continued)

B. DOD PROGRAMS

Item	NUDETS	SECOR	Transit	ASSET	SATAR	MILCOM	TRS
1. Interrogate DDC-Project Name	X	X	X	X	X	X	X
2. Interrogate DDC-Contact Nos.							
3. Evaluate Bibs (1 & 2)	X						
4. Order Documents from DDC	X						
5. Interrogate Contractor PIO	X	X	X	X	X		X
6. Interrogate Agency PIO	X	X	X	X	X		X
7. Library and Routine (Incl. PIO)	X						
8. RCA Letter to HQ Prog. Mgr.	X	X	X	X	X	X	X
9. RCA Letter to Agency Prog. Mgr.	X	X	X	X	X	X	X
10. Follow-up Telcons where Useful	X						
11. Personal contacts at HQ Level							
12. Personal Contacts at Agency Level	X						

TABLE 2-3. TYPES OF DOCUMENTS FOR WHICH INITIAL DATA COLLECTION WAS ATTEMPTED

SDDIS Library Reference No.	Document	SDDIS Library Reference No.	Document
1	Final Reports	17	Work Statement
2	Design Study Reports	18	Proposals
3	Interim Reports	19	Contractor Brochures
4	Quarterly Progress Reports	20	News Releases
5	Flight Evaluation Reports	21	Papers, Speeches, etc. (STIF and DDC)
6	Instruction Manuals	22	Specifications
7	Program Plans (Contractor)	23	Mission Return/Performance Summaries
8	Test Plans (Contractor)	24	New Technology Item Reports
9	Reliability Program Plans	25	Management (General) Reports
10	Monthly Reports	26	Technical (General) Reports
11	NASA Technical Notes or Memorandums	27	Funding and Cost Data
12	Reliability Analysis	28	NASA Operations Plans
13	Test Reports	29	NASA Program Plans
14	NASA Mission Plans	30	Project Development Plan (PDP)
15	Failure Summaries		
16	Special Technical Reports		

identified as providing the bulk of information required to satisfactorily complete the entries of the system-and subsystem-level data-sheet formats. The documents listed below therefore constitute the primary data sources for the SDDIS.

- Flight-Evaluation Reports (NASA and/or contractor generated).
- Final Technical Reports (as issued by NASA, the prime contractor, and each major subcontractor).
- NASA - issued work statements (system and subsystem and/or component levels).

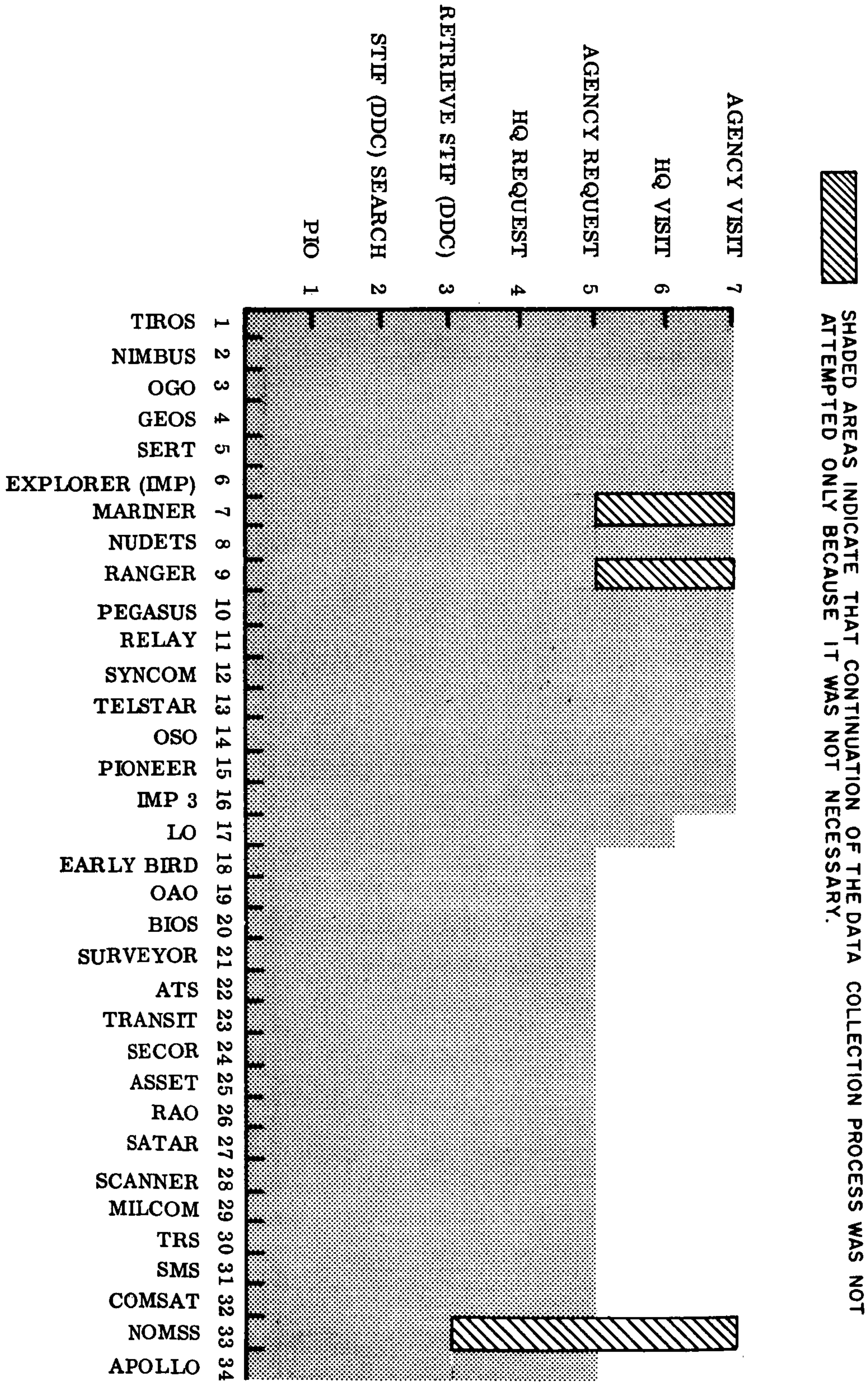


Figure 2-2. Status of the Data-Retrieval Effort for All Programs

TABLE 2-4. IDENTIFICATION OF PRIMARY DATA SOURCES ON PROGRAMS FOR WHICH "COMPLETE" DOCUMENTATION HAS BEEN COLLECTED

Project	Primary Source
TIROS	HQ and GSFC
OGO	NASA Office at Contractor Facility
NIMBUS	GSFC
GEOS	HQ and NASA Office at Contractor Facility
SERT	LeRC
EXPLORER/IMP	NASA HQ
MARINER	JPL
NUDETS (Vela Hotel)	AFSSD
RANGER	JPL
PEGASUS	Marshall Space Flight Center
RELAY	HQ and GSFC
SYNCOM	HQ and GSFC
TELSTAR	BTL/GSFC
OSO	GSFC
PIONEER	HQ and Ames

- Design Specifications at the (System and Subsystem levels).

- NASA and/or contractor technical notes describing system and subsystem design characteristics.

- NASA Mission and Project Development Plans.

- Handbooks of maintenance instructions.

- System Reliability Assessments

- Contractor program planning documents describing initial design considerations.

- NASA-issued press kits.

2. Data-Collection Procedure

During the course of Phase I, the procedure outlined in Paragraph B of this section was developed and performed (see Table 2-2). Based on evaluation of the results obtained from each step of that procedure, several conclusions were reached and are outlined below.

a. Interrogation of Central Information Agencies, Agency PIO, and Contractor PIO.

A great deal of effort was expended in attempting to retrieve requisite information from the central information agency of NASA, the Scientific and Technical Information Facility (STIF). Machine searches were performed by that organization on all programs included in the SDDIS, both by "subject title" and by contract numbers. Review of the bibliographies obtained were disappointing in that the majority of the entries were magazine or journal articles, or were documents so detailed in scope that they could not be considered as sources of design data. The absence of primary data sources such as final technical reports, flight evaluation reports, etc. was conspicuous. (The only exception to this was the retrieval of final reports for Telstar 1, TIROS I, and Relay 1.) STIF was, however, a source of selected NASA-issued technical notes and press kits, but overall, this facility cannot be considered a primary source of design data. Discussion of this situation with STIF personnel indicated that the problem lies in the fact that documentation must be submitted to them by the project offices in order to be included in their system, and such submittals are rarely complete.

Likewise, neither the NASA agency PIO nor the contractor PIO can be considered primary sources of design data. No real evaluation can be made of the NASA agency PIO's, since not one reply was received from these sources. Contractor PIO's proved more cooperative and provided press-release-type information useful as supplementary data and to provide "context."

b. Interrogation of Headquarters and Agency Project Offices.

The only valid sources of design information for the programs included in the SDDIS are project offices at the responsible agencies. There are, however, certain prerequisites for employing the technical agencies as sources of design data for the SDDIS. These are to enlist complete the cooperation of the Program Manager at NASA Headquarters and the Project Manager at the Agency. Such cooperation can be achieved only through personal contact. These individuals must be convinced of the usefulness of the SDDIS Project and written or telephone requests for information are not sufficient to accomplish this. In some cases, additional proof of authorization must be provided to these individuals by JPL or NASA Headquarters. (The routine delays encountered in obtaining such authorizations during Phase 1 made the enlisting of program and project cooperation a major effort rather than a routine task.)

The next step in the data collection effort is to gain access to the project library or filing system. Some programs do employ a project librarian or documentation coordinator; however, in most cases, program documentation is located in an individual's filing cabinet or desk. In the instances where project libraries are maintained, the retrieval of data is a simple procedure, provided duplicate copies of documents can be made available. The retrieval of data at later dates is also made easier.

In the cases where no project library exists, which seems to be the normal occurrence, retrieval of information is much more difficult. Assistance of project personnel is required on a larger scale, which should be avoided, and the availability of excess documents is greatly reduced. Also, in such cases, re-retrieval of information is more difficult and relies upon further cooperation of individual project members. (Although such cooperation does appear to be generally available, a concerted attempt must be made to limit demands upon the time of NASA personnel.)

A unique problem exists where a program has been completed and the agency project office has been disbanded (e.g., Syncom, Relay). In this case, permission must be obtained to release documentation from "dead storage", or documentation can be retrieved from the personal files of individuals previously associated with the program. Although gross system-level data may be available through STIF for such completed programs, the information demands of the SDDIS are generally well beyond those available from STIF. Thus, it is important to collect data on completed programs within a fairly short time after completion, as the quantity of subsystem information in such personal files rather obviously decreases with time.

c. Availability of Documentation

The one limiting factor to the SDDIS data-collection task was documentation availability, whether because of: (1) actual non-existence of, or less-than-ample documentation, or (2) hesitancy to release "project proprietary" information.

A second problem relating to "documentation availability" can be traced to three causes: (1) inadequate documentation requirements, (2) poor reporting techniques, and (3) project-schedule-imposed documentation lag. The most serious of these is "inadequate documentation requirements". By this it is meant that specific types of formal documentation are never generated on a program. For instance, flight evaluation or final technical reports on the system or subsystem level are not required. This problem occurs most frequently in NASA "in-house" projects. The second problem, "poor reporting techniques," means that the documentation submitted to the project is either "unreduced data" (such as a test report consisting of only the test procedure and completed data sheets) or data that are too greatly concentrated on one level (that is, all system-level or all subsystem-level reporting).

On some programs, concern with the schedule for future launches or with immediate design problems has resulted in documentation on previous spacecraft models taking on secondary importance. This problem often results in some documents never being formally published, and therefore not released as valid design data sources.

In cases where documents requested are non-existent, or the program has undertaken a very limited documentation effort, the only recourse is to collect information in greater detail than that actually required. Effectively all of the information required for the SDDIS must be available in some form, or the spacecraft could not have been built. Experiences to date suggest that the greatest level of "over-collection" required would be to acquire design and/or model specifications.

In the instances where project offices have hesitated or refused to provide certain documents, it has been because such documents are "for NASA Use Only". Varying with viewpoint of the project manager, documents such as Project Development Plans, design review reports, and even NASA-issued work statements have been classified as "project proprietary" information and would not be made available. Universally, requests for program cost data of any nature were refused on this basis.

Although it is almost certain that all of the requisite design information, including work statements and project development plans, would be made available with additional authorization from JPL and/or NASA headquarters, it is very doubtful that detailed cost information will ever be released directly to an industrial contractor.

F. DOD PROGRAMS

Although there has been much speculation as to probable difficulties in obtaining requisite information for programs developed under DOD direction, it now appears that the procedure used to collect NASA data is in all respects applicable to DOD. That is, for the one DOD program for which personal contacts were attempted (Nudets, or the Vela Satellite Program), complete data were obtained after (1) obtaining a headquarters (ARPA) authorization and (2) personally visiting the project office at the cognizant agency (AFSSD). However, a military "need to know" should be established so that secret documents can be obtained. Access to classified data is required because in some cases even the unclassified design information is contained only in classified source documents. Implicitly, then, a deviation in procedure will be required - that is, military agencies should be allowed to review data sheets prior to release in order to ensure that security has not been compromised.

It should also be noted that if the Vela Satellite Program is at all typical of military programs, effectively all of the format requirements can be met without violating security requirements. Discussions with the Vela Project Office revealed that the one item of information to which they could not respond because of security requirements was that of "advanced concepts." And, for the purposes of the SDDIS Project, a sufficient statement for this format entry could be developed from statements in the public domain.

G. SUMMARY

The data-collection effort of Phase 1 has resulted in the establishment of requisite data sources for satisfying the data-abstraction task, and in the development of a workable procedure for collecting the requisite sources.

The primary data sources are the types of documents listed earlier. These documents should provide all the information required to complete the data-sheet formats on the system and subsystem levels. However, the wide variation of scope provided, even in these documents, may require further data collection after preparation of data sheets has been started.

The recommended procedure for collecting data sources for the SDDIS is as follows:

(1) Interrogate NASA STIF and contractor PIO for "supplementary" information;

(2) Issue letter of authorization to responsible Program Manager and Project Manager;

(3) Personal contact with the Program and Project Managers;

(4) Review project-office library at agency for the 10 selected types of documents;

(5) Evaluate the documents obtained for scope of information;

(6) Re-retrieve specific additional documents required to satisfy any data requirements found lacking.

None of the above steps can be considered as routine. The personalities of the individuals contacted plays a role in the degree of assistance that will be provided, and problems relating to variations in the project approach to library maintenance, variations in types of documents generated, and the paucity of data available from discontinued project offices, must be solved on an "as encountered" basis.

SECTION III

DEVELOPMENT OF THE SDDIS BOOK FORMAT AND INDEXING SYSTEM

Phase 1 activity related to SDDIS book format and indexing development was divided into three levels of effort: First, in order to establish a direction for all developmental activity, an "Ultimate" system was defined, based on the concept of maximum user utility. Second, to provide a basis for evaluative critique and future activity, a "Baseline" system was defined, based on the requirements of the Phase 1 Statement of Work and JPL Guideline Document No. 1. And third, to provide a smooth transition between Phase 1 and Phase 2, a "Recommended" system was defined, which is a logical extension of the Baseline system in the direction of the Ultimate system and which is reasonably achievable within the presumed scope of the Phase 2 effort.

The material in this section is organized to reflect this three-level effort. The Ultimate system is described first, with emphasis on the logical interconnections of its constituent parts. Discussions of the Baseline and Recommended systems are then presented in order as specific outputs of the Phase 1 effort.

A. THE ULTIMATE SYSTEM – MAXIMUM USER UTILITY

The primary requirement of a data storage and retrieval system -- whether wholly manual, partially automated, or fully automated -- is Maximum User Utility. This requirement must serve as a continuing goal through all stages of system development. In terms of the SDDIS, the approach to maximum user utility involves four basic elements:

(1) The definition of a large number of storage categories, optimally selected, and each representing a "unit (minimum) information bit;"

(2) The development of a large system vocabulary, including a comprehensive set of common-usage synonyms for all index and retrieval parameters;

(3) The development of a detailed subject index, which is cross-indexed by synonyms and related subjects; and

(4) The development of an effective procedure for updating and revising each of the first three elements, above, as new programs and data are added to the system.

The goal of maximum user utility implicitly (and deliberately) ignores the practical aspects of its achievement. In point of fact (as will be seen), the scope of the ideal system and the basically iterative nature of system development are such that, at any stage of system development, there will always be room for a measure of improvement. Thus, in defining and describing the elements of the ideal system in the following paragraphs, the objective is more to establish a direction for developmental activity than to define a final product.

1. Selection of Storage Categories

The selection of an optimum set of information storage categories (or, what is the same thing, the definition of optimum data-sheet formats) provides four highly desirable results:

(1) It ensures the inclusion in the data sheets of all appropriate and significant data relative to all systems and subsystems.

(2) Through the establishment of firm formats, it facilitates cross-checking between data sheets for comparison of data.

(3) It minimizes the necessity for the data-sheet compilers to make qualitative judgments and interpolations in the abstraction of data from source documents.

(4) It largely defines the basic retrieval parameters of a subject index, exclusive of cross-indexing (by synonyms and related subjects).

To achieve these results, the governing ground rules which must be brought to bear on format and category selection are:

(1) The scope (number and type) of categories must be adequate to meet the needs of all spacecraft systems and subsystems considered for inclusion in the SDDIS.

(2) Each category must be carefully selected and defined for the most concise presentation of the required information.

(3) To the maximum possible extent, the requirements of each category must be defined and phrased to minimize the need for subjective evaluation and personal knowledge on the part of the data-sheet compiler.

The level of detail to be covered by the data sheets is a decision of critical importance. Whether the present concept of system and subsystem data sheets is optimum can be verified only by "field" use of the resulting data sheets. The question must be considered as still open.

2. Vocabulary Development

For the sake of consistency among all system and subsystem data sheets, it was considered advisable early in the development of the data-sheet formats to identify a unique set of subsystems (see Glossary of Terms, Exhibit C). The purposes of this unique subsystem "vocabulary" are (1) to assist data-sheet abstractors and compilers in identifying the constituent assemblies, components, functions, etc., peculiar to (and sometimes peculiarly identified by) each project and spacecraft system, and (2) to establish a basis for comparison by SDDIS users of parallel information categories among functionally similar equipments associated with two or more systems. On this basis, at least, once the user is "in" the system -- i.e., once he has located the information categories in the system and subsystem data sheets of interest to him -- he is helped in making comparative evaluations among the data that he finds.

But getting the user into the system is an altogether different problem. Here, the problem is one of bridging the gap between the "language" of the user and the "language" of the system. In the general case, the language of the user is apt to be highly variable; and to the extent that he is compelled to mentally re-phrase his questions to conform to a restricted system vocabulary, he is hindered in locating precisely what it is he is looking for. Moreover, in absence of personal assistance (or other means of instruction) from someone intimately familiar with the format and restricted vocabulary of the system he is likely to have difficulty in finding all that relates to his problem.

Thus, it is essential, if an approach is to be made toward maximizing user utility, that a useful, flexible system vocabulary be developed, which incorporates all common synonyms and near-synonyms for the subjects covered in the data sheets. As a correlary to such a vocabulary, and a preliminary step toward developing a cross-index, a technique must be established for combining related terms into subordinate, superior, and related classes. (For example, information regarding spacecraft television equipments should be cross-indexed by television electronics, cameras, optics, and sensors, and possibly also by equipments concerned with the transmission and reception of analog and digital television signals. The user-oriented index would direct the user to one or more of these related subject areas whenever he searched by any one of them.)

Just as the development of an optimum format must of necessity be an iterative process, so is the development of a comprehensive vocabulary necessarily iterative. But whereas synonym-identification is largely a straight-forward problem in memory and literature searching, the classification of related subjects may be approached at least quasi-systematically by establishing tables of superior, subordinate, and related terms and subjects relative to a given term.

3. Indexing and Cross-Indexing

Having defined what is to be retrieved (information categories) and the key words to identify the subject matter of the data sheets (system vocabulary), the technique of indexing and cross-indexing must be selected and implemented. Neither of the two most common indexing techniques -- (1) that used by most text books and encyclopedias, based on a single key word, modified to one indenture, perhaps, by an adjectivial word or phrase, and (2) some variation of the KWIC (Key Word in Context) program, which is used to index document titles and cross-index them by each significant word in the title -- neither of these two common indexing techniques was adaptable to the SDDIS needs. Both techniques are suitable for indexing only documents which can be uniquely defined by a word, a phrase, or a title which can be restricted to a two-indenture format (major and minor sort).

Because of the rigid format of the SDDIS data sheets (established to facilitate comparison of data between systems and subsystems), each system and subsystem data sheet is made up of entries which can be uniquely identified only by multiple-indenture titles. Moreover, the arbitrary user will approach the index randomly with respect to the ordering (in his own mind) of the indentures. Thus, for maximum user utility, it is not practical to rigidly fix the members of the major and (several) minor sort categories, but rather provisions should be made to allow "desirable" permutations among the major and minor sorts. This, in fact, is the basis for primary cross-indexing in the recommended system.

A practical example may serve to illuminate some of the problems. Assume a user approaching the SDDIS desiring information regarding the performance parameters of television systems flown on earth-orbiting spacecraft and used primarily for meteorological observation. Reducing his question to its logical parts, he recognizes that it relates simultaneously to all of the following possible search categories: (1) Earth-Orbiting Spacecraft, (2) Meteorological Observation Missions, (3) Television Equipments (Subsystems), and (4) Performance Parameters. Moreover, from the basic intent of the SDDIS (i.e., that it is to be used by and for the benefit of engineers and planners in the space industry), it may be assumed that the user already has some knowledge of the subject which he is searching. Thus, an additional search category that may occur to him is the Project Names of current and past spacecraft systems known by him to be describable by one or more of the four general search categories defined above. Such reasoning as this would prompt the user to search the index for some combinatory entry that would contain as many of the logical constituents of his question as possible, so as to direct him as quickly as possible to the desired performance parameters of all television subsystems flown aboard all earth-orbiting spacecraft whose primary missions have been meteorological observation. The ideal index entry in this case would be:

"Earth-Orbiter, Meteorological Observation, Television Subsystem, Performance Parameters, TIROS I (location)

TIROS II (location)

⋮

TIROS XII (location)

Nimbus I (location)

etc. (location)"

or some permutation thereof. This is an example of a multiple-indenture index. A cross-index entry of the above (primary) entry might be:

> "Television Subsystem, Earth-Orbiter, Meteorological Observation, Performance Parameters, TIROS I (location), etc."

Note that each of the five "identifiers" contained in this typical entry can be categorized in a definable sub-set. Thus, "Earth Orbiter" is classed as a member of the category: "Flight Category." This category would also include such other members as "Lunar Orbiter," "Planetary Probe," "Lunar Hard-Lander," etc. In the same way, the other four members of the typical index entry can be defined as members of classes of index entries. Exhibit G presents a preliminary set of index and search parameters for the SDDIS arranged in such sub-sets.

The typical index entry shown above is an example of a 5-indenture entry. This would probably be the maximum required in the SDDIS. There would also be a variety of 1-, 2-, 3-, and 4-indenture entries. They would all have to be carefully selected to maximize utility, while minimizing the total number of required entries.

4. Updating the System

Because the nation's space program will continue to grow and may be expected to accelerate in its rate of growth rather than slow down, the SDDIS must always remain dynamic and capable of considerable growth. It is imperative, therefore, that an effective updating and revision procedure be established early in the system development. This probably means that the system will have to be at least partially automated eventually, since machines can accommodate revisions to the data sheets more easily than can man and a printing press. "Updating," in the sense used here means both addition of new material, and revision or deletion of existing material (and, of course, revision of the index).

B. THE BASIC SYSTEM – MEETING MINIMUM USER NEEDS

On the philosophy that one must crawl before he can walk, the concept of the basic system has been to develop a baseline of categories and contents which (1) meets the requirements of the Contract Statement of Work for Phase 1 (as amended by JPL Guideline Document No. 1 and (2) encourages constructive user critique and evaluation.

Phase 1 activity related to book format and index development has largely been confined to the problem of optimum category selection to meet minimum user needs. It is the necessary first step toward the development of an efficient storage and retrieval system. A total of four iterations of the sample system and subsystem formats shown as Appendices A and B of the SDDIS Performance Plan (issued by RCA on January 10, 1966) were developed during Phase 1. Tables 3-1 and 3-2 summarize the intent and rationale of the major parts of the two basic formats (fourth and final iteration). Of

TABLE 3-1. RELATIONSHIP BETWEEN SYSTEM FORMAT AND TYPICAL USER REQUIREMENTS (See Exhibit A)

Format Entry	Basic Information Required	Remarks
1.0 PROJECT SUMMARY	Project title and general identification parameters.	Overall identification of project; used for machine and/or manual search and retrieval.
2.0 MISSION AND SYSTEM SUMMARY	Mission objectives and approach to achievement, including gross mission parameters and configuration identification.	Identification of project as required to compare with other missions and systems of interest.
3.0 SYSTEM DESIGN	Specific design and performance parameters, technical characteristics.	Defines essential characteristics of system and facilitates search by specific parameters of interest. The potential machine search capability depends on rigid definition of 3.0 entries.
4.0 FLIGHT PERFORMANCE	Actual flight and mission parameters, including general evaluation of mission results.	Intended to facilitate evaluation of design and determination of trends.
5.0 PROJECT POLICIES AND REQUIREMENTS	General management philosophy as it affected technical program performance; test philosophy, and supporting equipment requirements.	Shows evolution of project and allows limited correlation between management and test philosophy and performance.
6.0 PROJECT MANAGEMENT AND ORGANIZATION	Management organization, identification of contractors and subcontractors, project schedules.	Identifies project management structure and division of authority and responsibility; shows gross design, fabrication, and delivery schedules.
7.0 REFERENCES	Identity of all sources of data.	May be expanded to include drawing references, etc.
8.0 COST DATA	Program Obligation Plan data relative to program dollars budgeted and expended as a function of date.	Intended to provide a basis for planning future projects.

TABLE 3-2. RELATIONSHIP BETWEEN SUBSYSTEM FORMAT AND TYPICAL USER REQUIREMENTS (See Exhibit B)

Format Entry	Basic Information Required	Remarks
1.0 PROJECT SUMMARY	Overall project and subsystem titles and general information parameters.	Identification of project, system, and subsystem; used for machine and/or manual search and retrieval.
2.0 SUBSYSTEM SUMMARY	Summary description and requirements of the subsystem as imposed by associated system and procuring agency.	Identification of subsystem as required to compare with other missions and subsystems of interest.
3.0 SUBSYSTEM DESIGN	Specific design and performance parameters, technical characteristics.	Defines essential characteristics of subsystem and facilitates search by specific parameters of interest. The potential machine search capability depends on rigid definition of 3.0 entries.
4.0 FLIGHT PERFORMANCE	Actual flight and mission parameters, including general evaluation of mission results.	Intended to facilitate evaluation of design and determination of trends.
5.0 PROJECT POLICIES AND REQUIREMENTS	General management philosophy as it affected technical program performance relative to subsystem activity; test philosophy, and supporting equipment requirements.	Shows evolution of subsystem portion of project and allows limited correlation between management and test philosophy and performance.
6.0 PROJECT MANAGEMENT AND ORGANIZATION	Subsystem management organization, identification of contractors and subcontractors, project schedules.	Identifies subsystem project management structure and division of authority and responsibility; shows gross design, fabrication, and delivery schedules.
7.0 REFERENCES	Identity of all sources of data.	May be expanded to include drawing references, etc.
8.0 COST DATA	Program Obligation Plan data relative to program dollars budgeted and expended on subsystem as a function of date.	Intended to provide a basis for planning future projects.

the eight sections of each of the data-sheet formats, special note should be taken of the final sections (8.0) of each. These sections have been reserved to summarize cost and delivery information relative to the affected systems and subsystems. A major effort was expended during Phase 1 to obtain and interpret cost data affecting the primary programs of interest, with the following results:

It can be stated categorically that no industrial contractor can obtain detailed cost information on a consistent basis from either NASA headquarters or agency project offices without special authorizations. Requests for such data during Phase 1 were generally negatively received, to the point where further attempts at collection of cost data would have jeopardized the overall effort. RCA and JPL personnel visited the personnel at IITRI (Illinois Institute of Technology Research Institute), who are attempting to develop cost models which would allow actual program costs to be predicted on the basis of performance and design parameters. IITRI personnel revealed that their present cost models did not require use of any additional cost data for verification; the desired level of detail is simply the identification of gross program costs as noted in NASA Project Development and Obligation Plans (PDP's and POP's). It was further agreed that, since such data may be considered NASA proprietary, these data would be presented in separate sections of the data sheets, with information for these sections supplied by JPL. The cost formats presented in Section 8.0 of both the System and Subsystem data-sheet formats represent RCA's recommendations for the inclusion of such data, based on the present level of thinking and experience. It is planned, however, to examine this area further during Phase 2, with a view toward expanding the scope and detail of the presentation.

The fourth data-sheet iterations were "frozen" early in March, in order to ensure uniformity among the final editions of the data sheets required as specific outputs of the Phase 1 effort. The remaining three steps toward the recommended system -- vocabulary development, index development, and updating-procedure development -- are wholly dependent on the establishment of a basic "library" of information upon which to operate; Phase 1 activity in these areas was therefore subordinated to the more important task of developing the basic library.

With the establishment of firm formats and a basic library, the first step toward index development is the selection of a set of basic index and search parameters ("Authority List") based on the defined information categories and the indexing procedure described earlier in connection with the ideal system. An example of such a set is shown in Exhibit G. The selected combinations and permutations of the preliminary index parameters shown in Exhibit H collectively represent the plan to index the basic system. Relative to the plan to index the <u>ideal</u> system, the <u>basic</u> index plan is restricted in the following ways:

(1) Cross-indexing is restricted to permutating certain "primary" entries; no provisions are included for cross-referencing by synonyms or related subjects; indeed, a strict, single-valued vocabulary is used which recognizes no synonyms or related subjects.

(2) The arbitrary user approaching the basic SDDIS is compelled to formulate his question in terms of both a restricted vocabulary and a set of rules governing the method of combining the various parts of the vocabulary. Thus, it is necessary that the user be instructed in the use of the index before he can make efficient use of it.

(3) Although firm formats have been generally specified for the preparation of a basic library of data on a few programs (TIROS, Nimbus, and OGO), the formats cannot yet be considered optimum. In particular, the selection of fine-detail (minimum-information-bit) headings is still subject to some change, and thus could not usefully be included in the authority list (Exhibit G) for the basic index. Eventually, a set of tertiary parameters will be added to the authority list, in order to further refine the retrieval capability in terms of "minimum information bits."

With respect to restriction (2), above, part of the Phase 2 effort will be to prepare a set of prefatory notes for each of the ten system and subsystem volumes defined in Section I of this report. These notes will define the contents of each volume and will assist the user in, first, formulating his questions in terms which are compatible with the system vocabulary and organization, and second, finding all of the data of interest to him in the data sheets. These notes will be up-dated and revised as new data and procedures are introduced into the SDDID.

The plan for the basic index is compatible with existing machine techniques. It is, in fact, planned to utilize a simple computer program to generate the index and a computer printer to produce the actual index in reproducible form. By this means, a procedure for easily updating and revising the index is automatically established, since the computer can quickly and efficiently insert, delete, and/or revise internal (to the index) entries and print-out replacement index pages.

C. THE RECOMMENDED SYSTEM - IMPROVED SEARCH AND RETRIEVAL CAPABILITIES

The specific effort required to extend the basic system in the direction of the ideal system involves four tasks:

(1) Development of a system "Thesaurus" - the means, through the preparation of a comprehensive glossary of synonyms, of bridging the gap between "user request" and "system input."

(2) Expansion and Optimization of Index and Search Parameters - moving toward the goal of facilitating the retrieval of true "minimum information bits."

(3) Addition of Cross-Indexing to the Primary Index - by including both synonyms ("See ________" entries) and subject relations ("See also ________" entries).

(4) Development of Optimum Search Techniques - investigating (a) Man (user, system operators) versus machine functions, (b) Multi-level search (i.e., multiple-index) techniques, and (c) Machine search and/or display techniques.

With respect to Task (4), above - Development of Optimum Search Techniques - the field of Information Storage and Retrieval has become highly active within the last few years, and many specialized programs, techniques, and equipments have been and are being developed and made available. It is possible that one or more of these would be of use to the SDDIS. A thorough literature search, already initiated in Phase 1, will be continued and expanded in the next phase to ensure that the SDDIS is implemented (or at least is made compatible) with the latest advances in the state of the art.

SECTION IV
PREPARATION OF DATA SHEETS

A. TIROS DATA SHEETS

As soon as the project started, TIROS 1 data were abstracted to the first ("Sample") format, presented in the RCA performance plan. (This abstraction was initiated using data obtained from within RCA, prime contractor for TIROS, in anticipation of release of such data from NASA. However, no data were included in the TIROS data sheets until the appropriate documents had been released by NASA.) On the basis of experience gained, the first and second format iterations were completed. In both cases, TIROS 1 data were reworked in order to validate the format changes, resulting in the third iteration of the format.

One of the issues to be decided during the Phase 1 effort was the method of treating such projects as TIROS, where there are many flights with only minor configuration changes between flights. That is, should there be one data sheet for each flight, or one data sheet for the entire project? For TIROS, it was decided that one data sheet could be used for not more than the first four flights — that is, flights 5 through 12 are different enough from preceding flights that they should be covered by separate sets of data sheets. Therefore, the Phase 1 effort of the SDDIS Project considered only TIROS 1 through TIROS 4. TIROS 4 data (summarizing the TIROS 1 through 4 evolution) were abstracted to the third format iteration and then reworked to the fourth (and final) format iteration.

B. NIMBUS DATA SHEETS

Abstraction of Nimbus data was started to the second format iteration but completed to the third. Although it had been originally intended to submit the Nimbus data sheets as prepared to the second and third format iterations, it was subsequently decided that Nimbus data sheets should be the "preprototypes" of the recommended system. Therefore, all Nimbus data sheets were reworked and printed in accordance with the final format iteration. (Sample Nimbus data sheets are presented in Exhibits D and E of this report. The complete set of Nimbus data sheets is submitted under separate cover.)

C. OGO DATA SHEETS

Although it was originally intended to prepare OGO data sheets as the preprototypes of the recommended SDDIS, delays in obtaining OGO data precluded such an approach. Therefore, Nimbus was selected as the preprototype project and OGO data were simply abstracted to the final format. (Delays in receipt of OGO data allowed insufficient time to abstract, edit, and produce OGO data in final form.)

D. DEVELOPMENT OF AN ABSTRACTION AND EDITING TECHNIQUE

One of the goals established for this project was to limit the extent to which the individual abstractor must subjectively evaluate project events, both to ensure a uniformity of viewpoint and, hopefully, to allow the later use of abstractors with limited technical competence. It had been hoped that this goal could be realized by rigidly defining the format so that the abstractor could simply select applicable portions of documents and literally reproduce them within the data sheets. Editing of the resulting material would then provide the required presentation. However, it turned out that, using only published data sources, quite the inverse effect resulted — the more rigidly defined the format, the more the individual had to exercise judgement in preselecting the information, and in many instances, responses to specific format entries had to be developed by the abstractor. This was caused both by inconsistencies in the types of documents available and by the fact that for some format entries there were several slightly different but still applicable statements. Thus, it was not possible to "simply" select appropriate responses — if the format entries were to be specifically responded to, the abstractor often had to review several documents and then generate a statement embracing the diverse thoughts presented in those several documents. However, where the format entries were fairly general as to the type of information required, the abstractor could in fact simply select appropriate statements from the available documentation, responding to the general, if not the specific, intent of the format. In its simplest terms, the problem is one of "translating" from the language of the available documents into the language of the data sheets, and encompasses a wide range of efforts ranging from changing units to deciding whether the use of standard module sizes on Nimbus was part of the system "mechanization approach" or simply a subsystem "design requirement."

As the project progressed, compromises were effected, as noted by the several format iterations, to simplify the abstraction task without losing information. The net result of these simplifications can be assessed only by assessing the data sheets themselves. However, in the course of developing these (four) format iterations, the abstractor, having gained a certain level of experience with documentation pertaining to a certain program, was able to positively indicate those areas for which insufficient coverage was provided within the project library. To some extent, "reretrieval" of information then was required. Thus, the general technique for data abstraction and data sheet preparation was defined as follows:

(1) Read press releases, NASA mission plans, and NASA public statements to provide "contextual" information;

(2) Prepare the system-level data sheet for the first spacecraft, carefully defining all subsystems;

(3) "Rough" edit the abstracted data to reduce the bulk of the material presented and suggest the final style;

(4) Evaluate the data sheet and list all information noted as not available and identify source documents in which the missing information might be contained;

(5) "Reretrieve" documents suggested by item (3) above;

(6) Incorporate missing information;

(7) Evaluate overall impact of the data sheet, listing areas not covered in sufficient detail and noting any information which is important to the project being considered but not required by the format;

(8) Add additional sub-paragraphs within the format to accommodate the requirements of item (6) above;

(9) Final edit the abstracted data to ensure consistency of style, high graphic quality, and brevity; and

(10) Prepare data sheets for each of the subsystems, repeating steps (3) through (9) for each.

E. LIBRARY MAINTENANCE

Where specific data were not available within the existing documents selected for the project, notice of the difficulty was immediately provided both to the individual responsible for the library and to the individual responsible for the format development. Thus, simultaneous judgements were made as to whether the requested data were in fact necessary and whether or not they could or should be retrieved from existing data sources. In many cases, the difficulty turned out to be a communications problem in interpreting the format, and no library action was required. However, in a few instances, there were missing data important enough to warrant another attempt at data collection. (The most notable data missing from the basic Nimbus library were, for example, reliability predictions for the various subsystems. Although a reliability analysis had been retrieved, the actual predictions of success were presented in a different volume which had not been obtained. The missing data were obtained without difficulty by again visiting the GSFC project office, but the point had been rather forcefully made: regardless of how complete a list of documents collected for any given project, the only true test of sufficiency is to actually prepare data sheets. It is in the nature of things that in the general case some data will be lacking, and documents will have to be selectively "reretrieved" from the original data sources. Although such reretrieval must for the present purposes be limited to selection of specific documents, the possibility exists that specific queries could be addressed to individuals within the project offices, if such queries were limited to those which could be answered without extensive research. Although such a technique was not attempted, the level of cooperation achieved to data suggests the feasibility of such an approach, should it ever be needed.

F. VERIFICATION OF DATA SHEETS

Consistent with the interest in the project shown by almost all of the NASA project offices, it would seem appropriate to forward copies of completed (draft) data sheets to the cognizant project officer for review and comment. Such a verification process would not only guarantee the validity of the data presented, it would very possibly provide new insights into the formats, as project personnel most probably will suggest additional data for inclusion.

SECTION V
SYSTEM DEVELOPMENT

Although the system development effort was to some extent curtailed in order to support an increased data-collection effort, the system development effort did proceed far enough to suggest a general plan for processing SDDIS data. This plan, which combines features of both manual and computerized data processing, involves storage of bulk documentary data on reproducible masters and/or microfilm; abstraction and index keys, together with certain numerical information, would be stored in computer memory. Based on this overall approach to data storage, computer techniques would be used to perform the following functions:

- Automatically generate a published cross-reference index.
- Answer specific reference inquiries which request as an output a list of all data sheets meeting a specific criteron (or set of criteria). (For example, a list of all data sheets containing references to solar-cell power supplies for earth orbiters.) The output for this type of inquiry would be either a listing of file numbers (for the "baseline" system) or, potentially, a machine command aperture-card retrieval.
- Provide direct answers to specific inquiries where such inquiries can be related to specific quantitative entries specified in the format. (In general, this type of inquiry will involve numerical processing of abstracted data. An example of such a specific inquiry would be a request for the average weight and power requirements of earth-orbiting meteorological satellites launched after January 1, 1962. The output to this inquiry would be a direct computer print-out of the individual weight and power of each such satellite, together with the averages as calculated using a stored "averaging" program.)

A. FUNCTIONAL FLOW THROUGH THE TOTAL SYSTEM

The total system functions are outlined in Figure 5-1. As may be noted, the specific system functions are as follows:

1. Data are obtained from the established sources (refer to Section II of this report).
2. Selected data are used to prepare standard data sheets for the bulk SDDIS; these data are printed and generally distributed and then microfilmed or otherwise produced in a machine-retrievable form.

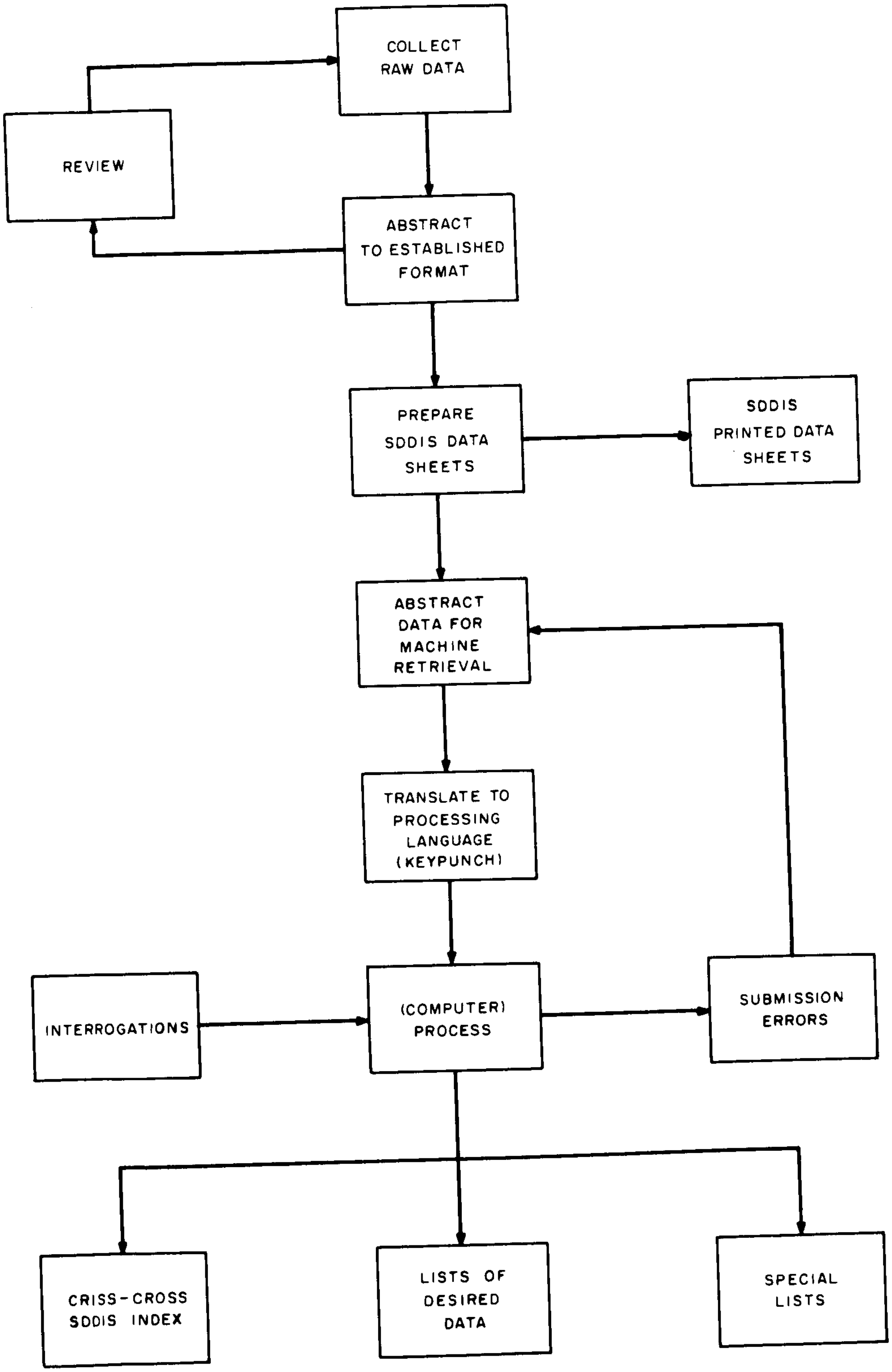


Figure 5-1. Functional Flow Diagram for SDDIS Operations

3. The final data sheets are further abstracted for entry into the computer system. Abstraction will include identification and tabulation of the following parameters:

   - Index Parameters –

     Index parameters are those parameters for which cross references will be generated and shown on a published cross-reference index. (Examples of such indexing parameters include TV, earth orbiters, lunar probes, tape recorders, etc.).

   - Retrieval Parameters –

     Retrieval parameters identify abstracted data which will be used as keys to specific inquiries. (Examples of retrieval parameters include functional descriptions, weight, power, size, transistor characteristics, vidicon resolutions, etc.).

   - Processing Parameters –

     Processing parameters identify quantitative information within the file for which elementary numeric processing will be required to answer specific inquiries without reference to the data sheets. (Examples of these parameters include weight, power, cost, etc.).

4. The abstracted data are keypunched on 80-column punch cards for input to the computer system.

5. The abstracted data are entered into the computer system where the total magnetic tape master file is maintained and a revised cross-reference index produced. Part of the computer process will be the identification of submission errors, which will be returned to the abstracting function for review and correction.

6. Interrogations submitted to the computer system are validated by computer techniques after which the proper answers are generated.

B. DESCRIPTION OF RECOMMENDED COMPUTER OPERATIONS

The system operations for computer processing are outlined in the system chart shown in Figure 5-2. A brief description of these operations is as follows:

1. Checks of Input Data

   All initial data would be processed using a computer program which verifies validity. Typical validity checks include verification of:

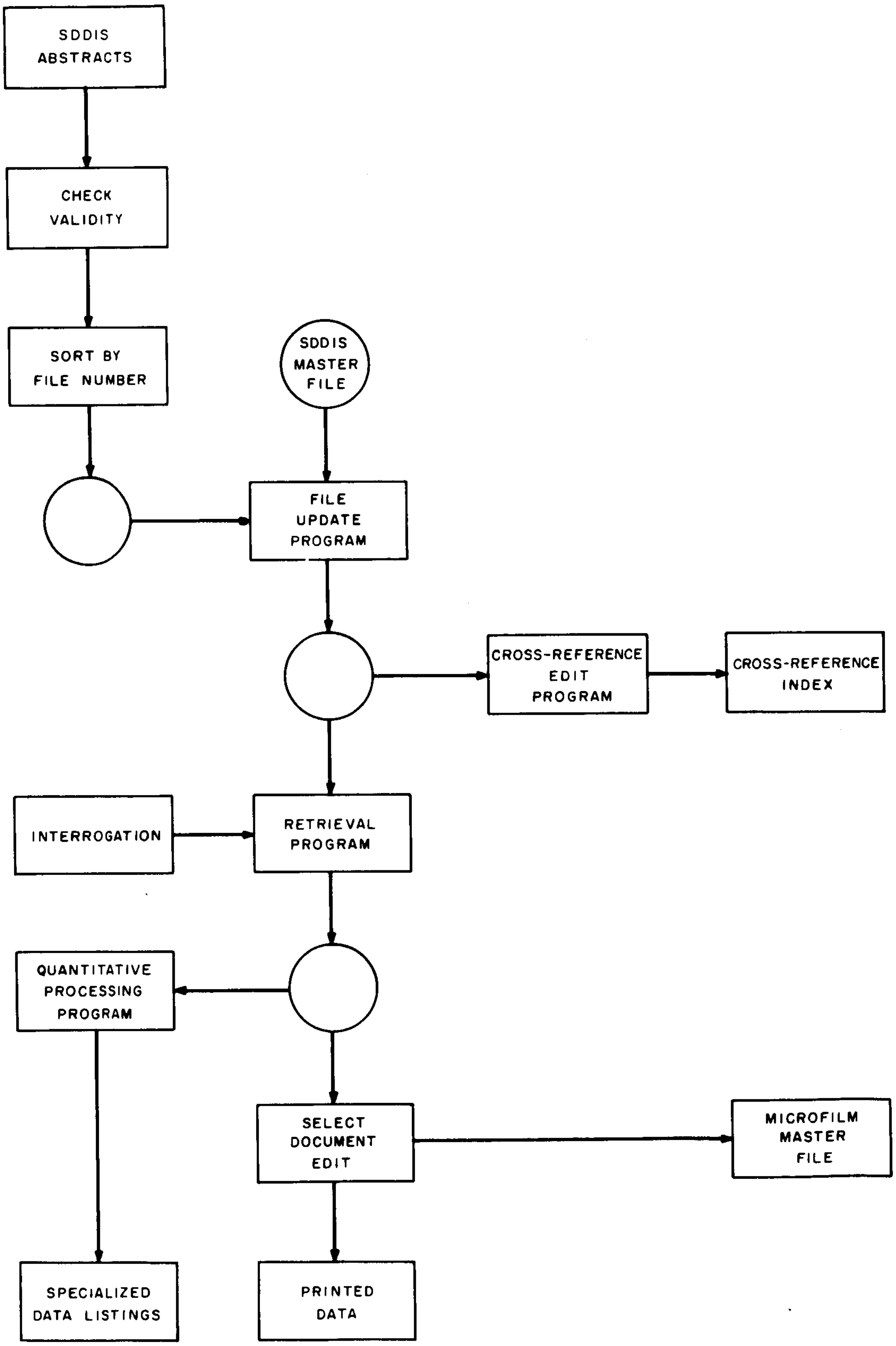


Figure 5-2. SDDIS Computer Processes

- Presence of a file number;
- Proper form of index and retrieval parameters; and
- Proper operation code identifying the processing required.

2. Sort Program

   All input data would be sorted by file number.

3. File Update Program

   The inputs to the system will be processed considering data already in the master file. Updating capability will include the following:

   - Adding new files to the system;
   - Adding new fields to files already in the system;
   - Deleting files in the system; and
   - Changing fields in the system.

   (Where a field within a file refers to either indexing or retrieval parameters.)

4. Cross-Reference Edit Program

   After each new input, the updated master file will be processed through the cross-reference edit program to produce, on reproducible form, a publishable cross-reference index.

5. Retrieval Program

   Interrogation data in the form of specific inquiries will be submitted to a retrieval program, together with the current master file. The output of this program will be selected data which meet the criteria of the specific inquiries. This data will be of two forms — reference keys to bulk data storage and selected quantitative information.

6. Select Document Edit

   The output of the retrieval program which calls for specific reference to bulk storage will be processed through a computer routine which will tabulate the file numbers or provide index search cards for an aperture-card retrieval system.

7. Quantitative Processing Routines

   Selected quantitative data will be processed to produce summations, averages, etc., responding to preselected processing routines.

C. INTERFACES WITH OTHER DATA PROCESSING AND RETRIEVAL SYSTEMS

Although it has been determined that presently available programs and equipments are not specifically suited to the SDDIS requirements, it is very possible that the SDDIS will prove to be compatible with certain data retrieval systems now being developed. Of particular importance is the effort being undertaken by NASA STIF to develop a console and programs for direct interrogations of the STIF libraries; both the technology and the concept may well prove appropriate to the SDDIS. Other possibilities to be examined include using the SDDIS as a superior index to data collections now being developed. (Such data collections typically provide histories and performance data on individual components, assemblies, and materials.) Certainly, if maximum use is to be made of an automated SDDIS, it will be through using it in conjunction with other data-retrieval systems.

SECTION VI
CONCLUSIONS AND RECOMMENDATIONS

The development of an SDDIS has been proven feasible. Sufficient data are in hand to prepare data sheets for 12 programs in addition to TIROS, Nimbus, and OGO. Data-sheet preparation could be started for several other programs, and no insurmountable difficulties have been identified. The major problem, acquisition of source data, can be solved by viewing the data-collection task as a continuing one involving personal contacts at government facilities. And, as the project progresses and data sheets become available, the data retrieval task should be somewhat simplified. (Each of the individuals contacted to date has expressed an interest in seeing typical data sheets, and it appears obvious that if such sheets were available even more effective cooperation would be obtained.)

In view of the proven feasibility of the SDDIS, it is RCA's recommendation that prompt implementation of the SDDIS be undertaken. Promptness is important because as projects terminate, portions of the subsystem data "disappear," and several of the projects considered for inclusion have already terminated*. However, concurrent with the actual preparation of data sheets, certain other aspects of the SDDIS should be more fully defined. Specifically, the following tasks are recommended for the Phase 2 effort:

(1) Re-define the data-sheet formats to incorporate JPL comments, develop fixed-field formats for performance parameters and other data likely to be significant retrieval parameters, and standardize the nature of qualitative data to be included in the SDDIS;

(2) Prepare data sheets, in lots of 10 programs each, to the final formats re-defined above;

(3) Maintain an SDDIS library, on a continuing basis, as required to support the preparation of data sheets;

(4) Develop a technique for automatically generating detailed SDDIS indexes compatible with a potential for machine search of data files; and

---

* The Relay, Telstar, and Syncom project offices at NASA already have been fully disbanded.

(5) In coordination with the index-development task immediately above, perform a study to determine the suitability of implementing a fully or partially automated SDDIS.

RCA's recommendations for a Phase 2 effort are fully detailed in the Phase 2 Development Plan, submitted under separate cover.

EXHIBIT A

FOURTH AND FINAL PHASE 1 ITERATION OF THE FORMAT AND CONTENT DEFINITION FOR SYSTEM DATA SHEETS

March 10, 1966

SDDIS
SYSTEM DATA SHEET FORMAT
AND
COMPILING INSTRUCTIONS
FOURTH ITERATION

1.0 PROJECT SUMMARY

1.1 rogram: e.g., TIROS, Mariner*

1.2 Project: e.g., TIROS, Mariner R*

1.3 Spacecraft System: TIROS I, Mariner II*

1.4 Launch Date(s): Include sites

1.5 Date of Data Sheet Preparation:

1.6 Nature of Mission: e.g., Meteorological Observation, Communications

1.7 Flight Category: e.g., Earth Orbiter, Lunar Probe

1.8 Procuring Agency:

1.9 Contract Number(s):

1.10 Design Status: e.g., Flight Proven, Prototype, Developmental

1.11 Manufacturer(s):

2.0 MISSION AND SYSTEM SUMMARY

(All of the entries in this section - 2.0, Mission and System Summary - should be related to and/or derived from project or system plan and design information, not actual flight performance.)

2.1 Primary Mission Objectives: A summary narrative description of the principal mission objective(s) to be satisfied by the project and spacecraft system. Example for the Ranger Block III project might be: "Obtain high-resolution television pictures of the lunar surface, specifically to investigate possible lunar landing sites, and generally to increase scientific knowledge of the lunar surface characteristics." List, if more than one primary mission objective.

2.2 Design Approach: A summary narrative description of the system design approach based on first-order mission and system constraints. Example for the Ranger Block III project might be: "System constrained to produce television pictures of the lunar surface having optical resolutions (in meters) at least one order of magnitude better than the best previously obtained by earth-based observatories. This constraint led to the decision to provide both wide-angle and narrow-angle cameras to ensure, first, that the required resolution would be obtained (with the narrow-angle cameras), and second, that adequate areal coverage would simultaneously be obtained (with the wide-angle cameras)." Include photo or sketch of system.

2.3 Configuration: Physical description of spacecraft. Include explanations of unique design aspects as necessary; relate to operational requirements. Include photo or sketch of spacecraft system. Discuss placement of principal subsystems and experiments, as appropriate to justifying particular configuration.

2.4 Design Requirements: (List only requirements imposed as fundamental to the mission.)

2.5 Orbital Parameters:

- 2.4.1 Launch Vehicle:
- 2.4.2 Apogee:
- 2.4.3 Perigee:
- 2.4.4 Inclination:
- 2.4.5 Period:

*See Glossary of Terms.

2.6 Sequence of Launch Events: (Present as listing of principal events e.g., lift-off, jettison shroud, separation, etc. – including time references where available. Launch/Trajectory/Injection diagram is desirable.)

2.7 Operation and Mission Chronology: A narrative description of the system operation related to the chronology of the mission, from orbit injection to the end of the mission; explain as necessary.

2.8 Critical Mission Phases: A list (with explanations as necessary) of critical mission phases, excluding launch, from the standpoint of mission accomplishment, e.g., Ranger Block III critical mission phases would be:

(1) Sun Acquisition (pointing of roll axis)

(2) Earth Acquisition by high-gain antenna

(3) Mid-course maneuver

(4) Terminal maneuver

(5) Television activation

2.9 Post-Encounter Phases: A list (with explanations as necessary) of planned events following satisfaction of the primary mission objectives, e.g., (Relay I) "Automatic shut-down by built-in clock after one year of operation;" "Reentry effected . . . . (time, place, method);" etc.

2.10 Data Return Modes: A list of functional return modes. Explanations should be included to the extent necessary to identify the functional flow of data through the system and subsystem. Examples of data-return modes (without explanations) are: Television, real-time; Television, delayed; VHF (or) S-band Communications; Telemetry (number of channels and types of data); etc.

2.11 Advanced Concepts: A list of planned or add-on extension systems if any; if none, so state.

3.0 SYSTEM DESIGN

(As Section 2.0, Mission and System Summary, the entries in this section should be restricted to plan and design information. This includes all detailed design, fabrication, and testing data, as well as in-flight performance.)

3.1 Functional Description: A description of the functional make-up of the spacecraft system, presented within the framework of paragraphs 3.1.1 through 3.1.11 below. The definitions of items 3.1.2 through 3.1.11 are included in the Glossary of Terms. This list is expandable as the need arises.

3.1.1 System Block Diagram: Show the system block diagram and accompany it with a brief narrative description identifying each of the constituent subsystems and experiments in terms of functions performed and shown in the diagram. Trace the data flow through the system; describe as concisely as possible.

3.1.2 Power:

3.1.3 Guidance and Stabilization:

3.1.4 Data Transmission and Reception:

3.1.5 Command, Control, and Telemetry:

3.1.6 Structure and Thermal Control:

3.1.7 Television:

3.1.8 Infrared Detection:

3.1.9 Propulsion:

3.1.10 Biological Experiments:

3.1.11 Other:

EXHIBIT B

FOURTH AND FINAL PHASE 1 ITERATION OF THE FORMAT AND CONTENT DEFINITION FOR SUBSYSTEM DATA SHEETS

3.2 Mechanization Approach: This section should give the user an insight into the basic mechanization approach to the system design, e.g., modular construction integrated with the spaceframe, integrated circuits used throughout (or in particular equipments), conventional wiring and potting mounted in a bedding of (specified) vibration- and shock-absorbing material, etc. It should be possible to present these data in one or two paragraphs.

3.3 Performance Characteristics:

3.3.1 Weight

3.3.1.1 Spacecraft Weight

3.3.1.2 Experiment Weight

3.3.1.3 Subsystem Weight/Volume Summary

3.3.2 Power

3.3.3 Stabilization Accuracy (per each of three axes):

3.3.4 Stabilization Mode: (e.g., spin stabilized and magnetic torquing, horizon sensing; inertial, sun sensing.)

3.3.5 Operational Life:

3.3.6 Data Transmission: For each spacecraft link, note such characteristics as type of data, frequency and bandwidth, transmitted power, and data rate.

3.3.7 Primary Experiments: (Note performance for experiments changing entries as required and covering only the experiments of primary importance to achieving the mission objectives.)

3.3.7.1 Purpose

3.3.7.2 Resolution

3.3.7.3 Sensitivity

3.3.7.4 Characteristics of Output Signal

3.4 Unique Developments: List new techniques, special hardware, etc., in abbreviated (declarative) form. A unique development need not have been created or originated as a direct result of the subject project or system; it may also be a device or technique which was developed elsewhere for other purposes and flight-proved for the first time on the subject system.

3.5 Reliability:

3.5.1 Reliability Requirements:

3.5.2 Reliability Approach:

3.5.3 Failure Modes and Effects Analysis: (If no specific failure modes were considered, discuss in general terms.)

3.5.4 Redundancies Employed:

4.0 FLIGHT PERFORMANCE

4.1 Spacecraft Performance: A summary of actual spacecraft performance relative to design performance. Present within the following framework:

4.1.1 Orbit Achievement and Overall Performance:

4.1.2 Power:

4.1.3 Guidance and Stabilization:

4.1.4 Command, Control, and Telemetry:

4.1.5 Structure and Thermal Control:

4.2 Experiment Performance: A list of the positive accomplishments of the flight. Present, first, as a listing of the data-return subsystems and experiments of the system, and then, as a sub-listing of the data-return modes of each subsystem of experiment. Accompany each listed mode with a brief factual summary of the data return. Subjective evaluations of the return should be avoided, except where the basis for measuring the degree of success can be clearly identified.

4.3 Failure Modes and Effects: This is a "hardware" explanation of any deviations in spacecraft performance. List by subsystem and sub-list by known failure mode. Use brief declarative phrases to describe the effects of each failure mode.

5.0 PROJECT POLICIES AND REQUIREMENTS

5.1 System Tradeoffs: This is a summary of project and system requirements which most directly influenced the direction of system design approach. List by system consideration, e.g., Spacecraft Weight, Reliability, Power, Environmental Design, etc., and sub-list by tradeoff consideration.

5.2 Specifications and Standards Invoked: A list of standard military, governmental or corporate standards (where available) and specifications invoked on the project; identify each by name and number.

5.3 Quantity of Systems Fabricated or Planned: Enter the number of each of the following:

5.3.1 Flight Models:

5.3.2 Prototype Models:

5.3.3 Test Models: (Identify the test category of each)

5.3.4 Spares: (i.e., spare flight models)

5.4 Test Program: List the primary test categories (as shown below), and tabulate the test parameters and levels for each.

5.4.1 Test Philosophy:

5.4.2 Qualification Test Parameters:

5.4.3 Other Tests:

5.5 Supporting Equipment: List special mission-dependent equipment built for the subject project in support of the spacecraft system and the attainment of the mission objectives; include brief descriptions of interface features.

5.6 Design Review Policy: Include the following, where available: (1) number of design reviews held during the course of the project; (2) participating groups (contractor, manufacturer, etc.); and (3) governing specifications, if any.

6.0 PROJECT MANAGEMENT AND ORGANIZATION

6.1 Type of Management Organization: List document numbers and titles of any program-management specifications invoked on the project, if any. Include other management data as available.

6.2 Project Organization: Show project management structure, beginning with the contracting agency, through the prime contractor, to the first tier of subcontractors, and identify the companies, agencies, etc. at each level.

6.3 Project Plan: Show schedule as planned at early phases of project.

7.0 REFERENCES

List of all data sources from which data were obtained.

8.0 PROJECT COSTS

The information for this section is to be included on a separate page for the convenience of separating this (possibly proprietary) material from the remainder of the data sheet. All of the information required should be available from NASA-issued Program Development Plans (PDP's) and/or Program Obligation Plans (POP's).

8.1 Costs Budgeted per First Program Obligation Plan

8.2 Costs Budgeted per Final Program Obligation Plan (issued after flight of equipments being considered)

8.3 Graph of Predicted versus Actual Expenditures - A typical such graph is shown in Figure 8.3-1; as shown, it is a bar-type graph showing variations in program obligations as a function of date of POP issues; it should also contain launch and/or other key milestone dates.

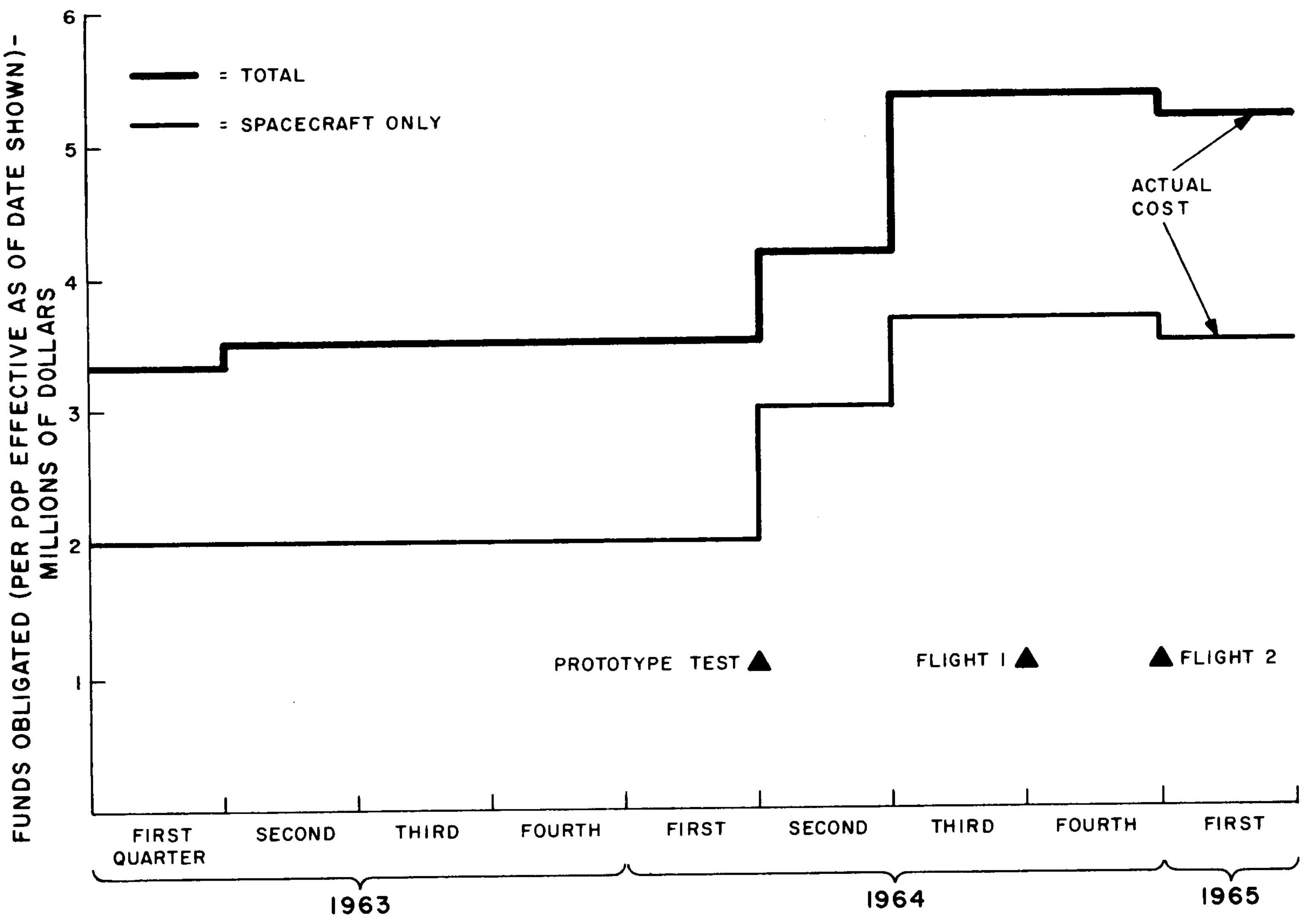


Figure 8.3-1. Typical Funding Schedule

March 14, 1966

SDDIS
SUBSYSTEM DATA SHEET FORMAT
AND
COMPILING INSTRUCTIONS
FOURTH ITERATION

1.0 PROJECT SUMMARY

1.1 Program: e.g., TIROS, Mariner*

1.2 Project: e.g., TIROS, Mariner R*

1.3 System: e.g., TIROS I, Mariner II*

1.4 Subsystem: See Glossary of Terms for defined subsystem categories. Where a unique title (e.g., Advanced Vidicon Camera System) has been defined in a project, the Glossary of Terms category will be modified by a dash (-), followed by the distinctive or unique name, e.g., "Television - Advanced Vidicon Camera System."

1.5 Date of Data Sheet Preparation:

1.6 Procuring Agency:

1.7 Contract Number(s):

1.8 Subsystem Design Status: Examples are: Flight Proven, Prototype, Developmental, etc.

1.9 Manufacturer(s):

2.0 SUBSYSTEM SUMMARY

2.1 Summary Description: Describe as concisely as possible. Include photo or sketch of system.

2.2 Design Requirements: The intent of this paragraph is to summarize the design characteristics of the subject subsystem imposed by (1) the procuring agency, and (2) the remainder of the spacecraft system.

3.0 SUBSYSTEM DESIGN

3.1 Functional Description: The subsystem block diagram will be presented here and accompanied by a narrative description of the data flow through the subsystem. Describe as concisely as possible; if appropriate, describe the functional operation in terms of the requirements of successive mission phases.

3.2 Mechanization Approach: Indicate the mechanization approach to subsystem design, e.g., modular construction, integrated circuits, etc.

3.3 Performance Characteristics: This is a listing of appropriate performance parameters.

3.4 Unique Developments: List new techniques, special hardware, etc., in abbreviated (declarative) form. A unique development need not have been created or originated as a direct result of the subject project; it may also be a device or technique which was developed elsewhere for other purposes and flight-proved for the first time on the subject system.

3.5 Reliability:

3.5.1 Reliability Requirements:

3.5.2 Reliability Approach:

3.5.3 Failure Mode and Effects Analysis:

3.5.4 Redundancies Employed:

4.0 FLIGHT PERFORMANCE

4.1 Subsystem Performance: A summary of subsystem performance relative to design performance. Discuss the positive accomplishments of the flight. Present, if appropriate, as a listing of the data-return modes of the subsystem. Accompany each listed mode with a brief factual summary of the data return; relate such return to flight deviations or variant subsystem performance, if any. Subjective evaluations of the return should be avoided, except where the basis for measuring the degree of success can be clearly indicated.

*See Glossary of Terms.

4.2 Failure Modes and Effects: List known subsystem equipment failures during the mission; sub-list effects.

5.0 PROJECT POLICIES AND REQUIREMENTS

Where the subsystem being considered is an experiment, it may be expected that the information required in this section may not be generally available (since such equipments are usually government-furnished). In such cases, it is not necessary to conform to the indicated requirements of this section.

5.1 Subsystem Tradeoffs: This is a summary of project requirements and design considerations which most directly influenced the direction of subsystem design. List by system consideration (e.g., Payload Weight, Reliability Power, Environmental Design, etc.), and sub-list by tradeoff consideration.

5.2 Specifications and Standards Invoked: A list of standard military, governmental, or corporate standards (where available) and specifications invoked on the subsystem project; identify each by name and number.

5.3 Quantity of Subsystems Fabricated or Planned: Enter the number of each of the following:

5.3.1 Flight Models:

5.3.2 Prototype Models:

5.3.3 Test Models: (identify the test category of each)

5.3.4 Spares: (i.e., spare flight models)

5.4 Test Program: List primary test categories (as shown below), and tabulate the test parameters and levels for each.

5.4.1 Test Philosophy:

5.4.2 Qualification Test Parameters:

5.4.3 Other Tests:

5.5 Supporting Equipments: List special mission-dependent equipment built for the subsystem; include brief descriptions of special interface features.

5.6 Design Review Policy: Include where available.

6.0 PROJECT MANAGEMENT AND ORGANIZATION

The data in this section refer to the overall management plan and organization of the subject manufacturer(s). Thus, if the same manufacturer is responsible for both the subject subsystem and associated system, the information required for this section may well be redundant with that appearing in the parallel section in the associated system data sheet, and no new entries will be required here. If the manufacturer of the subject subsystem has no system responsibility, then this section will be filled out with the subsystem manufacturer's management and organization data. Where the subsystem being considered is an experiment, it may be expected that the information required in this section may not be generally available (since such equipments are usually government-furnished). In such cases, it is not necessary to conform to the indicated requirements of this section.

6.1 Type of Management Organization: List document numbers and titles of any program-management specifications invoked on the project, if any. Include other management data as available.

6.2 Project Organization: Show project management structure, beginning with the contracting agency, through the prime contractor, to the first tier of subcontractors, and identify the companies, agencies, etc., at each level.

6.3 Project Plan:

6.4 Project Performance:

7.0 REFERENCES

List of all data sources from which data were obtained.

8.0 PROJECT COSTS

The information for this section is to be included (where available) on a separate page for the convenience of separating this (possibly proprietary) material from the remainder of the data sheet. All of the information which is available from the NASA-issued Program Development Plans (PDP's) and/or Program Obligations Plans (POP's) should be included. Where subsystem cost data are not available from these documents, such other sources of information as may be available should be used. In the latter case, it may not be possible to adapt the available information to the format outlined below; a logical presentation of such data should then be adopted which conforms to the intent of following format.

8.1 Costs Budgeted per First Program Obligation Plan

8.2 Costs Budgeted per Final Program Obligation Plan (issued after flight of equipments being considered)

8.3 Graph of Predicted versus Actual Expenditures - A typical such graph is shown in Figure 8.3-1; as shown, it is a bar-type graph showing variations in program obligations as a function of date of POP issues; it should also contain launch and/or other key milestone dates.

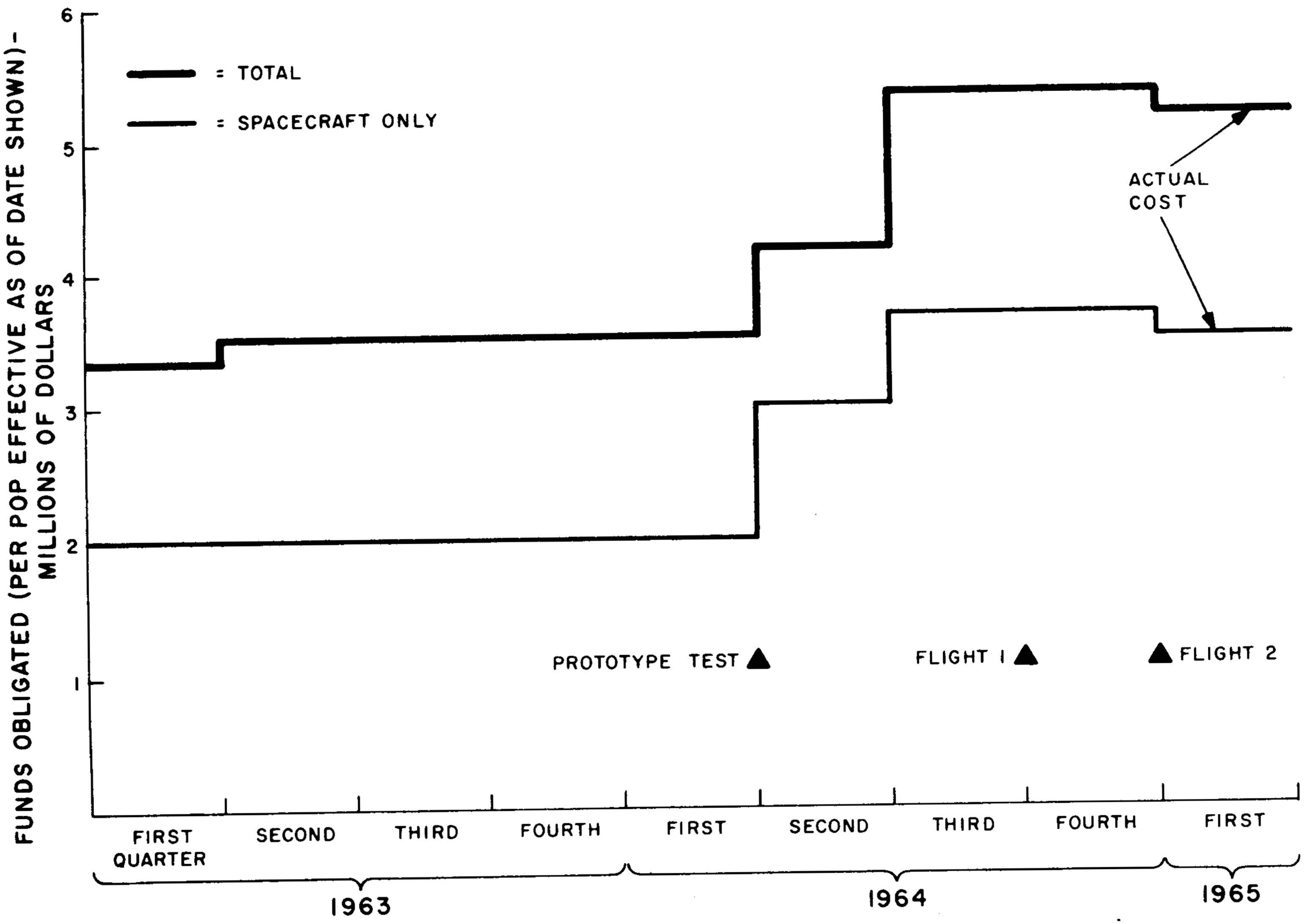


Figure 8.3-1. Typical Funding Schedule

EXHIBIT C

PRELIMINARY GLOSSARY OF TERMS (DEVELOPED TO ENSURE CONSISTENCY OF USAGE AMONG DATA SHEETS)

March 7, 1966

SDDIS
PRELIMINARY GLOSSARY OF TERMS

PROGRAM - Most inclusive organizational structure; includes the long-range planning and performance of system and project activities related to a broadly defined set of mission goals. Examples: Apollo, Mariner, TIROS.

PROJECT - Functionally similar to Program, but subordinate in scope; covers the planning and performance of system design and development to meet a specific set of Mission and Program goals. Examples: LEM, Mariner R, TIROS.

SYSTEM, SPACECRAFT SYSTEM - The functional envelope of all space-flight equipments, sometimes called "payload"; the integrated form of all flight subsystems. Examples: LEM-taxi, Mariner II, TIROS I.

SUBSYSTEM - A defined unit of the system. Since almost every spacecraft project adopts its own definition of subsystem and associated titles (e.g., Television Subsystem, Television Picture Taking Subsystem, Telecommunications Subsystem, Video Subsystem, etc.), the 10 subsystem categories defined in the following are adopted as standard definitions for the purpose of indexing and the retrieval of SDDIS data.

STRUCTURE AND THERMAL CONTROL SUBSYSTEM - Includes basic structure, harnesses, cabling, mounting hardware, pyrotechnics, wiring, etc. Also includes thermal-control techniques and hardware.

GUIDANCE AND STABILIZATION SUBSYSTEM - Consists of equipment necessary for attitude sensing, scanning, and selection and maintenance of flight path, for the determination and correction of position error (station-keeping) and the change of attitude, position, or flight path (station acquisition). Specifically includes stabilization and attitude-control subsystems, sensors, flight-control equipments, pheumatic- and electronic-detection devices, altimeters, and engines, motors, and thrusters used to maneuver and/or stabilize the spacecraft, together with their mechanical and electrical arrangements, valves, tanks, pipelines, propellant, and structures associated with the motor or thruster housings. It excludes such structures and mounting provisions which can be identified for inclusion in the Structure and Thermal Control category.

DATA TRANSMISSION AND RECEPTION SUBSYSTEM - Consists of equipment which, on receiving data from any source, directly facilitates two-way communication of data. (Occasionally, experimental equipment will include transmission equipment as an integral part of the experiment, such that it is impractical or impossible to separate the experiment's data-transmission equipment from the remainder of the experiment. In such cases, the transmission portion of the experiment will be described in the experiment's data sheet; appropriate mention of such equipment will be included in the Data Transmission and Reception data sheet, but reference will be made to the experiment data sheet for details.) Specific functions include the transmission and reception of all digital and analog communications (except as noted above in connection with particular experiments), telemetry, and spacecraft commands. Specific equipments include antenna assemblies, transponders, transmitters, and receivers. Excluded are radio-frequency equipments used specifically as or part of an experiment, data processing equipments (e.g., encoders, decoders, central computers, sequencers, multiplexers, data automation devices, etc.), data storage equipments, readout devices, and all mounting and packaging hardware which can be identified for inclusion in the Structure and Thermal Control category.

POWER - Consists of equipment necessary to supply and condition power to the spacecraft subsystems. It specifically includes solar cells and panels, batteries, RTG systems, converters, inverters, regulators, transformers, and chargers. It excludes mounting provisions and structures which can be identified for inclusion in the Structure and Thermal Control category.

COMMAND, CONTROL, AND TELEMETRY SUBSYSTEM - Includes all on-board housekeeping equipment concerned with the command and control of spacecraft functions (excluding the transmission and reception of signals) and the monitoring of spacecraft performance. Specific equipments include data processing equipments (e.g., data encoders and decoders, central computers, sequencers, multiplexers, data automation devices), telemetry points and channeling, and functional control equipments (switches, relays, etc.). Excluded are radio-frequency equipments used specifically as or part of an experiment, data transmission and reception equipments, data storage equipment, and all mounting and packaging hardware which can be identified for inclusion in the Structure and Thermal Control category.

TELEVISION SUBSYSTEM - A separate data sheet will be prepared for each distinguishable television subsystem, whether the equipment is experimental or operational. Except where it has been designed as an integral and inseparable part of a television subsystem, television transmission equipment will not be included in television data sheets. All other equipment associated with television subsystems (optics, sensors, electronics) will be included. Television telemetry points will be identified, even though such entries are partially redundant with those appearing in the Command, Control, and Telemetry category. Tape recorders and other data storage equipment will normally be excluded, except where such devices have been designed for exclusive use by the subject subsystem. Excluded also are all equipments associated with data processing and transmission, as are all command and control equipments, and such mounting and packaging hardware which can be identified for inclusion in the Structure and Thermal Control category.

PROPULSION SUBSYSTEM - If considered to be an experiment and not part of normal guidance and control, a Propulsion subsystem will be assigned a separate subsystem data sheet. As such, it will include sensors, electronics, controls, housings, motors, thrusters, mechanical and electrical arrangements. valves, tanks, pipelines, propellant, and structures associated with the motor or thruster housings. Excluded are such structures and mounting provisions which can be identified for inclusion in the Structure and Thermal Control category.

INFRARED DETECTION SUBSYSTEM - Same reasoning as for "TELEVISION," above.

BIOLOGICAL EXPERIMENTS SUBSYSTEM - Same reasoning as for "TELEVISION," above.

EXHIBIT D

TYPICAL (NIMBUS) SYSTEM DATA SHEET

EXHIBIT D

1.0 PROJECT SUMMARY

1.1 Program: Nimbus Meteorological Satellite.

1.2 Project: Nimbus Meteorological Satellite.

1.3 System: Nimbus 1 (also Nimbus A).

1.4 Launch Date: August 28, 1964 (PMR).

1.5 Date of Data Sheet Preparation: March 14, 1966.

1.6 Nature of Mission: Meteorological Observations.

1.7 Flight Category: Earth Orbiter (Earth-Oriented).

1.8 Procuring Agency: NASA GSFC.

1.9 Contract Number: NAS5-978 (for integration and test).

1.10 Design Status: Nimbus 1 was intended as an operational spacecraft; however, Nimbus B and C are being reworked.

1.11 Manufacturers: NASA GSFC is prime contractor. (General Electric Missile and Space Vehicle Division is responsible for integration and test.)

2.0 MISSION AND SYSTEM SUMMARY

2.1 Primary Mission Objectives: Develop an operational meteorological satellite system to:

- Collect and distribute meteorological data both for immediate operational use and for the study of atmospheric processes;
- Develop spaceborne systems and ground techniques to provide a basis for advanced operational meteorological satellites; and
- Develop and flight test advanced meteorological sensors.

2.2 Design Approach: Nimbus is a second-generation meteorological satellite following the experimental and quasi-operational TIROS. In contrast to the spin-stabilized TIROS, Nimbus is a stabilized platform tailored to carry sensors for measuring a wide range of atmospheric phenomena. Nimbus 1 provides global coverage of the earth's daytime cloud cover by using a three-camera television subsystem which can store up to a two-orbit accumulation of three-frame pictures. Nighttime cloud cover is observed with an IR scanner sensitive in the 4-micron atmospheric windows. The Nimbus 1 APT Subsystem takes pictures of cloud cover over 1000-mile square areas and transmits the information directly to simple, inexpensive, ground stations within sight of the spacecraft.

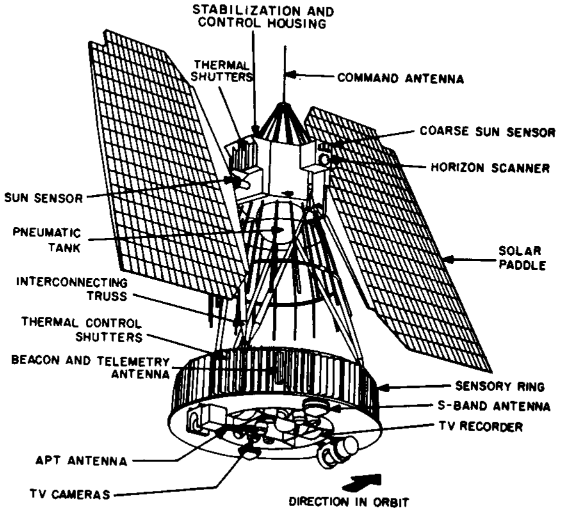


Figure 2.3-1. Nimbus Spacecraft

The need for viewing the entire earth each day dictated an earth-oriented vehicle in a polar orbit at an altitude between 500 and 1500 nautical miles. (Latitudinal coverage is then provided by orbital travel, longitudinal coverage is provided by rotation of the earth.) Considering the viewing, communications, and camera resolution requirements, orbit altitude was further restricted to between 500 and 750 nautical miles. To provide proper lighting for the camera subsystems, an 81-degree retrograde sun-synchronous orbit was ultimately selected, with an equatorial crossing time of local noon (and local midnight). (The choice of retrograde orbit matches the rate of orbital precession around the earth with the rate of the earth's rotation rate about the sun, thereby keeping the orbital plane in phase with the earth-sun line.)

2.3 Configuration: The Nimbus spacecraft is earth-oriented and stabilized in all three axes so that one area continuously faces the earth and has a fixed azimuth with respect to the spacecraft velocity vector. It consists of two rigidly interconnected structures. The upper, smaller structure contains the IR horizon sensors, gyros, pneumatics, inertia wheels, computer, inverters, and voltage and temperature regulators used to control the attitude of the satellite and keep it pointed to the local vertical. (See Figure 2.3-1.) The solar array is attached to the control subsystem and is stabilized normal to the sun while in orbit. (As the orbital plane drifts at the same rate as the earth moves around the sun, the solar power collectors need rotate only once per orbit around a single axis.) The low, larger structure houses the meteorological sensors. The lower structure also contains clocks, transmitters, and the telemetry, data storage, programming, command, and other electrical, electronic, and mechanical components required for the functioning of the meteorological subsystems.

2.4 Design Requirements:

2.4.1 Spacecraft Weight: 1000 pounds (maximum).

2.4.2 Stabilization Accuracy: $\pm 1^\circ$ (earth pointing).

2.4.3 Maximum Spacecraft Diameter: 5 feet.

2.4.4 Thermal: Maximum rate of change = 10°C/min.

2.4.5 General: Carry wide variety of sensors.

2.5 Orbital Parameters:

2.5.1 Launch Vehicle: THOR/AGENA B.
2.5.2 Apogee: 1000 km (600 nautical miles).
2.5.3 Perigee: 1000 km (600 nautical miles).
2.5.4 Inclination: 80.45° ± 0.5°.
2.5.5 Apogee/Perigee Difference (3 sigma): 30 nautical miles.
2.5.6 Period: 100 minutes.
2.5.7 Rate of Nodal Regression: 0.98 degree per day.
2.5.8 Injection Time: Local noon ± 30 minutes.
2.5.9 Launch Window: Midnight launch from PMR (Western Test Range, Vandenberg AFB).

2.6 Sequence of Launch Events: See Figure 2.6-1.

2.7 Operation and Mission Chronology: Immediately after injection, the spacecraft operates automatically to unfold the solar paddles and acquire the earth and sun. (See Figure 2.7-1.) Initial stabilization is achieved using a sun sensor, which subsequently provides error signals for solar-paddle orientation. The spacecraft is stabilized relative to the earth using IR horizon sensors and a rate gyro.

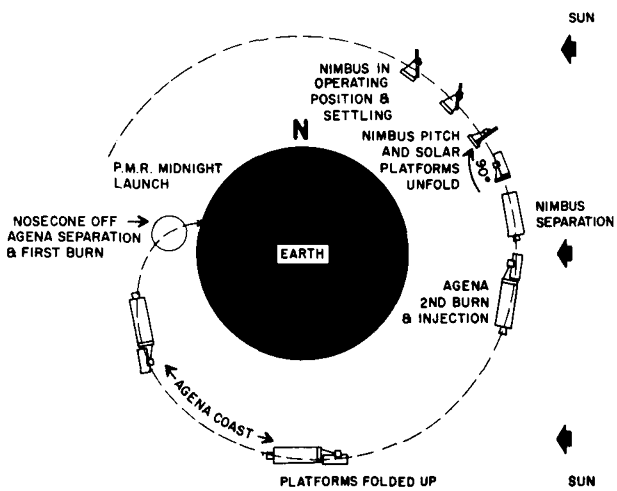


Figure 2.6-1. Nimbus Launch and Injection Sequence

After the spacecraft has been acquired by the ground station, all spacecraft functions may be controlled by ground command. For normal operational modes, the APT Subsystem provides real-time television continuously throughout daylight hours. AVCS and HRIR data are stored on magnetic tape and read out on command. The system design called for an operational life of six months, but mission life is fundamentally limited only by the gas available for stabilization propulsion.

2.8 Critical Mission Phases: All events noted in Figure 2.6-1 may be considered critical.

2.9 Post-Encounter Phases: Nimbus operations were planned to continue as long as useful data were obtained.

Figure 2.7-1. Plans for Spacecraft Events from Injection through Ground-Station Acquisition

ΔT* (seconds)	Event
90	Fire separation-ring squibs.
110	Yaw Agena-B by impulse from yaw jets.
110	Begin unfolding spacecraft paddles.
140	Complete unfolding spacecraft paddles.
140	Spacecraft IR horizon sensors begin search program. Pitchup of spacecraft begins.
1400	Solar platform sun sensors acquire sun.
1600	Solar platforms tracking sun.
1800	Spacecraft acquired by high-altitude acquisition site.

* Time after orbit injection (orbit injection approximately 3550 seconds after lift-off).

2.10 D[illegible] Return Modes:

- Television (APT): Continuous read-out of real-time data at 200 seconds/frame; 136- to 137-Mc band.
- Television (AVCS): Pictures stored on magnetic tape and transmitted upon command; 1700-Mc S-band transmission.
- HRIR: Signals multiplexed with other data and stored until read-out is commanded; 1700-Mc S-band transmission.
- Telemetry: 544 channels of stored and real-time telemetry data, transmitted PCM at 136.5 Mc; 4000 words stored per minute, and about 375,000 words transmitted in a 3.6-minute read-out.

For tracking, Nimbus 1 used a 350-milliwatt 136-Mc beacon to transmit the standard (AM) Minitrack time signal. When interrogation of telemetry is requested, the time signal is turned off and the PCM signal is played back from the tape recorder and tramsitted through the beacon transmitter.

2.11 Advanced Concepts:

Specifically and Immediately: Nighttime readout of HRIR data through the APT Subsystem, providing local HRIR data to local users. Incorporation of a medium-resolution IR subsystem (MRIR) to study the global heat budget.

Generally: Follow-on Nimbus flights will emphasize meteorological objectives more fundamental than the cloud-mapping problem which has previously dominated the meteorological satellite program. Follow-on flights will measure such atmospheric parameters as: temperature distribution; pressure density; wind velocity; water vapor; etc. Because a satellite cannot make direct measurements in situ, techniques being considered include use of indirect atmospheric sounding

2.11 Advanced Concepts: (continued)

("spectrometric inversion") and using the satellite as a data collection device which interrogates sensor platforms on the earth's surface and/or within the earth's atmosphere.

3.0 SYSTEM DESIGN

3.1 Functional Description:

3.1.1 System Block Diagram: Three advanced meteorological sensors were flown on Nimbus 1: the APT (Automatic Picture Transmission) Subsystem; the AVCS (Advanced Vidicon Camera Subsystem); and the HRIR (High-Resolution Infrared Radiometer) Subsystem. The APT (see Figure 3.1.1-1) is a slow-scan, relatively low-power subsystem which provides real-time television observations to local, inexpensive, ground stations. The AVCS provides a higher picture quality than had been previously obtainable.

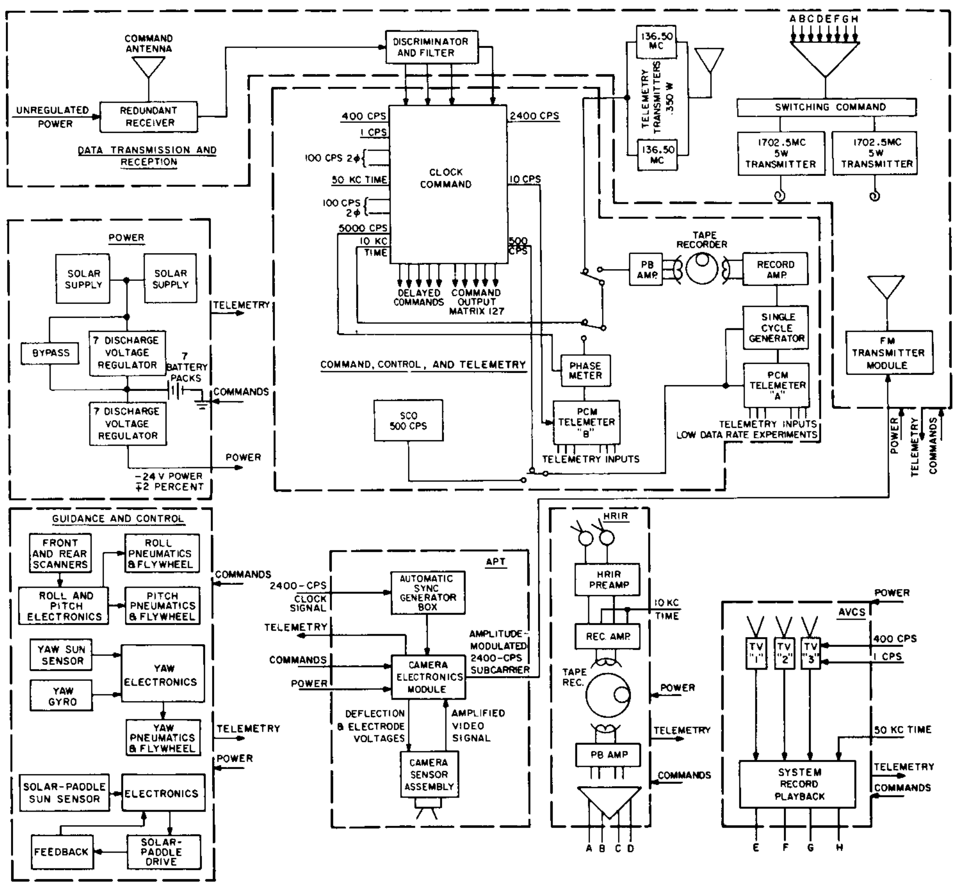


Figure 3.1.1-1. Nimbus Block Diagram

Spacecraft functions are controlled by an internal clock and by direct command from the command ground station. Routine commands allow readout of stored HRIR and AVCS data and provide for direct transmission of APT data. Both real-time and stored telemetry data are transmitted on command. The guidance and control subsystem operates continuously to maintain the proper orientation with respect to earth; the solar arrays are controlled through a sun-sensing loop to continuously track the sun.

The basic Nimbus subsystems are briefly described in the following paragraphs.

3.1.2 Power: The Nimbus solar-conversion power supply delivers -24.5 volts (regulated ± 2 percent) to meet the requirements of the experiments and spacecraft subsystems. Power is obtained from the sun and converted to electric power by two solar-oriented platforms. Each solar array measures approximately 3 by 8 feet and is covered with 10,500 2 × 2-cm (n-on-p) silicon solar cells. The power is transmitted from the arrays through sliprings on the solar platform shaft. Initial power output during periods of full solar illumination is 450 watts.

The solar array provides spacecraft primary power and also recharges seven nickel-cadmium storage batteries located within the sensory ring. The batteries have a 25-ampere-hour capacity and provide power for nighttime operation. Average regulated power available for spacecraft use is 170 watts.

3.1.2 Power: (continued)

The power supply was designed as a separate unit, but closely associated with the design of both the structure and control components. Solar power was chosen for best weight economy, and because it has sufficient reliability and longevity to be used for extended periods of time in a space environment.

When Nimbus is orbiting at 1000 km in a circular orbit, it spends 69 minutes in sunlight and 38 minutes in the earth's shadow. Therefore, during the period of sunlight 41.040 cm^2 of silicon cell surface area are available to intercept a maximum solar energy equivalent to 5700 watts. The power-supply design called for 2×2-cm silicon cells to be selected with efficiencies better than 10.5 percent (air-mass zero).

3.1.3 Guidance and Stabilization: The stabilization subsystem is a three-axis active torquing and damping system tailored to the mission requirements. Fore and aft infrared horizon scanners in the 12 to 16 micron region are used for pitch and roll attitude determination; a yaw gyro is used to sense the yaw attitude. (See Figure 3.1.3-1.)

Basic control is achieved through the use of three axially-aligned inertia wheels. Pneumatic jets compensate for accumulated torques which saturate the inertia wheels. The subsystem was tailored to achieve pointing accuracies in all three axes of ± 1 degree, with rates restricted to values below 0.05 degree/second to preclude picture smear.

Initial stabilization is achieved with the assist of near-vertical vehicle positioning prior to separation. Calibrated springs in the adapter are used to achieve low tip-off rates at separation. The horizon scanners acquire the earth and initial vertical stabilization is achieved through the pneumatic system and the inertia wheels. After vertical stabilization, yaw stabilization is activated.

Initial stabilization is accomplished by means of a sun sensor. The gyro is reset when Nimbus crosses from the earth's umbra into sunlight. The gas jets are mounted to provide control within ± 3 degrees to the local vertical. (A sufficient gas supply is carried to sustain operation for 6 months.) The inertia wheels, in conjunction with the gas systems, then stabilize the spacecraft to ± 1 degree. The flywheels function primarily to control periodic disturbances; the gas system will unbias the inertia wheels when maximum speed is reached and when steady disturbances occur.

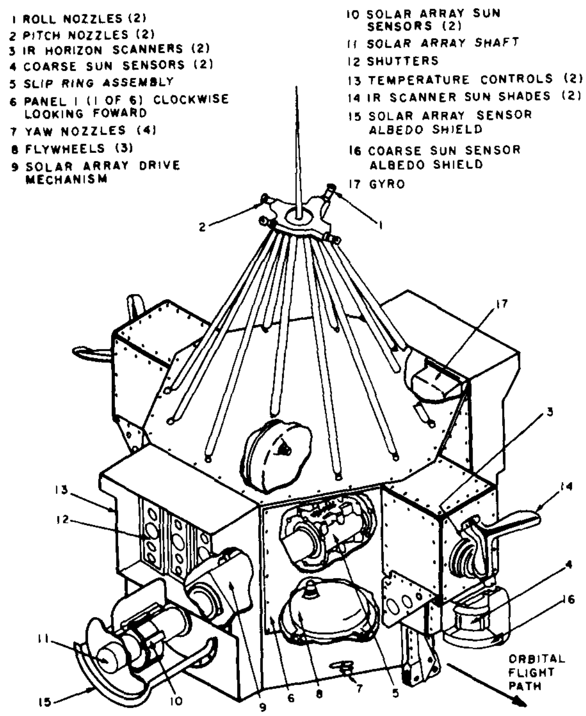


Figure 3.1.3-1. Spacecraft Guidance and Stabilization Assembly

3.1.4 Data Transmission and Reception: A two-way communication link between the satellite and ground tracking stations is provided by the data transmission and reception subsystem. Communications between the vehicle and the earth are required to perform the following functions: (1) reception of command and timing; (2) transmission of television data, telemetry, and satellite attitude information; and (3) generation of beacon tracking signals. Satellite commands and reference timing signals are received from the ground stations with a VHF AM/FM command reciever. A narrow-band VHF transmitter serves as the satellite beacon and is amplitude modulated to provide transmission of telemetry, attitude data, and timing data. AVCS and HRIR television pictures are transmitted with a frequency-modulated S-band transmitter. APT television pictures are transmitted with a frequency-modulated VHF transmitter.

Each transmitter or receiver uses its own antenna located on the spacecraft periphery. A whip antenna is mounted at the top of the vehicle between the solar paddles and is used with the command receiver in the 120-Mc range. Quadraloop antennas are used for transmitting the 136-Mc beacon signal and telemetry data. Four quadraloop antennas are mounted on the periphery of the sensory ring. A conical spiral antenna, mounted on the bottom of the satellite, is used for transmission in the 1700-Mc range. A quadraloop antenna, mounted at the bottom of the satellite, is used to transmit the APT television pictures in the 137-Mc range.

3.1.5 Command, Control, and Telemetry:

Command: The Nimbus command subsystem permits control of spacecraft functions from the ground stations. The command clock provides absolute time reference in days, hours, minutes, and seconds as well as a series of precise frequency outputs from 400-kc down to 1 cps, by means of accurate timing signals generated by an 800-kc crystal-stabilized oscillator.

3.1.5 Command, Control, and Telemetry: (continued)

Operating in conjunction with the clock, the command circuitry is capable of receiving and storing ground commands at the rate of one per second. A total of 128 different functions can be commanded through this subsystem, which can be expanded to handle up to about 256 functions. However, only 99 encoded and 4 unencoded commands were actually used in Nimbus 1.

Commands are in the form of binary coded information. Each command message is sent twice; if parity is verified on either transmission, the command is stored. Each command message contains an address which consists of the first twenty binary bits generated in the Clock. The information is in the Minitrack Time Code form. (The Clock time code can be set in orbit to any time desired through a coded command channel.) The Clock is capable of storing five commands which it executes when clock time reaches the stored command time. Any coded channel can be commanded in this manner. There are four unencoded command channels which consist of a pure tone for each channel: two channels are used to actuate battery bypass relays, a third is for emergency PCM operation, and the fourth is to recover time from the clock if the address fails.

Telemetry: Nimbus uses a pulse-code-modulated (PCM) telemetry subsystem to monitor subsystem test points. Low data-rate experiments can also be accommodated by the PCM subsystem, which handles real-time and stored telemetry data of 544 channels. The stored telemetry data are recorded on tape during a complete orbit and are played back on ground command. The real-time data are not stored on tape but are transmitted directly upon ground command. All data are gathered by the telemetry subsystem in analog form, converted to digital form, and transmitted by the 135.6-Mc transmitter. The telemetry subsystem stores 4000 words of data per minute, transmitting approximately 375,000 words of data in 3.6 minutes.

There are seven audio channels. The first four channels are amplitude modulated and are at 400, 560, 780, and 960 cps. The other three channels are frequency modulated and are at 1300, 1700, and 2300 cps. The three frequency-modulated channels are transmitted simultaneously. The amplitude-modulated channels are transmitted singly.

Telemetry information is recorded on 2 tracks of a tape recorder. One track contains all the information from low data-rate experiments and from "housekeeping" test points. The other channel is used for a timing signal from the electronic clock. Record speed is 0.4 inch/second. Playback speed is 12 inches/second. Two hundred feet of tape is stored in the recorder. A redundant recorder is part of the subsystem.

The stored telemetry data unit has a bit rate of 500 bits/second. Information is gathered in frames. Each frame contains 64 words of 8 bits each; one word is used for frame synchronization. The frame structure and sampling times are as follows:

- Word No. 1 — Frame synchronization.
- Word No. 2 — Subcommutation synchronization.
- Word Nos. 3 to 32 — Highest data rate 30 channels — 1.024 second sampling rate.
- Word Nos. 33 to 64 — Subcommutated to provide a large number of information channels.

The direct telemetry unit has a bit rate of 10 bits/second. The maximum number of words is 128, including a synchronization word. The unit is energized and de-energized on command from the ground station. The unit is de-energized upon completion of one frame. The output information bits phase-shift-modulate a 4000-cps coherent subcarrier and then amplitude-modulate a 136-Mc transmitter.

3.1.6 Structure and Thermal Control: The Nimbus spacecraft consists of three major elements: a 56-inch torus ring that forms the base of the spacecraft and houses the major spacecraft electronics; a smaller hexagon-shaped housing, connected to the ring by a truss, that houses the attitude stabilization and control system; and the two large solar paddles. The basic material for the structure was magnesium because of its favorable strength-to-weight ratio. The spacecraft features the following design characteristics:

- A large base area for earth viewing instruments;
- A mass distribution with a favorable gravity-gradient orientation to support stabilization requirements;
- A separable control package;
- A modular torus design consisting of 18 uniformly sized bays;
- A large central area to house large units; and
- Active thermal controllers on each bay.

3.1.7 Television:

3.1.7.1 Advanced Vidicon Camera Subsystem (AVCS): The AVCS provides cloud-cover pictures of the sunlit portion of each orbit with a ground resolution of about one-half mile, and consists primarily of a bank of three synchronized TV cameras and a magnetic tape recorder. The three TV cameras are deployed in a fan-like array to produce a three-segment composite picture 107 degrees by 37 degrees, providing the lateral field of view (with 2 degrees overlap at the equator) necessary to cover the 27-degree rotation of the earth between spacecraft passes; the 27-degree rotation of the earth produces approximately 1620 nautical miles of arc at the equator. Pictures are transmitted over a 1700-Mc S-band antenna located on the bottom of the sensory ring.

3.1.7.2 Automatic Picture Transmission (APT) Subsystem: The APT subsystem permits transmission of local, daytime cloud-cover pictures directly to local users in real time. It is similar to the AVCS but does not have a tape recorder. It consists primarily of a vidicon tube capable of long-duration storage and a very slow readout rate. Pictures are read out at a rate of 200 seconds/frame, compared to 6.5 seconds/frame for the AVCS, and transmitted over a narrow bandwidth. The narrow bandwidth permits the use of relatively simple and inexpensive ground-station equipment. (Fifty such ground stations located throughout the world were built before the Nimbus 1 launch. The stations are operated by the United States Weather Bureau, the meteorological services of the United States Armed Forces, foreign weather services, and, in some cases, by educational institutions. Additional stations will be built in the future.)

3.1.8 High-Resolution Infrared Radiometer (HRIR) Subsystem: The HRIR senses earth radiation in the 3.6 to 4.2 micron region to produce cloud-cover pictures of the nighttime portion of the orbit. Because this spectral region is in the atmospheric "window" region, it provides measurements of the equivalent blackbody temperatures of the radiating surfaces. The subsystem has an accuracy of ± 1°K and a resolution of about eight kilometers. Thus, high-resolution maps of either earth temperatures or cloud-top temperatures are achieved.

The HRIR consists of an optical system, a photoconductive detector, and associated electronic and mechanical components enclosed in a suitable housing. The HRIR magnetic-tape recorder is mounted on the H-frame within the sensory ring. In contrast to television the radiometer forms no image, but instead integrates the energy received from the target. A picture is composed by a scanning mirror technique. The mirror, located in the radiometer, scans the earth from horizon to horizon as the satellite advances in its orbit. The scan rate of 45 rpm was chosen to match the satellite's forward velocity in order to achieve contiguous coverage. The mirror reflects the received energy and focuses it on a mechanical chopper, which provides the necessary modulation of the energy signal. The modulated signal actuates the detector, which produces an electrical output signal corresponding to the energy signal intensity. After suitable preparation, the HRIR output is recorded on the HRIR tape recorder.

The signals are multiplexed with other spacecraft intelligence, and the composite signal is transmitted by the 1700-Mc S-band transmitter upon ground command. The picture is reconstituted at the ground station by a facsimile recorder and is immediately available for analysis. The analog electrical signal is also digitized to permit detailed quantitative analysis.

3.2 Mechanization Approach: A distinctive feature of the Nimbus spacecraft is the complete modular design approach. The separate and independent control system, together with a sensory ring design consisting of 18 separate module bays, allows for separate development, evolution, and improvement of individual subsystems with a minimum of interface problems. To further assure ease of integration and flexibility in accommodating a variety of experiments, each Nimbus assembly must be packaged in conformance with one of eight predetermined module sizes. (Refer to Paragraph 3.3.) This flexibility is required to permit the smooth product improvement and evolution which is fundamental to the Nimbus concept.

3.3 Performance Characteristics:

3.3.1 Weight and Volume:

3.3.1.1 Spacecraft Weight: 831 pounds.
3.3.1.2 Experiment Weight: 138 pounds.
3.3.1.3 Overall Dimensions: With paddles extended, 9.5 feet high by 9.5 feet wide.

3.3.2 Power:

3.3.2.1 Maximum Power Available: 450 watts.
3.3.2.2 Required for "Housekeeping": 92 watts average.
3.3.2.3 Power Profile: See Figure 3.3-1.

3.3.3 Stabilization Accuracy*:

- Pitch: ± 1°
- Roll (in direction of velocity vector): ± 1°
- Yaw (local vertical): ± 1°
- Pointing of Solar Arrays: ± 10°
- Angular Rates: less than 0.05°/second.

3.3.4 Stabilization Mode: Gas jet and inertial; earth-oriented using horizon sensors.

3.3.5 Operational Life: Six months.

Figure 3.3-1. Subsystem Weight and Power Requirements for Nimbus 1

Subsystems	Weight (lbs)	Power Requirements (watts) Earth Day*	Earth Night*	Interrogation
Torus	72.6			
Truss	8.7			
Controls	174.7	71.05	71.05	
Solar Paddles (2)	75.5			
Power Supply	126			
AVCS	78.7	27.3	1.5	10.5
HRIR	32.1	1.47	13.5	12.04
S-Band Transmitter	20.7			145
APT	27.2	40.1	0.3	
Clock/Command	34.4	9.3	9.3	
Telemetry	46.7	11.42	11.42	8.1
Miscellaneous	133.7			
TOTAL	831.0	160.64	107.07	175.64

* Not including interrogation load.

3.3.6 Command Capability: 99 encoded commands, 4 unencoded.

* Stabilization accuracy not achieved in flight; refer to Figure 4.1-1.

3.3.7 Data Transmission: See Figure 3.3.7-1.

3.3.8 AVCS (Television Experiment):

Ground Resolution: 0.5 mile.
Focal Length: 16.5 mm.
Effective Focal Length: 76.0 mm.
Scanning Time: 6.5 seconds/frame.
Dynamic Range: 14 foot lambert (at f/4) to 11,400 (at f/6).
Limiting Resolution: 725 lines.
Coverage: 107° (for 3-camera array).
No. Pictures/Orbit: 96.
Smear: Less than one-half TV line (500 nautical-mile orbit).
Vidicon Sensitivity: 0.004 to 0.4 foot-candle second.
Time Between Frames: 92 seconds.
Linearity: 0.5 percent.

3.3.9 APT (Television Experiment):

Limiting Resolution: 700 lines.
Scan Rate: 4 lines/second.
Scanning Time: 208 seconds (200-second scan plus 8-second "recovery").
Linearity: 0.5 percent.
Sensitivity: 0.7 foot-candle second to 0.03 foot-candle second.

3.3.10 HRIR (High-Resolution Infrared Radiometer Experiment):

Ground Resolution: 2 to 5 miles (± 1°K).
Spectral Response: 3.4 to 4.2 microns.
Detector Material: PbSe.
Output Signal Levels: -6 volts (for 360°K) to zero volts (for 4°K).

Figure 3.3.7-1. Nimbus Data Transmission Characteristics

Transmitter Designation	Type of Data Transmitted	Frequency	Modulation	Output Power (watts)
S-Band Transmitter	HRIR and AVCS video	1700 Mc	FM, 30 cps to 750 kc	5
Beacon Transmitter	Beacon and Telemetry	136.5 Mc	80% AM, by 15- or 5-kc subcarrier	0.35
APT Transmitter	APT (slow-scan) video	137 Mc	FM, 2400-cps subcarrier	5

3.4 Unique Developments: Nimbus was the first spacecraft to permit complete earth coverage on a daily basis, achieving this goal by combining a polar orbit with an earth-oriented three-axis stabilization subsystem. It was also the first spacecraft to provide right time (HRIR) pictures of the earth's cloud cover. The Nimbus APT Subsystem provided local cloud-cover observations to local, relatively simple, ground stations, thus providing the feasibility of using satellite systems for local meteorological observations.

3.5 Reliability:

3.5.1 Reliability Figure: See Figure 3.5.1-1.

Figure 3.5.1-1. Reliability Figures for Nimbus 1 Subsystems

Time, Months	Structure	Thermal	Control	Clock	Power Supply	AVCS	HRIR	APT	PCM Unit A	PCM Unit B
1	1	0.975	0.843	0.902	0.986	0.920	0.978	0.965	0.887	0.941
2	1	0.952	0.711	0.813	0.952	0.847	0.956	0.930	0.787	0.885
3	1	0.928	0.599	0.733	0.904	0.779	0.934	0.897	0.698	0.833
4	1	0.905	0.506	0.660	0.848	0.717	0.913	0.866	0.618	0.783
5	1	0.883	0.426	0.595	0.787	0.655	0.893	0.835	0.544	0.737
6	1	0.862	0.359	0.536	0.725	0.615	0.873	0.805	0.475	0.693

3.5.2 Reliability Approach: Based on the experience accumulated during the design of the TIROS satellite, a large amount of redundancy was considered desirable. Redundancy can be provided in spacecraft systems in two ways — either by duplication of entire subsystems, or by making use of identical components among subsystems. The first approach is only a small step towards the final goal of achieving integrated redundancy in spacecraft systems. However, Nimbus 1 used only redundant subsystems and not integrated component redundancy; redundancy was not included to the extent originally planned because of weight restrictions.

4.0 FLIGHT PERFORMANCE

4.1 Spacecraft Performance: There were two significant deviations from planned performance:

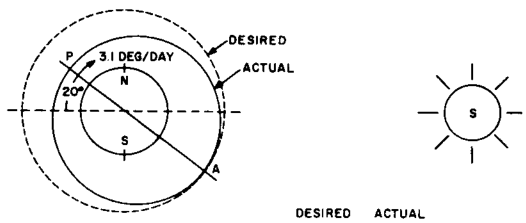
- The orbit was highly elliptical (932-km apogee, 423-km perigee) rather than circular; and
- A failure in the solar-array drive mechanism caused subsystem operations to be suspended after 26 days in orbit.

4.1.1 Orbit Achievement and Overall Performance: Nimbus 1 was launched from the Western Test Range at 0756 UT on August 28, 1964. The first-stage Thor performance was nominal. However, the second burn of the Agena stage was shortened by about 2 seconds owing to fuel exhaustion. Therefore, the desired 930-km circular orbit was not attained. Instead, an elliptical orbit, with a 932-km apogee and a 423-km perigee, was obtained. Figure 4.1.1-1 compares its characteristics with the desired orbit. The initial perigee was located at 20 N and moved northward at 3.1 degrees per day. Fortunately, an acceptable degree of sun synchronism was obtained so that no power supply degradation would result. Thus, although the desired orbit was not obtained, the orbit achieved did not seriously compromise the major mission objectives.

The anomaly in the orbit had a number of significant impacts on the mission, the most serious of which were the following:

- Loss of data caused by an increase in the number of blind orbits per day (up from the expected 2 to 3 per day to 2 to 7 per day);
- Significant gaps in successive TV picture frames on the perigee side of the orbit; and
- The lower altitudes increased the sensitivity of the control system horizon scanners to cold clouds, with a resultant increase in the pneumatic gas utilization. (Refer to Paragraph 4.1.3.)

On the other hand, the orbital anomaly did provide some benefits. Resolution for both the TV picture and HRIR data was improved and covered a range of values from the expected resolutions twice as high. With the exception of the large difference in apogee-perigee, almost all the mission requirements were achieved as planned and in some cases were exceeded. (See Figures 4.1.1-2 and 4.1.1-3.)



	DESIRED	ACTUAL
ORBIT (MI)	576	579-263
(KM)	929	932-423
PERIOD (MIN)	103.5	98.7
HIGH NOON	±8°	-8.1°
SUN SYNC. (DEG/MO)	±2.3	+3.3
ORBITS/DAY	13.9	14.7
BLIND ORBITS/DAYS	2-3	2-7

Figure 4.1.1-1. Actual Orbit Achieved for Nimbus 1

Figure 4.1.1-2. Nimbus 1 Performance Summary (August 28 to September 23, 1964)

Total Orbits	379
Blind Orbits	125
AVCS Data	190 (12,000 pictures)
HRIR Data	178 (6,000 minutes)
APT Data	171 (1,930 pictures)

4.1.2 Power Subsystem:

4.1.2.1 Solar-Array Orientation: The decision to terminate the flight after 379 orbits was based primarily on the failure of the solar-array drive mechanism. This failure occurred on the morning of September 23, 1964, in orbit 371, and was detected by the telemetry which indicated no paddle rotation with maximum voltage applied to the drive motor. The paddles were frozen in a near vertical position. The flight failure was subsequently duplicated in a series of post-flight ground tests, and it was concluded that failure was caused by excessive temperature in the motor bearings, chemically degrading the lubricant to its soap base.

Starvation of the power supply thus led to battery depletion, which in turn fed wrong voltages to the attitude control electronics, causing large momentum errors by firing excessive gas, finally resulting in a spin-up about the maximum inertia roll axis. However, a favorable paddle aspect did supply adequate daytime power for limited spacecraft activity over a period of several months. The spacecraft was monitored continuously during this period to assess subsystem performance.

4.1.2.2 Power Supply Electronics: The Nimbus 1 power supply functioned properly during both the nighttime and daytime portions of the orbit and provided all required power from launch until failure of the solar-array drive mechanism. The solar array provided an average current of 13 amperes, which was within design

Figure 4.1.1-3. Nimbus 1 Flight Performance versus Design Objectives

Parameter	Design Objectives	Actual
Attitude Control		
Pitch	± 1°	± 2°
Roll	± 1°	± 3°
Yaw	± 1°	± 8° - 10°
Paddle Pointing	± 10°	± 2°
Power (max)	450 watts	470 watts
Power (avg)	170 watts	160 watts
Current (avg)	13 amps	13 amps
Thermal Control		
Sensory Ring (avg)	25° ± 10°C	22° ± 1-1/2°C
Control Housing (avg)	25° ± 10°C	25° ± 3°C
Data Transmission	400 million bits/orbit	Achieved

4.1.2.2 Power Supply Electronics (continued): specification, and maximum power output of 470 watts, which exceeded the original maximum power requirement by 20 watts. The supply delivered -24.5 volts regulated to within ± 2 percent. Battery voltages were maintained within specification through the use of auxiliary and compensating loads. No degradation in solar-cell power output was observed during the short life of the spacecraft.

4.1.3 Guidance and Stabilization: Separation and solar-paddle deployment maneuvers were executed as programmed, and initial stabilization was accomplished as planned with a minimum of gas expenditure. As the control system was designed for a 500-nautical-mile circular orbit, strain was placed on it by the low-perigee orbit. The system worked satisfactorily, but several anomalies occurred.

The control system depends on the large relative temperature difference between the earth and cold space to define where the earth's horizon is in order to align the yaw axis of the spacecraft to the local vertical of the earth. When a cold cloud is near the edge of the earth, the horizon scanners make an erroneous determination of the horizon location, and thus the attitude control system will point the spacecraft erroneously. Owing to the lower altitude, the clouds appeared larger, and therefore the attitude errors were larger than they would have been for a proper circular orbit. The performance specifications had restricted allowable errors to a maximum of ± 1 degree, and allowable error rates to ± 0.05 degree/second. The flight data indicated that the specifications were not met, and errors up to a few degrees and rates up to 0.25 degree/second were observed.

Because of these larger motions, much gas was wasted. The pneumatics fired in equal and opposite directions to cancel out spurious rates caused by the clouds. The yaw axis, being coupled through a gyrocompass to the roll axis (which in turn was very sensitive to cloud disturbances), moved nearly five times as much as the other axes, and thus was the greatest consumer of gas. As, at this rate, the gas supply would not have lasted for the design goal of 6 months, the yaw pneumatics were turned "off" by ground command, thereby increasing the gas life to more than 6 months.

4.1.4 Telecommunications: The telecommunications equipments performed satisfactorily throughout the operational life of the spacecraft. However, some minor anomalies did occur.

4.1.4.1 Command and Control: Clock time remained within one second of standard for more than 612 hours, during which time approximately 9025 commands were transmitted. A total of 26 anomalies occurred, two involving unintentional playback of PCM, and 24 involving unexecuted encoded commands, many of which were transmitted at low station-antenna angles.

4.1.4.2 PCM Telemetry: PCM telemetry performed well within design specifications, although an unknown triggering source caused the telemetry count to be prematurely incremented. This phenomenon was uncontrollable from the ground and accounted for a small portion of the error rate.

4.1.4.3 Data Transmission: All transmitters operated satisfactorily, although there was some minor difficulty experienced with the S-band system — that is, during early orbits there was some S-band interference with the APT pictures, and on a few occasions the ground stations had difficulty in tracking the narrow S-band beam. Generally, however, useful data were received on all links, down to very low elevations (and frequently down to horizon levels).

4.1.5 Structure and Thermal Control: During the operational life of Nimbus 1, a continuous temperature record was maintained of the solar-array paddles, sensory ring, and control housing. The structure subsystem performed to design specifications. (See Figure 4.1.1-3.)

The temperature of the solar-array paddles remained well within the design limits, from a positive peak excursion of +64.0°C to a negative peak excursion of -66.9°C. The maintenance of relatively uniform temperatures on the sensory ring and control housing during flight amply justified the incorporation of a shutter type of temperature-control system.

4.2 Experiment Performance:

4.2.1 AVCS (Advanced Vidicon Camera Subsystem): Judged by the quality of the video data received and processed, the overall performance of the AVCS during the active life of the spacecraft was excellent. However, detailed evaluation of picture quality indicated that the pictures were somewhat overexposed at the equator and underexposed near the poles, reflecting improper settings in the automatic iris settings. (This deficiency has been corrected for later flights.)

As indicated earlier, the low perigee orbit combined with the fixed optics to produce gaps in the picture coverage. These gaps degraded the usefulness of the pictures. The large perigee-apogee difference of 263 to 579 nautical miles provided the advantage of having a variable resolution capability. The AVCS resolution in the desired circular orbit of 576 nautical miles would normally be 1/2-mile; however, the resolution improved to 1/4-mile in the perigee part of the orbit. From a research point of view, the variation in resolution provided new data for evaluating the utility of high resolution.

AVCS picture data were obtained from 190 orbits during the 26-day spacecraft life. A total of 12,100 frames of data were collected.

4.2.2 APTS (Automatic Picture Transmission Subsystem): The overall performance of the APTS during the operational life of the spacecraft was most satisfactory. The subsystem operated for a total period of 6,999 minutes, 315 minutes of which were during dark periods of the orbit. During 171 orbits of operation, ground stations acquired 1,903 of the approximately 2,000 pictures transmitted by the APTS.

4.2.2 APTS (Automatic Picture Transmission Subsystem): (continued)

The experience with the APTS on Nimbus conclusively demonstrated to many meteorologists that the wide-area coverage obtained with the direct-picture system provided very adequate cloud-cover data for almost all local forecast requirements.

4.2.3 HRIR (High-Resolution Infrared Radiometer Subsystem): Perhaps the most impressive achievement of the Nimbus 1 flight was the outstandingly successful operation of the HRIR subsystem, which provided continuous nighttime cloud-cover pictures with resolutions from 2 to 5 miles. It was successful in resolving equivalent blackbody temperatures of the radiating surfaces within about ± 1°K, thus permitting a gross resolution of the heights of clouds. This latter feature has added a "third dimension" to the observation of clouds from meteorological satellites.

During 178 orbits, the ground stations recorded 6,000 minutes of HRIR data on tape, to be used for further analysis. Although the HRIR subsystem was designed for nighttime use only, experiments were conducted to determine its utility for daylight observations.

4.3 Failure Modes and Effects:

4.3.1 Early Burn-Out of Agena B: The second burn of the Agena B was about two seconds shorter than intended, evidently because the fuel was exhausted. Thus, although the spacecraft achieved the desired 932-km altitude, the available thrust was not sufficient to provide a circular orbit, and the Nimbus 1 orbit was elliptical, with an apogee of 423 km. The most serious effect of the orbital variation was the fact that the horizon scanners were sensitive to cold clouds that appeared within their field of view. In order to prevent early depletion of the gas reserves available for attitude control, operation of the attitude-control subsystem was limited by ground command, causing the stabilization accuracy to be less than planned.

4.3.2 Failure of Solar-Array Drive Mechanism: The greatest anomaly occurring during the Nimbus 1 flight was the failure of the solar-array drive mechanism. This failure occurred on the morning of September 23, 1964, during orbit 371. Telemetry data indicated that there was no paddle rotation, even with maximum voltage applied to the drive motor. This failure was subsequently duplicated in a series of post-flight ground tests, and it was concluded that the failure was caused by excessive temperature of the motor bearings, chemically degrading the lubricant to its soap base.

With no ability to orient the solar arrays, the batteries were eventually depleted. Before full battery depletion, the resulting change in voltage supplied to the attitude-control electronics caused large attitude errors which, in turn, caused excessive firing of the gas jets. Thus, the spacecraft built up an uncorrectable spin up about the maximum-inertial roll axis. Even after failure of the solar-array drive, however, a favorable aspect with respect to the sun provided sufficient power for limited spacecraft activity over a period of several months.

5.0 PROJECT POLICIES AND REQUIREMENTS

5.1 System Tradeoffs: The Nimbus spacecraft was conceived at a time when TIROS I had not yet been launched, although the development experience from the TIROS satellite was available. The design was aimed primarily at support of the basic sensors which would measure atmospheric phenomena; therefore, many of its features were tailored specifically to the requirements for continued television coverage of the earth, and for infrared radiation measurement. It was obvious that a stabilized platform would be most useful for the measurement of terrestrial phenomena, and that consequently a stabilization and control system would be needed; it was also recognized that the design of such a control system would be the most significant advance in the state-of-the-art beyond the TIROS satellite. To minimize the effort of developing the control system, many features of the design were chosen to keep it as simple as possible.

Other important design considerations for Nimbus were a high degree of flexibility, making it possible to change sensors and experiments in the future, and to take advantage of advances in technology with the fewest possible modifications to the structure. Constraints placed on the system design included complying with dimensions and weight requirements of a medium-size booster system (the Thor-Agena B) and the design objective of a 6-month lifetime, which dictated the use of state-of-the-art components and techniques.

One of the factors that led to the choice of a high-noon retrograde orbit was that of placing the least possible burden on the development of the control system. The orbital plane drifts around the earth when the satellite is launched with an arbitrary inclination; by choosing an 80-degree angle from the equator toward the southwest, the orbital drift is exactly that of earth' s rotational movement around the sun, so that the earth-sun line always remains in the orbital plane. As a consequence, the solar-power collectors have to rotate about only one axis.

Other features of the control system resulted from the requirements of the TV cameras; the design objective was to point as accurately as ± 1 degree in all three axes and at a rate slower than 0.05 degree/second. The conflicting requirements of a low orbit for best TV camera resolution, and a high orbit for the maximum area of TV coverage, was reconciled by the choice of a 600-nautical-mile altitude orbit. (Changing this orbit to 500 nautical miles or to 700 nautical miles makes no significant difference in the system parameters.)

Finally, a mechanical design promoting a flexible system was chosen, with the control system connected at only three points to the rest of the spacecraft, and the sensory ring subdivided into modules for easy replacement and serviceability.

5.1 System Tradeoffs (continued): The spacecraft design had to comply with the testing philosophy of the project, which essentially dictates that an entire orbital flight must be simulated on the earth; this posed the requirement for the spacecraft center of gravity to be accessible. In the present arrangement, the control system is assisted by the mass distribution of the spacecraft structure, balanced and connected like the end sections of a dumbbell.

Further advantage of the structural design include the large base area available for interference-free installation of optical sensors and scanners. The multiple compartments in the sensory ring make it possible to balance the spacecraft and to maintain this balance even when changes in subsystems occur; the cylindrical volume in the sensory ring offers flexibility for the packaging of bulky equipment, such as tape recorders and cameras. Alignment of the control system is easy, since only three points are affected. Alignment of cameras can also easily be accomplished within the sensory ring. Relatively high packing density in the electronic compartments of the sensory ring helps to maintain an isothermal range in this portion of the spacecraft. Thermal control on individual compartments is provided, in order to maintain as narrow a temperature range as practical under given load conditions, the optimum being 25°C with ± 10°C deviations. Many subsystem compartments are regulated ± 3°C.

The guidance and control subsystem is the only subsystem where an initial design objective had to be modified substantially. Although it appeared desirable, initially, to stabilize within a cone of 2 degrees centered at the principal axis of the spacecraft, difficulties encountered later in the error detector of the control system relaxed this requirement to approximately 3 or 4 degrees. Accuracies could not be improved because of inherent limitations in the error detector; only the use of a more advanced type, such as the one used in the Orbiting Geophysical Observator (OGO) satellite, can alleviate this situation.

5.2 Specifications and Standards Invoked:

Quality Assurance:	NPC 200-2, 200-3, and 200-4; NPC 250-1; Semi-Conductor Burn-In Specification GSFC 5-650-P-1.
Management:	NASA General Management Instruction 4-1-1, "Planning and Implementation of NASA Projects" (revised March 8, 1963).

5.3 Quantity of Systems Fabricated or Planned:

5.3.1 Flight Models: Three (of which Nimbus 1, or Nimbus A, was the first).

5.3.2 Prototype Models: One.

5.3.3 Test Models: Three mechanical test models: one mock-up for dynamic tests of separation and shroud clearance; one mechanically correct model, including a qualified sensor and simulated controls subsystem, for vibration tests; and one mechanically and dimensionally correct full-scale mock-up, or preprototype.

5.4 Test Program:

5.4.1 Test Philosophy: Suppliers of subsystems and/or experiments were individually responsible for qualification tests of their equipments. As the prototype test program was intended to demonstrate "a sufficiently conservative margin of design safety in the complete spacecraft and all subsystems," qualification levels were more severe than anticipated flight environments. The flight acceptance test program was intended to demonstrate "the successful reproduction of the complete spacecraft and all its subsystems," and acceptance test levels were the best possible simulations of those anticipated in flight.

A special environmental test committee, established by the NASA/GSFC Project Manager, was responsible for monitoring and rejecting or accepting results of qualification and acceptance tests. This committee made periodic reports to the GSFC Project Manager to recommend changes in the program or test levels as dictated by new information. (The committee consisted of four members. The chairman was a representative of the GSFC Meteorology Branch; the other members were a test coordinator from the GSFC Test and Evaluation Division, and an electronic engineer and a senior mechanical engineer from the system integration contractor.)

5.4.2 Environmental (Qualification) Test Levels: See Figure 5.4.2-1.

5.5 Supporting Equipment:

5.5.1 NTCC: A Nimbus Technical Control Center (NTCC), was established at GSFC to provide ground control of the spacecraft and coordinate the data retrieval and processing efforts.

Prolonging the life of the batteries is the most important consideration in programming the spacecraft. Therefore, stored-A telemetry, which offers the information required to know the status of the battery, is treated as the prime telemetry mode. The acquisition of telemetry data for the safety of the spacecraft has priority over meteorological data.

Coordination is maintained with the TIROS Technical Control Center to coordinate camera utilization of both systems. Communications between NTCC and other facilities of the Nimbus system are maintained by voice and teletype circuits and wide-band data links. Voice communications between NTCC, GILMORE, ROSMAN, the GSFC/NDHS, and PMR are provided via the SCAMA network. Teletype receiving equipment is located in NTCC for receiving spacecraft data and operational reports. Facilities for transmission of teletype messages are available in SOCC.

5.5.1 NTCC: (continued)

Selection of the mode of data processing and priority of data transmission is a responsibility of NTCC. ROSMAN transmits raw sensor and telemetry data in real time to the GSFC/NDHS for processing. Selective data are processed at both NDHS facilities for NTCC operational and engineering evaluation.

5.5.1.1 Data Required: To accomplish its mission, NTCC requires continuous spacecraft and ground equipment data as follows:

- Launch countdown status and time, Agena B second ignition, pitchup, separation, solar-paddle deployment, control system activation;
- Predicted spacecraft position for at least one week in advance;
- Spacecraft interrogation schedules;
- Spacecraft time and Greenwich mean time;
- Values of all spacecraft telemetered functions; and
- All operational modes.

5.5.2 Special Test Equipment: Four adapter and separation devices, for mating the spacecraft to the launch vehicle, were required for test operations.

Figure 5.4.2-1. Nimbus Qualification Test Levels

Sinusoidal Vibration: Three 2-minute sweeps of 5 to 14 cycles, one 40-minute sweep of 14 to 3000 cycles.

Frequency Range (cps)	Amplitude (in g, 0-peak)	
	Thrust Axis	Transverse Axes
5-14	1/4" 0-peak	1/4" 0-peak
14-400	5	1.5
400-3000	10	3

Random Vibration: 4 minutes in each direction, or 12 minutes total.

Direction	Frequency Band (cps)	Spectral Density (g^2/cps)	g rms
Thrust Axis	20-2000	0.07	11.5
Transverse Axes	20-2000	0.07	11.5

Acceleration

Direction	Level	Duration
Thrust Axis	15 g	5 minutes
Transverse Axes	3 g	5 minutes

6.0 PROJECT MANAGEMENT AND ORGANIZATION

6.1 Type of Management Organization: Goddard Space Flight Center (GSFC) was assigned the overall responsibility within NASA for the execution of the Nimbus project. To meet this responsibility, GSFC assigned full responsibility for execution of the project to the Nimbus Project Office, organized as part of the Aeronomy and Meteorology Division. Figure 6.1-1 shows the basic organization structure of the Nimbus Project Office, which consists of the project manager and his immediate technical and administrative staffs, comprising about 20 people.

Actual development of the various systems is assigned to the following four systems managers:

- The launch vehicle manager at Marshall Space Flight Center (the center responsible for providing the Thor-Agena vehicle);
- The spacecraft manager at GSFC;
- The data-acquisition manager at GSFC; and
- The data-utilization manager at the U.S. Weather Bureau (full-time project assignee).

Each of the managers calls on the organizations involved for the support required to accomplish their missions. This support includes the technical officers responsible for the management of individual contracts, as well as various technical and administrative specialists who assist them in directing and managing the individual activities.

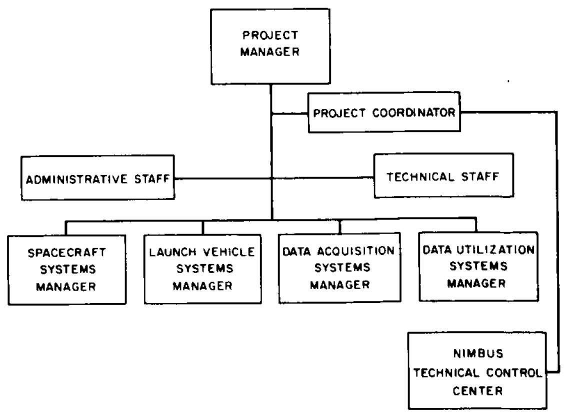


Figure 6.1-1. Organization of the Nimbus Project at GSFC

In all, about 100 government employees were directly occupied on a full-time basis in developing the Nimbus system. This group, in a sense, constituted the prime contractor on the Nimbus project, and provided the overall system engineering, the subsystem technical management, and the administrative management for the project. Responsibility for integration and test was contracted to the General Electric Missile and Space Vehicle Division (see Figure 6.1-2).

Developing the actual hardware for the various systems required the services of many industrial concerns to assist in the design, fabrication, test, and operation of the various systems. Some 15 major contracts, 11 separate contractors, and numberous subcontractors were involved in the development of the spacecraft system alone. An estimated 3000 to 4000 government and industry people were engaged in the Nimbus program on essentially a full-time basis.

6.2 Project Organization: See Figures 6.1-1, 6.2-1, and 6.2-2.

6.3 Project Plan: The overall program plan (see Figure 6.3-1) shows in broad terms the planned schedule for prototype and flight spacecraft development, integration, and testing. Estimated completion dates for the ground stations are also shown. Each of the spacecraft subsystems is developed independently by each contractor, with appropriate management and coordination by technical officers and the spacecraft manager. The systems are then collected, integrated into the spacecraft at the General Electric Company, and tested as a complete system. (See Figure 6.3-2.)

Figure 6.2-1. Identification of Primary Nimbus Spacecraft Contractors

Task	Responsible Contractor
Integration and Test	GE Missiles and Space Division
Controls and Stabilization	GE Missiles and Space Division
Advanced Vidicon Camera Systems	RCA Astro-Electronics Division
S-Band Transmitter	General Electronics Laboratory
PCM Telemetry	Radiation, Inc.
PCM/AM Transmitter	Hughes Aircraft Company
Command Clock	California Computer Products
Clock Receiver	RCA Astro-Electronics Division
Solar Power	RCA Astro-Electronics Division
PCM Tape Recorder	Raymond Engineering
High-Resolution Infrared Radiometer	International Telephone and Telegraph
High-Resolution Infrared Radiometer Tape Recorder	RCA Astro-Electronics Division
Automatic Picture Transmission	RCA Astro-Electronics Division

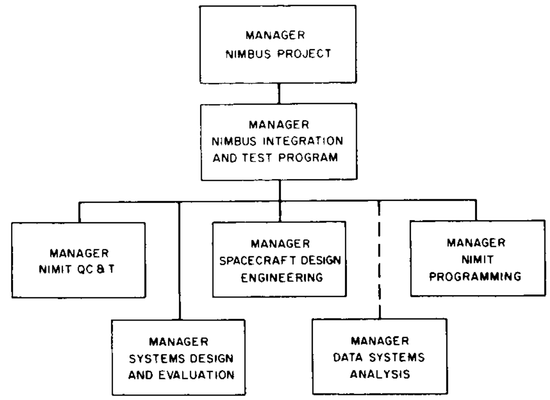


Figure 6.1-2. Organization Chart for Nimbus Integration and Test (at General Electric Missile and Space Vehicle Division

Figure 6.2-2. Identification of Secondary Nimbus Contractors

Task	Responsible Contractor
Launch Vehicle	Lockheed Missile and Space Co.
Separation System and Shroud	Douglas Aircraft Company
85-Foot Antenna	Rohr Corporation
Antenna Electronics	Collins Radio Company
Reliability	Operations Research, Inc.
Spacecraft Antenna Design	University of New Mexico
Computers	Control Data Corporation
Ground Station	Fairchild Stratos
Real-Time Data Study	Stanford Research Institute
Data Utilization Handling System	Ess Gee, Inc.
Wide-Band Transmissions	American Telephone and Telegraph Company
Atmospheric Research	Geophysical Institute, University of Alaska

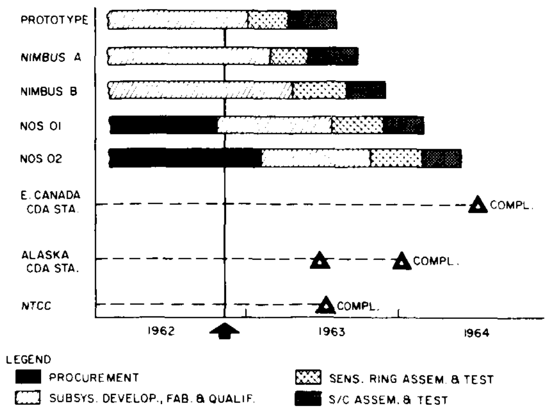


Figure 6.3-1. Nimbus Program Plan (as of November 1962)

Figure 6.3-2. List of Scheduled Deliveries of Nimbus Subsystems (as of July 1961)

Subsystem	Prototype	First Flight Model
Guidance and Control	12/15/61	4/15/62
Solar Power Supply	12/15/61	4/15/62
AVCS	10/1/61	12/15/61
Electrostatic Tape Camera	10/1/61	12/15/61
HRIR	11/1/61	2/1/62
Storage	10/15/61	12/15/61
Command	10/1/61	12/1/61
Telemetry	6/15/61	9/15/61
Transmitter	7/15/61	3/15/62
Earth-Sun Experiments	2/15/62	4/15/62
Clock	9/1/61	12/1/61

7.0 REFERENCES

Title	Date of Issue	Issuing Agency	Source Retrieval No.
Proceedings of the Nimbus Program Review	11/14-16/62	NASA GSFC	X-650-62-226
Nimbus 1 User's Catalog: AVCS and APT	3/65	NASA GSFC	--
Alignment and Assembly of the Nimbus Weather Satellite	1/31/63	NASA GSFC GE Corp.	GE-10235
Data Evaluation Guide Nimbus "A" Flight	12/15/64	NASA GSFC	64SD4393
GSFC Program Plan for the Integration and Testing of the Nimbus Meteorological Satellite	3/17/61	NASA GSFC	61SD4215
NASA Technical Note D-1422 — The Nimbus Spacecraft and Its Communication System as of September 1961	1/63	NASA GSFC R.A. Stampfl	NASA TN D-1422
Integration and Testing of the Nimbus Meteorological Satellite — Operating Time/Failure Chart No. 4 Flight Spacecraft Serial No. 301 — Nimbus A	5/31/64	NASA GSFC GE Corp.	64SD4302
The Nimbus Spacecraft and Its Communication System	6/62	NASA GSFC R.A. Stampfl	X-652-62-87
The Nimbus Meteorological Satellite Program	7/65	NASA GSFC H. Press	X-650-65-267
Observations from the Nimbus 1 Meteorological Satellite	1965	NASA	NASA SP-89
The Nimbus Spacecraft System	--	NASA GSFC H. Press	N65-15494
Statement of Work and Specifications for the Integration and Testing of the Nimbus Spacecraft	7/61	NASA GSFC	--
Mission Operations Plan Nimbus A	6/64	NASA GSFC	X-650-64-160
A Reliability Assessment of the Nimbus Spacecraft	11/26/62	Operations Research, Inc.	TR No. 188b

This data sheet was prepared for the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, by the Astro-Electronics Division, Defense Electronic Products, Radio Corporation of America, Princeton, New Jersey, under Contract No. 951335.

EXHIBIT E

TYPICAL (NIMBUS POWER) SUBSYSTEM DATA SHEET

1.0 PROJECT SUMMARY	1.5 DATE OF DATA SHEET PREPARATION: March 1966
1.1 PROGRAM: Nimbus	1.6 PROCURING AGENCY: NASA/GSFC
1.2 PROJECT: Nimbus Meteorological Satellite	1.7 SUBSYSTEM CONTRACT NUMBER: NAS5-943
1.3 SYSTEM: Nimbus 1	1.8 SUBSYSTEM DESIGN STATUS: Flight proven
1.4 SUBSYSTEM: Power	1.9 MANUFACTURER: RCA, Astro-Electronics Division

2.0 SUBSYSTEM SUMMARY

2.1 Summary Description: The Nimbus 1 Power Subsystem is designed to provide electrical power to all spacecraft subsystems. It comprises a pair of sun-orientable solar-cell platforms mounted outboard of the main spacecraft structure (see Figure 2.1-1), seven nickel-cadmium battery modules, and conversion and regulation circuitry. In operation, the solar platforms are designed to acquire and track the sun for maximum efficiency in solar-energy acquisition. The spacecraft launch time yields a retrograde polar orbit that contains the earth-sun line, so that the acquisition of the sun is simplified by requiring only one axis of rotation for the solar-cell platform. The solar cells, mounted on one side of each of the two platforms, are maintained continuously normal to the earth-sun line, and are thus able to intercept a maximum of solar energy during the period of sunlight. Sun sensors, mounted around the driveshaft of each platform, detect solar radiation so that the sun can be acquired by the solar-cell platforms regardless of the attitude of the spacecraft or the position of the platforms with respect to the sun-satellite line. A servomotor located in the control housing rotates the driveshaft. During the 450-nautical-mile orbit, 68.7 minutes are spent in sunlight and 34.9 minutes in the earth's shadow; a preset potentiometer continues to turn the platforms until they reach the position for acquisition of the "rising" sun. The batteries, of course, supply the needed spacecraft power during periods of eclipse.

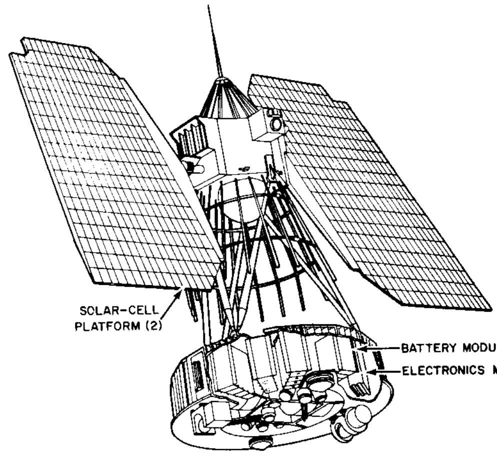


Figure 2.1-1. Nimbus 1 Solar Conversion Power Subsystem

2.2 Design Requirements: The following were primary design requirements of the Nimbus A power subsystem:

2.2.1 Mechanical

2.2.1.1 Maximum Subsystem Weight: 150 pounds

2.2.1.2 Stabilization: The solar-cell platforms must be actively controlled with a single degree of freedom about the spacecraft pitch axis to achieve a sun-pointing accuracy of ±10 degrees.

2.2.2 Electrical

2.2.2.1 Minimum Solar Array Output in Full Sunlight: 620 watts

2.2.2.2 Regulated Voltage Available to Spacecraft Systems: -24.5 ± 0.5 volts dc Spacecraft

2.2.2.3 Fraction of Battery Modules Required to Support Mission: 3/4

2.2.2.4 Number of Battery Modules: 8 (later revised to 7)

2.2.3 Environmental

2.2.3.1 Vibration: 3g (lateral)
10g (thrust)

2.2.3.2 Steady-State Acceleration: 3g (lateral)
15g (thrust)

2.2.3.3 Thermal: Battery and Electronics, -5° to +55°C
Solar Array, -81° to +44°C

2.2.3.4 Vacuum: 10^{-5} mm Hg

3.0 SUBSYSTEM DESIGN

3.1 Functional Description: See Figures 3.1-1, 3.1-2, and 3.1-3

3.1.1 Overall Operation: During the satellite day, an array of silicon solar cells mounted on two solar-oriented platforms provides conversion of solar radiation to electrical energy. During satellite night, seven nickel-cadmium battery modules supply the power required to operate the spacecraft subsystems.

3.1.2 Launch and Solar Acquisition: During launch, the solar array is folded against the truss and torus of the spacecraft structure. After the spacecraft has been established in orbit, the solar array is extended to expose the cells to solar radiation. The opening of the platform is controlled by a drive motor and gear train forming part of the Stabilization and Guidance subsystem. When the solar array is extended, it is locked into the open position and is constrained to follow the sun by rotating about the spacecraft pitch axis. From the folded position, the solar array is driven approximately 135 degrees to the open position in less than 30 seconds.

The solar cells, mounted on one side of the solar array, are maintained continuously incident to the sun-earth line, and hence are able to intercept a maximum of solar energy during the period of sunlight. Sun sensors, mounted around the driveshaft of each platform, detect solar radiation so that the sun can be acquired by the solar-cell platforms regardless of the attitude of the spacecraft or the position of the platforms with respect to the sun-satellite line. A servomotor located in the spacecraft control housing rotates the driveshaft. During the 450-nautical-mile orbit, 68.7 minutes are spent in the sunlight and 34.9 minutes in the earth's shadow. When the satellite is in the earth's shadow, a preset potentiometer continues to turn the platforms until they reach the position for acquisition of the "rising" sun.

As indicated in Figure 3.1-1, the solar-cell circuitry consists of a series of silicon blocking diodes which prevent those solar-cell strings producing low voltages from loading those that produce high voltages.

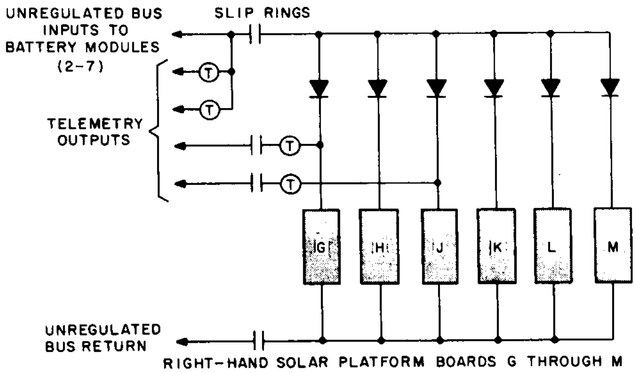


Figure 3.1-1. Solar-Cell Circuitry, Simplified

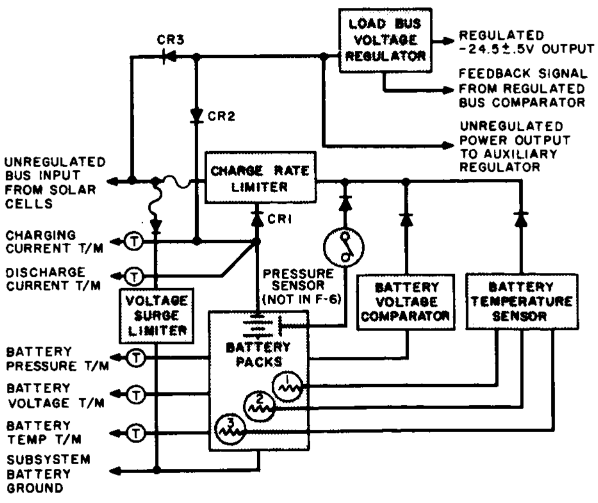


Figure 3.1-2. Battery Module, Functional Block Diagram

3.1.3 Battery Operation: Seven nickel-cadmium storage batteries provide the energy storage capability of the subsystem. During the period of sunlight, the batteries are in a state of charge, and during the period of the earth's shadow, they are in a state of discharge to operate all of the spacecraft's subsystems. On the basis of system power requirements, 3.2-ampere cells were chosen, and 15 percent of their full ampere-hour capacity is discharged by the end of the nighttime portion of the orbit. The total load is satisfied by about 86 percent of available discharge capacity, or six battery packs.

Protective circuitry limits the maximum charging rate of the batteries to 1.5 amperes, reducing the charge rate to less than 0.2 ampere in the event of excessive temperature or pressure buildups which might destroy the cells.

3.1.4 Voltage Regulation and Distribution: The spacecraft design concept requires a single power supply source of -24.5 volts dc at ±2 percent regulation. Each spacecraft subsystem provides its own dc-to-dc converter with auxiliary regulator to modify this source voltage to meet its own individual voltage requirements.

Power generated by the solar array is transferred to the storage and regulating system through a set of slip rings, and is then transferred to the unregulated bus. The unregulated bus supplies the shunt losses of the power-supply regulating circuitry, and is used to charge the batteries and to establish the regulated bus.

The voltage regulator drops the voltage of the unregulated bus to that of the regulated bus (-24.5 volts). Regulation of this output voltage is maintained within ±2 percent of nominal by means of a feedback circuit. The voltage level of the regulated bus is sensed by the feedback amplifier which, in turn, supplies drive current for the voltage-regulator control circuits. Thus, fluctuations caused by load changes in the regulated bus voltage are minimized by compensating changes in the output of the voltage regulators.

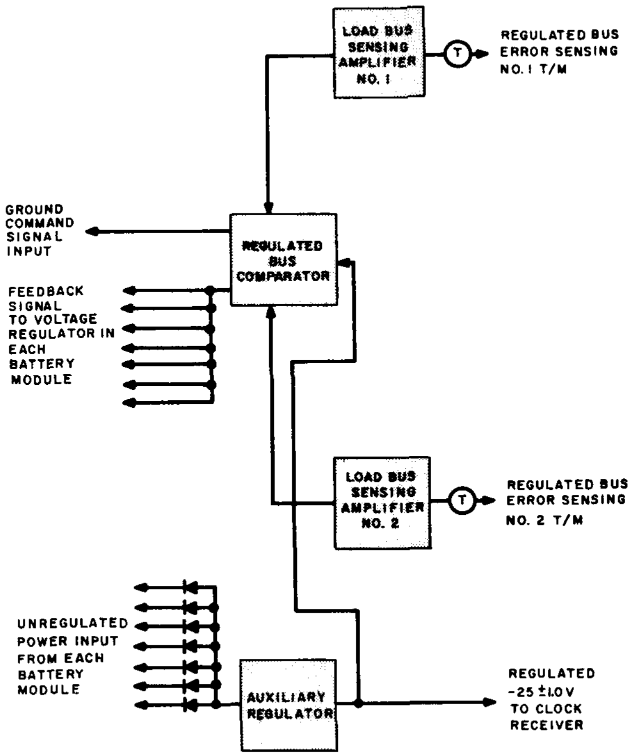


Figure 3.1-3. Electronics Module, Functional Block Diagram

3.2 Mechanization Approach:

3.2.1 Overall: Modular design was incorporated wherever possible to facilitate standardization of components and assemblies.

3.2.2 Solar-Cell Platforms: The power subsystem contains two solar-cell platforms, each consisting of a solar-cell array, a transition section, a latching assembly, a drive motor with an associated gear-reduction unit, and a control-shaft clamp. The two solar-cell platforms are attached to the control housing of the spacecraft by means of the platform driveshaft (see Figure 3.2.2-1). Slip rings on the platform shaft provide the electrical interface connections between the solar platforms, the batteries, and the platform control electronics. The structural separation and relatively simple mechanical and electrical interface connections between the solar platform, control housing, and sensory ring provides for independent thermal control of each of these major assemblies.

Each solar platform contains 5472 solar cells which cover the outside sun-facing skins of the platforms. These cells are grouped on six boards. Four of the boards contain 98 ten-cell solar modules; one board contains 97 ten-cell modules. The cells in each module are connected in parallel, the modules are connected in series, and the boards are connected in parallel.

3.2.3 Battery Modules: The Nimbus battery pack consists of seven identical battery modules. Each module, shown in Figure 3.2.3-1 contains 23 series-connected cells, together with electronic circuits which provide control, regulation, and protection for the subsystem circuits and components in a precision-cast, two-piece housing and a magnesium sheet metal cover. The front and bottom surfaces of the battery module are coated with a substance of high emissivity to decrease the direct and reflected solar energy absorbed by these surfaces. This coating also provides for maximum radiation of the battery module internal heat.

3.2.4 Power Electronics: The electronics module housing, shown in Figure 3.2.4-1, is a two-piece machined-magnesium case with top and bettom magnesium sheet metal covers. The covers, which are secured to the outer face of each piece, provide a means of easy access to the module subassemblies and wiring. The case is divided into two compartments: one compartment contains the heat sinks, terminal boards, and wiring, and the other compartment contains the circuit board subassemblies. A Dow No. 7 finish is applied to all magnesium parts of the electronics module so that it will resist corrosion when subjected to its operational environment. All metals used, other than magnesium, are corrosion-resistant. A substance of high emissivity is applied to the module surfaces to provide for maximum radiation of internal module heat. Eight removable mounting tabs provide the interface surface for mechanical connection of the module to the vehicle structure.

3.3 Performance Characteristics: -

3.3.1 Weight and Dimensions:

	Wt. (lb)	Width (in)	Height (in)	Depth (in)	Vol. (cu in)
Solar Array (2) *	77.0	46.75	96	$\frac{1}{4}$ to 1	--
Battery Modules (7)	106.4	6	8	6-$\frac{1}{2}$	312
Electronics Module	6.8	6	4	13	312
Total	190.2				

* The solar-array drive transition section is included as part of the guidance and stabilization subsystem.

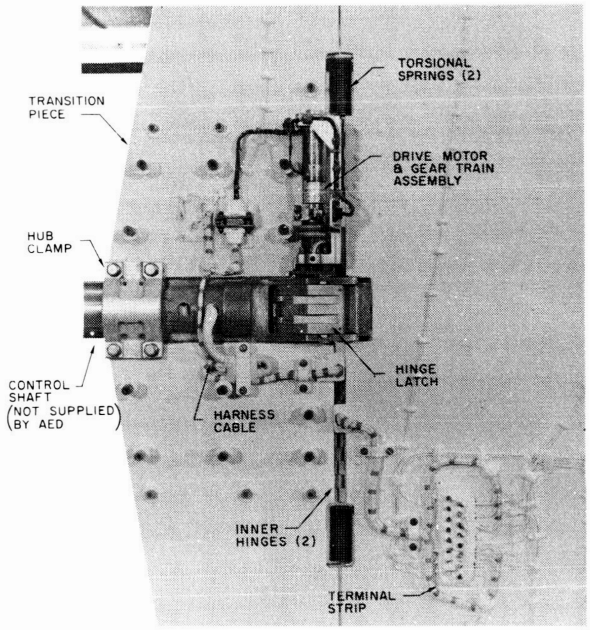


Figure 3.2.2-1. Solar-Platform Transition Piece and Associated Assemblies

3.3.2 Electrical: (See Figure 3.3.2-1)

Solar Array
Input - 136.6 mw/cm^2 (solar energy)
Efficiency - 10.1 percent (air-mass-zero)
Power Dissipation - less than 12 watts

Battery Module
Output - 28.5 volts dc (nominal) at 3.2 ampere-hours per module
Normal Discharge - 15 percent during nighttime orbit
Total Load - satisfied by six modules (86-percent usable capacity)
Charge Rate - less than 1.5 amperes
Power Dissipation - 18.1 watts, maximum

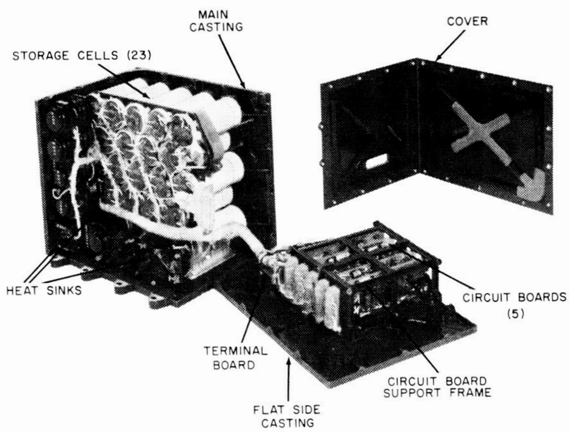


Figure 3.2.3-1. Battery Module Chassis Configuration

Power Electronics
Input - 28 to 39 volts dc
Output - -24.5 volts dc regulated to ±2 percent from 0 to 13 amperes
-28 volts unregulated
Transient Response - 25 microseconds to 4 ampere charging load
Power Dissipation - 11.6 watts, maximum
Power Output - 470 watts maximum, 160 watts normal

3.4 Unique Developments: None

3.5 Reliability:

3.5.1 Reliability Requirements: The power subsystem is required to ensure the life and reliability of six months in an orbital environment to match the lifetime of the other satellite subsystems.

3.5.2 Reliability Approach: The approach is rational, rather than empirical. It places primary emphasis on using the proper tools and methods and doing the job correctly. Use of redundancy is limited to wherever required to ensure a reliability of six months or otherwise approved. Simplicity of design is also employed wherever possible to increase reliability. Redundancy was not included to the extent originally planned because of weight restrictions.

3.5.3 Failure Mode and Effects Analysis: see Figure 3.5.3-1.

Figure 3.5.3-1. Failure Modes and Effects

Failure	Effect	Explanation
Failure of one battery module	No adverse effect on normal operation	Seven batteries are used where only six are required for normal operation. Failure of two batteries would reduce power available for night operations.
Solar cell short of open	No adverse effect on normal operation	Solar panels are wired in series-parallel (see para. 3.2.2) to reduce the effect of cell failure (short or open). Partial failures up to and including the catastrophic failure of one of the two solar panels can be accommodated with no or little reduction in available power. Such reduced power (in the event of solar-panel failure) would limit mission operations, but not necessitate termination of the mission.
Failure of voltage regulator	No adverse effect on normal operation	A monitoring circuit is provided to continuously check the operation of the voltage regulator. If the voltage regulator fails, the monitoring circuit initiates action to switch in an auxiliary regulator. Should both regulators fail, a catastrophic failure would result.
Overheating of battery	No adverse effect on normal operation	A temperature-sensing circuit is provided to prevent normal charging of the batteries if an overheating condition occurs. The trickle charge applied to the batteries during the overheating condition will still maintain proper operation for sometime.
Insufficient charging current to maintain proper battery operation	Reduced night operations to conserve power	A voltage monitoring circuit is provided to show charge level of batteries. If the batteries are not being charged to the proper level or will not hold a sufficient charge, control is provided to reduce mission operations and therefore reduce current drain from batteries. Reduced operations such as shutting down non-mission-dependent equipment or reduction of picture taking operations will reduce the power requirements and can still maintain a certain degree of mission success.

3.5.4 Redundancies Employed:

3.5.4.1 Solar-Array Panels

(1) Wired in series-parallel arrangement. Twelve series strings are wired in parallel to provide redundancy in the event of a failure of one string.

(2) Two separate solar-array panels used with separate slip-ring mechanisms.

3.5.4.2 Battery Modules: Seven battery modules are used where only six are required.

3.5.4.3 Voltage Regulators: Two voltage regulators are provided with automatic monitoring and switching.

4.0 FLIGHT PERFORMANCE

4.1 Subsystem Performance: The power subsystem functioned essentially as designed during both the daytime and nighttime portions of the flight and provided all required power from launch to the last subsystem failure. The solar array provided an average current of 13 amperes, which was within design specification, and the maximum subsystem power output of 470 watts exceeded the design estimate by 20 watts. Up to the time of failure of the solar-array drive mechanism (see para. 4.2, below) the supply delivered the required -24.5 volts dc regulated within ±2 percent; and battery voltages were maintained within specification by the selected use of auxiliary and compensating loads. No degradation of the solar cells' power output was observed during the short life of the spacecraft.

4.2 Failure Modes and Effects: Failure of the solar-array drive mechanism occurred on the morning of September 23, 1964, in orbit no. 371, and was detected by the telemetry which indicated no paddle rotation with maximum voltage applied to the drive motor. The paddles were frozen in a near vertical position. The flight failure was subsequently duplicated in a series of post-flight ground tests, and it was concluded that failure was caused by excessive temperature in the motor bearings, chemically degrading the lubricant to its soap base.

Starvation of the power supply thus led to battery depletion, which in turn fed wrong voltages to the attitude-control electronics, causing large errors which fired excessive gas, giving the spacecraft a large momentum, and finally resulting in a spin-up about the maximum inertia roll axis.

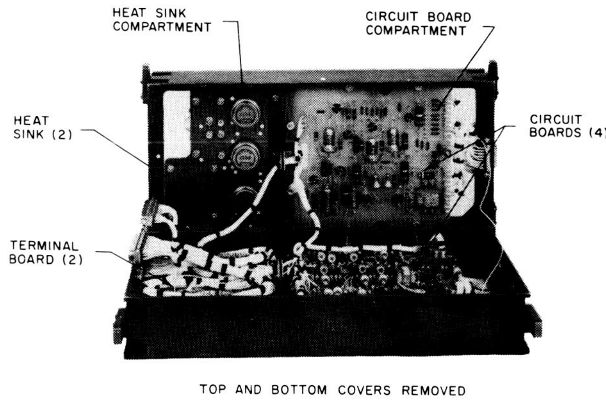


Figure 3.2.4-1. Electronics Module Chassis Configuration

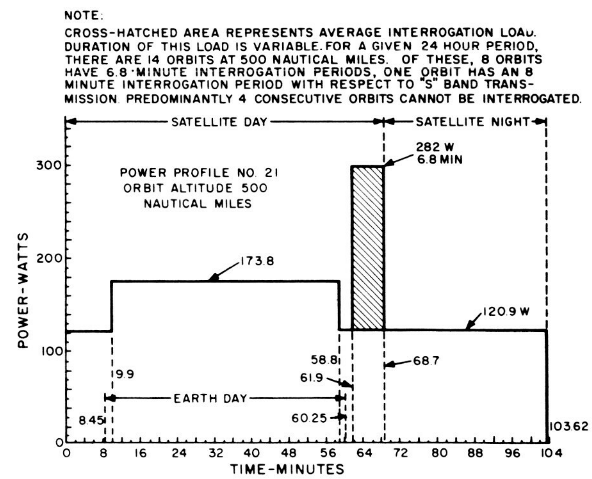


Figure 3.3.2-1. Power-Time Profile, Nimbus 1

5.0 PROJECT POLICIES AND REQUIREMENTS

5.1 Subsystem Tradeoffs: Two considerations contributed to the decision to make use of n-on-p solar cells instead of the more common p-on-n solar cells on the Nimbus A spacecraft:

(1) The contacts for p-on-n solar cells are formed by an electrolytic nickel-plating process. It was concluded early in the design of Nimbus A the normal in-orbit solar-cell-contact degradation due to thermal cycling would seriously compromise the design lifetime of the spacecraft unless an improved contact could be employed.

(2) The solar-cell problem was further complicated by the creation of the artificial radiation belt ("Starfish" experiment), since considerable degradation results when the p-on-n solar cells are exposed to radiation.

It was decided that both of these problems could be solved by making use of n-on-p solar cells to replace the p-on-n cells. The n-on-p cells have contacts formed by a sintering process, which forms a more reliable contact than electroplating with nickel, and the n-on-p cells are more radiation resistant than p-on-n cells.

5.2 Specifications and Standards Invoked: "Statement of Work and Specification for a Power Supply Subsystem for the Nimbus Spacecraft," Contract No. NAS5-943, prepared by Aeronomy and Meteorology Division, Goddard Space Flight Center, NASA (July, 1961).

5.3 Quantity of Subsystems Fabricated or Planned:

5.3.1 Flight Models: Two

5.3.2 Prototype Models: One

5.3.3 Preprototype Models: One

5.4 Test Program:

5.4.1 Test Philosophy:

5.4.1.1 Solar-Cell Platforms: The primary purpose of the qualification tests on the prototype solar-cell platforms was to ensure that the platforms could retain their mechanical integrity and electrical capability when exposed to an environment more severe than expected in actual operation. Furthermore, after completion of the tests, the platforms should be capable of operation without measurable evidence of degration in performance.

5.4.1.2 Battery and Electronics Modules: The purpose of the qualification testing of the battery and electronics modules was to provide assurance that the design of these modules was adequate to meet the rigors of space flight and six-months' orbital life. The environmental exposure levels used in the tests were more severe than those anticipated in actual flight to prove the design integrity of the subsystem.

5.4.2 Qualification Tests:

5.4.2.1 Solar Array:

5.4.2.1.1 Humidity:

Nonoperative - +30° ± 1.1°C at 95-percent humidity
Operative - +25° ± 1.1°C at 95-percent humidity

5.4.2.1.2 Vibration: The board shall be subjected to an acceleration level in both directions such that the curvature at the resonant frequency is 0.005. The frequency shall be varied from 20 to 80 cycles and back to 20 cycles at the rate of 2 octaves per minute to determine the resonant frequency. The resonant frequency shall be recorded.

The board shall then be subjected to an acceleration level such that the curvature at the resonant frequency is 0.015. This level shall be maintained for 4 minutes or until failure, whichever occurs first. The curvatures will be calculated from the following equation:

$$\text{Curvature} = \frac{d^2y}{dx^2} = \frac{\epsilon}{c}$$

where ϵ = strain (average of top and bottom strain gages)
and c = section thickness ÷ 2

5.4.2.1.3 Acceleration Test: Each board shall be exposed to 30g acceleration for 5 minutes along the thrust axis.

5.4.2.1.4 Thermal Vacuum:

a. Solar-Cell Component Board: With the boards nonoperative, the exposure chamber shall be evacuated to a pressure of 10^{-5} torr, or less, at a rate not exceeding that of the pressure-time profile of actual flight. Liquid nitrogen shall be supplied to the cooling shrouds throughout the test. The filament heaters shall be used, as necessary, to cycle the boards from +60°C (140°F) to -81°C (-113.9°F) 1000 times. The boards will be removed from the thermal-vacuum chamber after the tenth, one-hundredth, and four-hundredth cycle.

b. Solar-Cell Platform: The exposure chamber shall be evacuated to a pressure of 10^{-5} torr, or less, at a rate not exceeding that of the pressure-time profile of actual flights. The solar-cell side of the platform shall be exposed to a heat flux equivalent to one solar constant (0.9 watt per square inch) for a time period equal to actual orbital sun time (66.5 minutes). During a period of time equal to the actual eclipse time (35.1 minutes), the heat flux shall be reduced to simulate the flight condition (approximately 0.08 watt per square inch). Cooling shrouds shall be maintained at liquid nitrogen temperatures for the entire test to provide correct background conditions. This cycle (66.5 minutes of sun time and 35.1 minutes of eclipse) shall be continued until 350 cycles are accomplished.

5.4.2.2 Battery Modules, Power Electronics, and Solar-Array Drive:

5.4.2.2.1 Humidity:

Nonoperative - +40 ±1.1°C at 95-percent humidity
Operative - +25 ±1.1°C at 90 ±5-percent humidity

5.4.2.2.2 Vibration: See Figure 5.4.2.2.2-1.

Figure 5.4.2.2.2-1. Vibration Qualification Test Limits

Sinusoidal Vibration		
Frequency Range (cps)	Amplitude g (0-to-peak)	
	Thrust Axis	Transverse Axis
5 to 2000	10.0	10.0
Vibration limited to 1/4-inch single amplitude Sweep rate: 5 to 2000 cps 2 minutes per octave		

Random Vibration			
Direction	Frequency Band (cps)	Spectral Density (g^2/cps)	Amplitude g (rms)
Thrust Axis	20 to 2000	0.2	20.0
Transverse Axis	20 to 2000	0.2	20.0
Test Duration: Four minutes in each direction (12 minutes total)			

5.4.2.2.3 Acceleration Test: Each board shall be exposed to 30g acceleration for 5 minutes along the thrust axis.

5.4.2.2.4 Thermal Vacuum: With the subsystem in the operational mode normal to boosted flight, the exposure chamber shall be evacuated to a pressure of 10^{-5} torr, or less, at a rate not exceeding that of the pressure-time profile of actual flight. This minimum vacuum shall be maintained throughout the duration of the test. After pressure stabilization, the subsystem shall be operated in a simulated orbital flight mode and shall be performance checked bihourly throughout the thermal-vacuum exposure. The temperature of the subsystem shall be varied as shown in Figure 5.4.2.2.4-1.

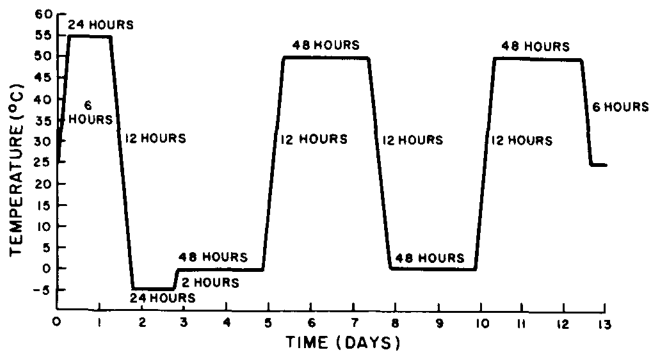


Figure 5.4.2.2.4-1. Storage and Control Subsystem Thermal-Vacuum Temperature-Time Profile

5.4.3 Reliability Tests: Reliability tests are conducted on the system integration and test level by the integration contractor. (See Nimbus 1 System Data Sheet.)

5.5 Supporting Equipments: The Ground Checkout Equipment (GCE), consisting of the two racks of equipment shown in Figure 5.5-1, is required for testing the power-supply-subsystem modules. The GCE provides facilities for completely testing the modules without connecting to the solar array by simulating the following: (1) solar-array power input to the modules, (2) power supply loading during orbit, and (3) by rapidly switching load conditions. The GCE also monitors the subsystem telemetry signals before, during, and after the simulated orbit.

5.6 Design Review Policy: None specified.

6.0 PROJECT MANAGEMENT AND ORGANIZATION

6.1 Type of Management Organization: See System Data Sheet, Paragraph 6.1.

6.2 Project Organization: See Figure 6.2-1.

6.3 Project Plan: (as of March 1961)

6.3.1 Project Start: April 1961
Project End: November 1962

6.3.2 Start Development Date: February 1961

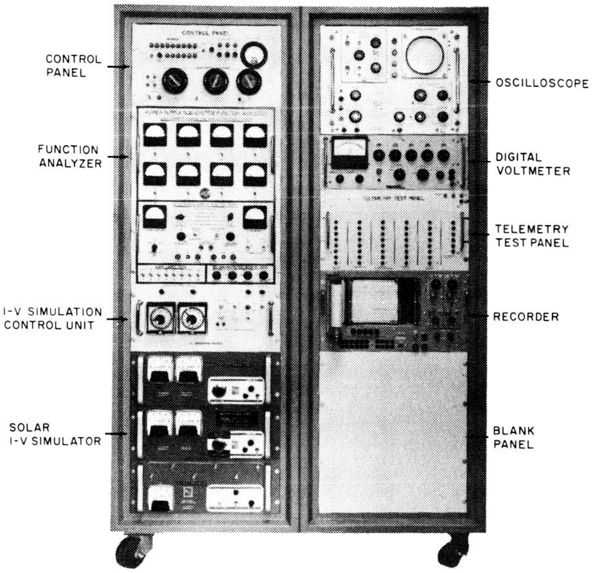


Figure 5.5-1. Ground Checkout Equipment Racks

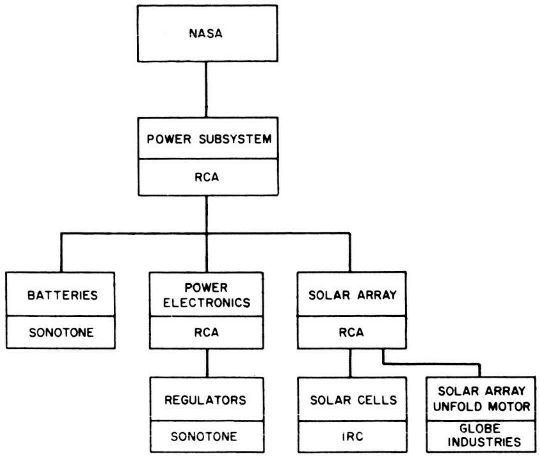


Figure 6.2-1. Identification of Nimbus Power Subsystem Contractors

6.3.3 Start Fabrication Date: May 1961

6.3.4 Flight Model Delivery Dates: August 1961

7.0 REFERENCES

Title	Date of Issue	Issuing Agency	Source Retrieval No.
Nimbus Instruction Manual for the Solar-Conversion Power-Supply Subsystem	4/20/64	NASA GSFC RCA	AED M-1798
Proceedings of the Nimbus Design Review	11/14-16/62	NASA GSFC	X-650-62-226
Nimbus A Flight 1 Report	2/65	NASA GSFC GE Corp.	65SD4259
Interim Technical Report - Volume I, Prototype Battery and Electronics Modules	12/11/63	NASA GSFC RCA	AED R-2143
Interim Technical Report - Volume II, Solar-Cell Platforms	4/27/64	NASA GSFC RCA	AED R-2144
Program Plan for the Integration and Test of the Nimbus Meteorological Satellite	3/17/61	NASA GSFC	61SD4215
The Nimbus Meteorological Satellite Program	7/65	NASA GSFC	X-650-65-267
Statement of Work and Specification for a Power Supply Subsystem for the Nimbus Spacecraft	7/61	NASA GSFC A&M	---
Environmental Test Plan for Prototype and Flight Models	7/30/63	NASA RCA	AED T-1060

This data sheet was prepared for the Jet Propulsion Laboratory, California Institute of Technology, by the Astro-Electronics Division of the Radio Corporation of America, under Contract No. 951335.

EXHIBIT F

SAMPLES OF LETTERS SENT AS PART OF THE INITIAL DATA-COLLECTION EFFORT

RADIO CORPORATION OF AMERICA
DEFENSE ELECTRONIC PRODUCTS
ASTRO-ELECTRONICS DIVISION
PRINCETON, NEW JERSEY 08540

March 23, 1966

(Cognizant Agency)

Attention: Public Relations Officer

Dear Sir:

Under Contract No. 951335 to the Jet Propulsion Laboratory (JPL), NASA Contract No. NAS7-100, the Astro-Electronics Division of RCA is developing a "Spacecraft Design Data Information System" (SDDIS) which will contain summary design and performance data on more than 30 programs. The following programs, for which the NASA Goddard Space Flight Center has prime management and/or technical cognizance, will be included:

(Reference Programs)

It is quite possible your office has prepared brochures, press releases, or other general material describing this program. If you have such information available for public release, we would greatly appreciate your forwarding it to us. This information will be used not only as a source of design and performance, but also to verify other data sources. All information will be forwarded to NASA/JPL upon completion of the SDDIS Project.

LEON J. ROSENBERG
SDDIS Project Manager

LJR/fpf

RADIO CORPORATION OF AMERICA
DEFENSE ELECTRONIC PRODUCTS
ASTRO-ELECTRONICS DIVISION
PRINCETON, NEW JERSEY 08540

March 22, 1966

(Cognizant Project Manager) Re: (Project)

Dear Sir:

Under Contract No. 951335 to the Jet Propulsion Laboratory (JPL), the Astro-Electronics Division of RCA is developing a "Spacecraft Design Data Information System" (SDDIS) that will serve as a reservoir of design and performance data for virtually all of the U.S. space programs. As your program has been selected for inclusion in the SDDIS, I would greatly appreciate any assistance you may offer. Specifically, we are interested in obtaining the following types of documents as applicable to the program:

- Flight Evaluation Reports (NASA and contractor originated);
- Final Technical Reports (as issued by NASA, the prime contractor, and each major subcontractor);
- NASA-issued work statements;
- Design Specifications at the System and Subsystem Levels;
- System Data Books;
- NASA and/or contractor technical notes describing system and subsystem design characteristics;
- NASA Mission Plans;
- Handbooks of maintenance instructions;
- System reliability assessments; and
- Contractor program planning documents describing initial design considerations.

I would greatly appreciate your forwarding any of the above documents which you feel that you can release at this time, or referring us to a source of such documents. Any suggestions as to additional documents that might be appropriate to our efforts would be most welcome. If you have any questions, please do not hesitate to call me (609-448-3400, extension 7259). Alternately, you may wish to contact the JPL technical representative (Mr. R. Osborn, 213-354-4429) or the cognizant headquarters officer (Mr. M. Gill, 202-962-4585).

LEON J. ROSENBERG
SDDIS Project Manager

LJR/fpf

RADIO CORPORATION OF AMERICA
DEFENSE ELECTRONIC PRODUCTS
ASTRO-ELECTRONICS DIVISION
PRINCETON, NEW JERSEY 08540

March 21, 1966

(Company Name and Address)

Attention: Public Relations Officer

Dear Sir:

Under Contract 951335 to the Jet Propulsion Laboratory (NASA Contract NAS7-100) the Astro-Electronics Division of RCA is developing a "Spacecraft Design Data Information System" (SDDIS) which will contain summary design and performance data on more than 30 programs. Of these, the following program(s) for which you are Prime Contractor will be included:

(Reference Program)

Due to your contribution to the program, it is quite possible that you have prepared brochures, press releases, etc., describing the program and your role. If you have such information available for public release, we would greatly appreciate your forwarding it to us. This information will be used not only as a source of design and performance information, but also to verify other data sources. All information will be forwarded to NASA/JPL upon completion of the SDDIS Project.

LR:jma

Leon Rosenberg
SDDIS Project Manager

EXHIBIT G

PRELIMINARY SDDIS INDEX AND SEARCH PARAMETERS

EXHIBIT G

PRELIMINARY SDDIS INDEX AND SEARCH PARAMETERS

A. PRIMARY PARAMETERS*

1. Nature of Mission. Category includes:

Communications (M)	Equipment Test (M)
Meteorological Observation (M)	Biological Investigation (M)
Satellite Inspection (M)	Physical Investigation (M)
Planetary Investigation (M)	Tactical Reconnaissance (M)
Lunar Investigation (M)	Navigation and Mapping (M)
Satellite Interception (M)	Apollo Support (M)

2. Flight Category. Category includes:

Earth Orbiter (FC)	Lunar Hard-Lander (FC)
Earth Probe (FC)	Lunar Soft-Lander (FC)
Planetary Probe (FC)	Planetary Orbiter (FC)
Lunar Probe (FC)	Planetary Hard-lander (FC)
Lunar Orbiter (FC)	Planetary Soft-Lander (FC)

3. Program Title. Category includes:

TIROS (PG)	Lunar Orbiter (PG)
Nimbus (PG)	OSO (PG)
OGO (PG)	Pagasus (PG)
GEOS (PG)	Relay (PG)
SERT (PG)	Syncom (PG)
Explorer (PG)	Telstar (PG)
Pioneer (PG)	

*Applicable to Both System and Subsystem Data Retrieval.

4. Project Title. Category includes:

TIROS (PJ)
Nimbus (PJ)
OGO (PJ)
GEOS (PJ)
SERT (PJ)
IMP (PJ)
Pioneer (PJ)
Lunar Orbiter (PJ)
OSO (PJ)
Pegasus (PJ)
Relay (PJ)
Syncom (PJ)
Telstar (PJ)

5. Spacecraft System. Category includes:

TIROS 1 (S)
⋮
TIROS 8 (S)
Nimbus 1 (S)
OGO 1 (S)
OGO 2 (S)
GEOS 1 (S)
GEOS 2 (S)
SERT 1 (S)
IMP 1 (S)
IMP 2 (S)
Pioneer 6 (S)
Lunar Orbiter 1 (S)
OSO 1 (S)
OSO 2 (S)
OSO 3 (S)
Pegasus 1 (S)
Pegasus 2 (S)
Relay 1 (S)
Relay 2 (S)
Syncom 1 (S)
Syncom 2 (S)
Syncom 3 (S)
Telstar 1 (S)
Telstar 2 (S)

6. Spacecraft Subsystem or Experiment. Category includes:

Power (SS)
Guidance and Control (SS)
Data Transmission and Reception (SS)
Command, Control, and Telemetry (SS)
Structure and Thermal Design (SS)
Television (EX)
Propulsion (EX)
Infrared Detection (EX)
Biological Experiments (EX)

B. SECONDARY PARAMETERS

1. System-Level Secondary Parameters

   Primary Mission Objectives

   Design Approach

   Configuration

   Design Requirements

   Orbital Parameters

   Sequence of Launch Events

   Operation and Mission Chronology

   Critical Mission Phases

   Post-Encounter Phases

   Data Return Modes

   Advanced Concepts

   Functional Description

   Mechanization Approach

   Performance Characteristics

   Unique Developments

   Reliability

   Spacecraft Performance

   Experiments Performance

   Failure Modes and Effects

   System Tradeoffs

   Specifications and Standards Invoked

   Quantity of Systems Fabricated or Planned

   Test Program

   Supporting Equipment

   Design Review Policy

   Type of Management Organization

   Project Organization

   Project Plan

   References

2. Subsystem-Level Secondary Parameters

Summary Description

Design Requirements

Functional Description

Mechanization Approach

Performance Characteristics

Unique Developments

Reliability

Subsystem Performance

Failure Modes and Effects

Subsystem Tradeoffs

Specifications and Standards Invoked

Quantity of Subsystems Fabricated or Planned

Test Program

Supporting Equipments

Design Review Policy

Type of Management Organization

Project Organization

Project Plan

References

GLOSSARY OF SUFFIXES

M	Mission, Nature of Mission
FC	Flight Category
PG	Program, Program Title
PJ	Project, Project Title
S	System, Spacecraft System
SS	Subsystem, Spacecraft Subsystem
EX	Experiment, Spacecraft Experiment

EXHIBIT H

BASIC SDDIS INDEX PLAN FOR COMBINING AND PERMUTATING CATEGORIES OF INDEX AND SEARCH PARAMETERS

EXHIBIT H

BASIC SDDIS INDEX PLAN FOR COMBINING AND PERMUTATING CATEGORIES OF INDEX AND SEARCH PARAMETERS

1. Spacecraft System
2. Spacecraft System, Spacecraft Subsystem or Experiment
3. Spacecraft Subsystem or Experiment, Spacecraft System
4. Nature of Mission, Flight Category, Spacecraft System
5. Flight Category, Nature of Mission, Spacecraft System
6. Nature of Mission, Flight Category, Spacecraft Subsystem or Experiment, Spacecraft System
7. Flight Category, Nature of Mission, Spacecraft Subsystem or Experiment, Spacecraft System
8. Spacecraft Subsystem or Experiment, Flight Category, Nature of Mission, Spacecraft System
9. Spacecraft System, System-Level Secondary Parameter
10. System-Level Secondary Parameter, Spacecraft System
11. Spacecraft System, Spacecraft Subsystem or Experiment, Subsystem-Level Secondary Parameter
12. Spacecraft Subsystem or Experiment, Subsystem-Level Secondary Parameter Spacecraft System
13. Subsystem-Level Secondary Parameter, Spacecraft Subsystem or Experiment, Spacecraft System

(Above set of 13 indexing categories identifies approximately 13,000 references, of which approximately 4700 are unique; the remainder are permutations of the unique entries.)

EXHIBIT I

REFERENCES

EXHIBIT I

REFERENCES

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