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SPAR-R.810

(1) VOLUME III

IMPLEMENTATION PLAN AND COST FOR GENERAL PURPOSE BUS

SPAR

SPAR-R.810

VOLUME III

IMPLEMENTATION PLAN AND COST

FOR

GENERAL PURPOSE BUS

Prepared for:

Department of Supply and Services
and Department of Communications

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SPAR-R.810 ISSUE A

VOLUME III

IMPLEMENTATION PLAN AND COST FOR GENERAL PURPOSE BUS

PREPARED BY Staff

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1.0 INTRODUCTION

The implementation plan suggested in this volume is for the qualification and delivery of three flight General Purpose Bus (GPB) units to be launched from Delta 3910 and PAM or Shuttle STS/SSUS launch vehicles. It is proposed that future Canadian payloads will fly on this bus, and they are the SHF payloads as identified in Volume I of this report, SPAR-R.813 (MUSAT payload). The plan assumes also that the GPB units will be delivered to a prime contractors facility where it will be integrated with the payload, supplied from a separate contractor, systems tested and delivered to the test range for launch.

The schedule given in this report identifies the above (see Figure 1-1) and shows that the:

- Bus Structure and other bus subsystems can be qualified by month 20, ARO.
- Complete qualification of the spacecraft can be achieved by month 25, ARO on the assumption that the payload is delivered by month 20 for integration.
- First spacecraft can be made available for launch by month 33 followed by other spacecraft at six-month intervals.

In keeping with the above plan, design reviews will take place with the customer attending to verify and approve various stages of the program. These include:

- Initial design review (IDR) at program start.
- Preliminary design review month 3 ARO.

IMPLEMENTATION PLAN SCHEDULE

GENERAL PURPOSE BUS

BY:

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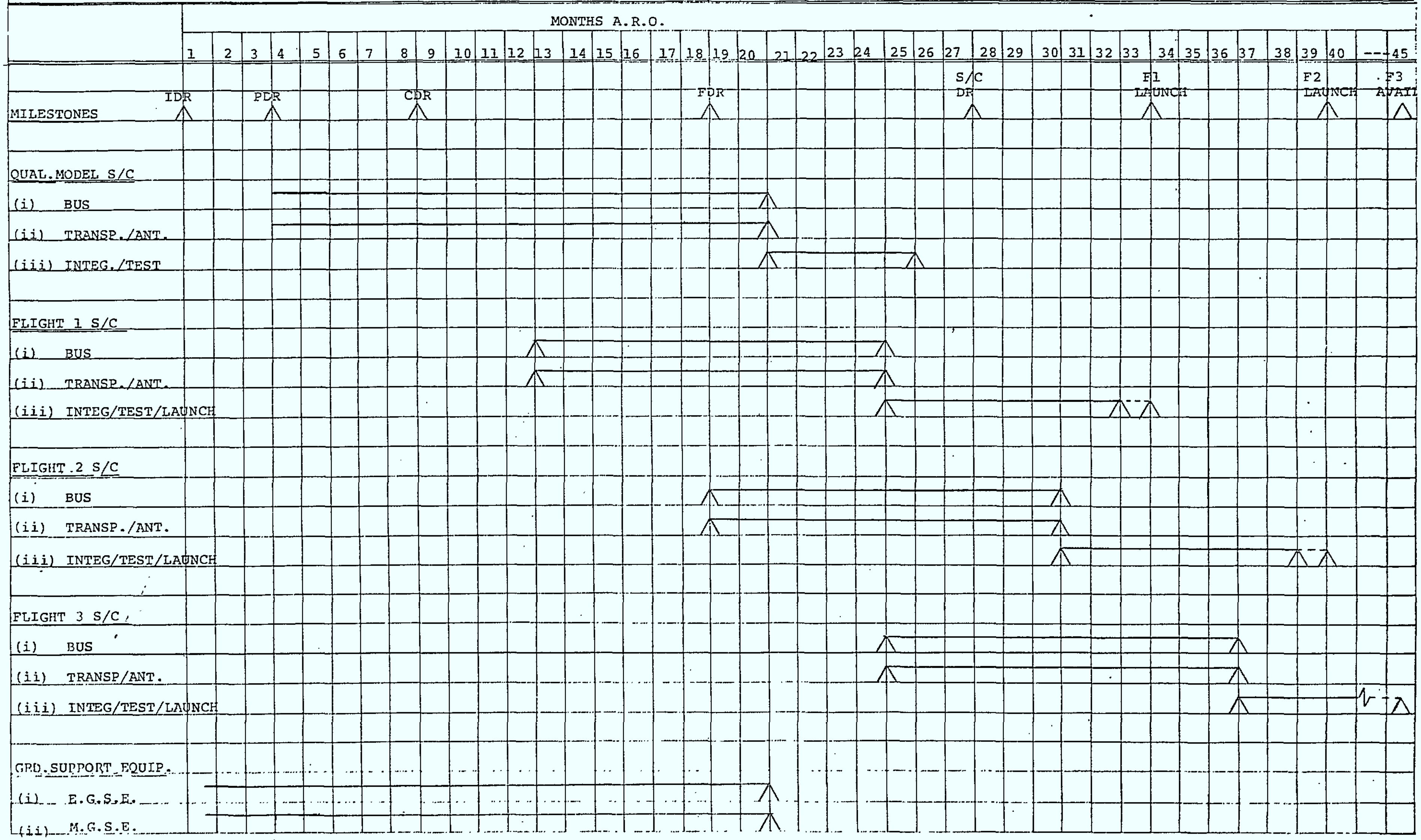

Figure 1-1

- Critical design review month 8 ARO.

- Final design review months 18 and 27. This is broken down into 2 months where the Bus subsystems qualification status is reviewed at month 18 and the complete S/C at month 27 ARO.

Major critical items associated with this suggested plan are related to the shuttle environment, which at this time is fairly fluid, and delivery of critical components non-spinning earth sensor (NESA) and screened parts for electronics assembly.

The implementation plan considered in this study reflects a low cost program approach utilizing existing CTS designs in the area of the Solar Array Drive, Array Electronics and the Attitude Control System, with minor changes to include North-South station keeping. In addition proven new subsystem technology is adopted, Canadian content is maximized, and this is reflected in the budgetary costs submitted in a separate letter. An attempt is made to achieve the additional intent of the Statement of Work, wherein a program utilizing international low price bids would also be examined. This has been only partially successful because U.S. companies consider this to be a paper study as against live programs such as ANIK C and Satellite Business System (SBS). Furthermore, most of them are extremely busy on Intelsat V, TDRSS, Discs III, and negotiations on Aerosat.

Specifications have been issued to international companies for bought out components and subsystems not manufactured in Canada, sufficient response has been received to establish the budgetary pricing submitted with this report.

The organization for this plan will be headed by a program manager responsible to the Director of Space Programs and the Vice-President and General Manager of Engineering Division. Under the program manager will be direct line managers covering the necessary disciplines to support such a program with Quality Assurance who reports to the Director, Q.A., who in turn is responsible to the President, and contracts and manufacturing managers reporting to their respective Vice-Presidents and General Managers. This provides full visibility to senior officers of the company on the status of events throughout the program.

Further details on this implementation plan and details of the subsystem schedules are presented in the following text.

2.0 PROGRAM IMPLEMENTATION PLAN

The Plan assumes that the contractor will deliver an integrated Bus which will have adapted to it a communications payload by the customer. Final compatibility and spacecraft acceptance testing will be the responsibility of the customer.

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2.1 Major Phases

Basically, the Plan can be broken down into four major phases:

- Specification release, system design and hardware development phase.
- Subsystem and bus qualification phase.
- Spacecraft qualification.
- Flight spacecraft hardware delivery, acceptance testing and launch support.

In formulating the overall plan emphasis has been placed on early development and qualification testing of subsystems and components and recognition of the need of some of the more difficult subsystems such as the RCS to have development hardware. Top level and detail program bar charts giving major Bus subsystems and spacecraft integration test periods are provided in Figures 2-1 and 2-2. Chart 2-1 indicates the above four phases which will be discussed in the text along with detailed implementation plans for individual subsystems.

G.P. BUS SATELLITE PROGRAM SCHEDULE

MONTHS ARO

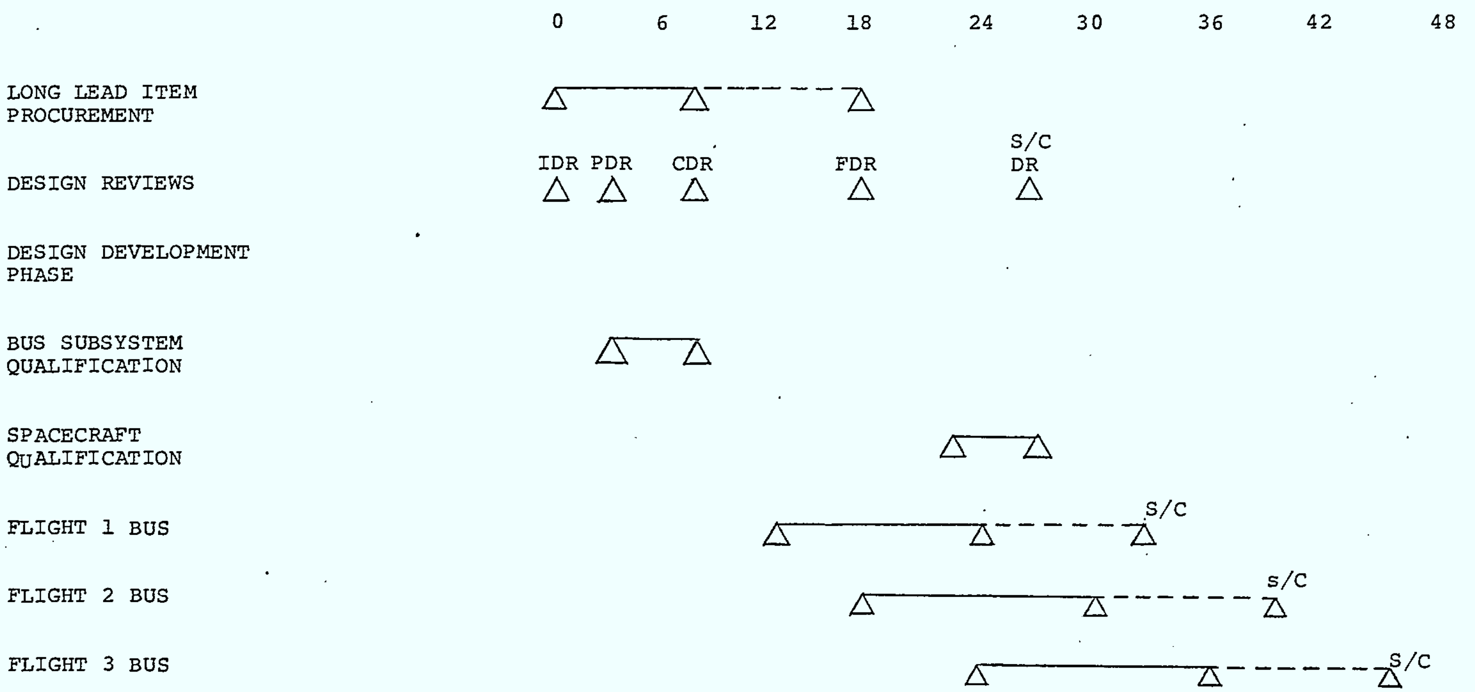

Figure 2-1

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PROGRAM PLAN SCHEDULE

GENERAL PURPOSE BUS

BY:

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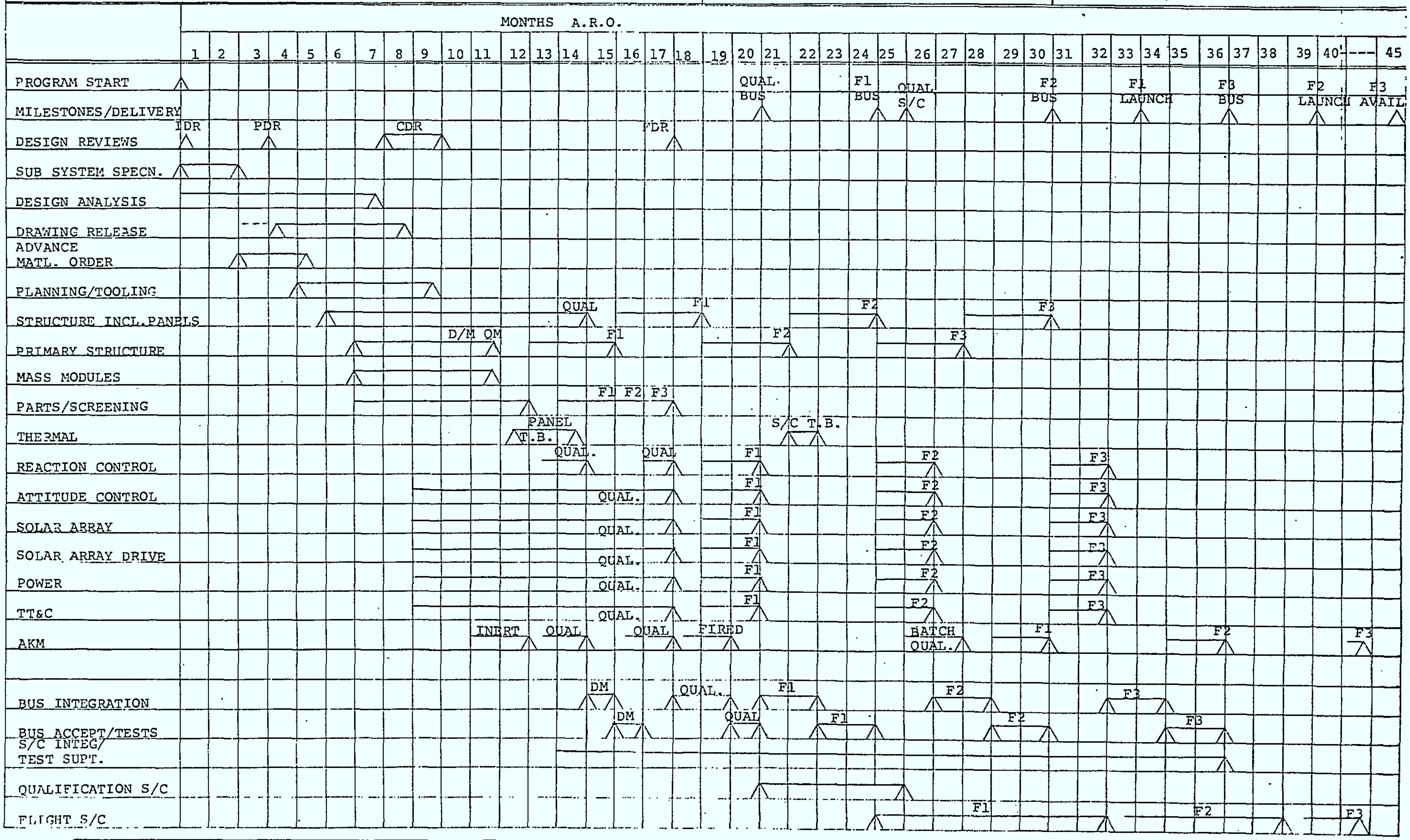

Figure 2-2

To achieve this plan it has been recognized that management of the Bus and its subsystems requires that the contractor set up a program office and management plan. The follow-on text defines the management organization, duties of key members, and controls required to ensure satisfactory technical and hardware quality within cost and schedule constraints.

2.1.1 Specification Release, System Design and Development Phase

This phase covers the first 8 months of the program during which time Bus subsystems will be designed, developed and made ready for qualification. It is assumed that prior to the start of the program, specifications and interface details between subsystems, communications payloads and mission requirements are resolved and parameters fully defined. In addition, indications are that long lead procurements must take place shortly after program start, see Figure 2-1 (e.g. titanium and magnesium forgings for apogee motor and structure, long lead electrical components, etc).

Major activities during this phase will be related to the items listed below; however, it should be emphasized that every effort will be made to derive the maximum benefit possible from existing spacecraft, particularly CTS, experience:

- Firming up the Bus design with emphasis on resolution of interface problems, specification requirements, payload parameters, etc.

- Issuing ACS, RCS, DSA, Power, TT&C and AKM subsystems and component specifications.

- Finalizing the Structure, Thermal, DSA, RCS, Power, TT&C and ACS designs.

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- Carrying out the necessary trade-off studies, and carrying out sensitivity studies for subsystem and component selection, i.e., solar cell configuration, motor types, etc.

- Soliciting proposals from vendors, reviewing proposals and selecting vendors.

- Completing development tests, (i.e. static test, thrust tube) on any critical/risk areas in any of the Bus subsystems.

- Manufacturing a dynamic model, (later to be refurbished to a Qualification Model), with representative qualification subsystems for vibration/thermal balance testing.

- Carrying out subsystem design reviews which, during this phase, will be limited to preliminary and critical design reviews.

- Preparation of detail drawings for subsystem manufacture.

- Ordering of long lead items for in-house subsystem qualification tests. These include solar cells, forgings, bearings, honeycomb panels, etc.

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2.1.2 Subsystem Qualification Phase

During this phase of the program, the Structure Subsystem will be qualified when the dynamic model spacecraft is vibrated at a suitable test facility to be defined by the customer. This will be followed by the thermal balance testing of a north or south payload panel and finally the spacecraft, again in a suitable test facility to be defined by the customer.

For all these tests, representative hardware will be required. Mass/thermal modules for tests on the Bus subsystems have been costed. The RCS and AKM (inert) will be representative of flight hardware, and the RCS system will be structurally qualified during the structure dynamic test.

It is assumed in this plan that suitable communications payload hardware in the form of flight representative hardware for the antennas and mass/thermal modules for payload components will be supplied by the customer in the time frame listed.

The structure test will be an overweight test in order to establish margins and determine potential growth capability.

Preparation of procedures, test plans, test prediction analysis and analysis of test results are included in this phase. The results of these qualification tests will culminate in a Final Design Review which will approve the subsystems for flight hardware manufacture.

In parallel with the above, other Bus subsystems will be qualified either at the component (in critical areas) and/or subsystem level. Typically, the apogee kick motor vendor will conduct qualification tests on the AKM. This will include high/low temperature firings at high altitudes.

The Reaction Control Subsystem vendor will carry out component and subsystem qualification testing followed by hot firings on the subsystem. This will be integrated with the Bus qualification schedule as discussed in Section 2.4.

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The deployed Solar Array, with the Solar Array Drive System, will be qualified with live cells installed on one wing of the array, and the stowage and deployment operations demonstrated. (See Section 2.5 and 2.11).

The Attitude Control Subsystem components will be qualified by similarity with CTS components and by individual vendors and compatibility tests performed at the subsystem level (see Section 2.3.3.2.1.1).

Finally, following these qualification tests, Final Design Reviews will be held at the vendors on all subsystems and components, thus clearing them for proceeding with manufacture of flight hardware.

2.1.3 Qualification Model Spacecraft Tests

Having completed the qualification testing on the Bus subsystems and components, the plan calls for qualified subsystem units to be refurbished and a complete qualification model Bus be delivered to the customer for integration/compatibility tests with the communications payload and other customer supplied subsystems. This testing will be followed by complete spacecraft vibration and thermal vacuum tests.

Prior to the delivery of the bus to the prime contractor, the bus integration and test operations will be completed.

2.1.3.1 Bus Integration

The bus integration operations will commence with the installation of the RCS subsystem to the structure. The structure will be shipped to the RCS vendor's facility for this operation since the interface between these subsystems is complex and the testing is so specialized that it is best done at the RCS vendor's plant. After this operation is completed, the structure will be shipped back to the bus contractor's facility. The other subsystems such as the power, TT&C, ACS, SAD, Solar Array and AKM (inert) would be installed in the approximate sequence listed. The installation of the harness and thermal subsystem will conclude the integration phase.

2.1.3.2 Bus Test

During the integration phase, subsystem to subsystem checks will be conducted to assure their compatibility. All electrical, thermal and mechanical interface interactions will be tested and adjusted. Harness checks will take place, so that the bus will be completely checked out before delivery to the prime contractor.

The Bus subcontractor will provide the necessary support to complete spacecraft integration of subsystems, test plans, procedures and any pre- or post-test analysis requested by the customer. The related costs are not included in this study report.

It should be noted that this is the first time the payload will be integrated with the Bus and unless the interface parameters are correctly defined, there could be numerous changes ensuing at this part of the program (a condition which should be avoided).

The Bus delivered to the customer will be subjected to an acceptance test, (levels to be defined), the intent being to confirm compatibility between all Bus subsystems and deliver to the customer a unit which meets all defined requirements.

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2.1.4 Flight Hardware Delivery

In order to meet the 33 month launch, the plan projects that Flight hardware manufacture will commence prior to spacecraft qualification test completion. This is an indication that the Bus subsystems will be moving out at slight risk. Attention to interface definition in the system design phase will ensure that the risk has been minimized. F-1 hardware start is projected as 12 months ARO when most of the Bus subsystems will have completed their development test programs.

A further area in which some risks must be taken in order to achieve the 33 month ARO launch date is associated with ordering long lead items and parts for screening. This is always a difficult problem area and the Implementation Plan recognizes the need to have sufficient screened parts early in the program and intends procuring parts by month 9 ARO for F1 and month 18 for the F2 and F3 Buses.

Finally, the plan indicates that the three Buses can be delivered at six month intervals.

2.2 Program Management

For the implementation plan previously discussed, a proposed program organization (Figure 2-3) is submitted. This organization is fairly standard for spacecraft programs and, in the main, consists of:

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- A staff organization reporting to a Program Manager who is responsible for cost, schedule, product effectiveness and systems tasks.
- Individual Subsystem Project Managers reporting to the Program Manager.
- Operations and Contracts personnel who report to their respective departments, and also to the Program Manager.

Details and descriptions of responsibilities for key organization members follow:

2.2.1 Program Manager

The Program Manager will report to the Director of Engineering Programs or the Vice-President and General Manager Engineering, and will be responsible for:

(a) The technical, cost and schedule performance of the program, in accordance with the terms of the contract, and the work breakdown structure given in Figure 2-4.

(b) Such decisions as may be necessary to ensure that the work meets the requirements of the contract within the financial limitations imposed.

(c) Liaison with the company's internal departments to ensure that all resources are utilized to the full extent necessary throughout the program.

GENERAL PURPOSE BUS PROPOSED PROGRAM OFFICE ORGANIZATION

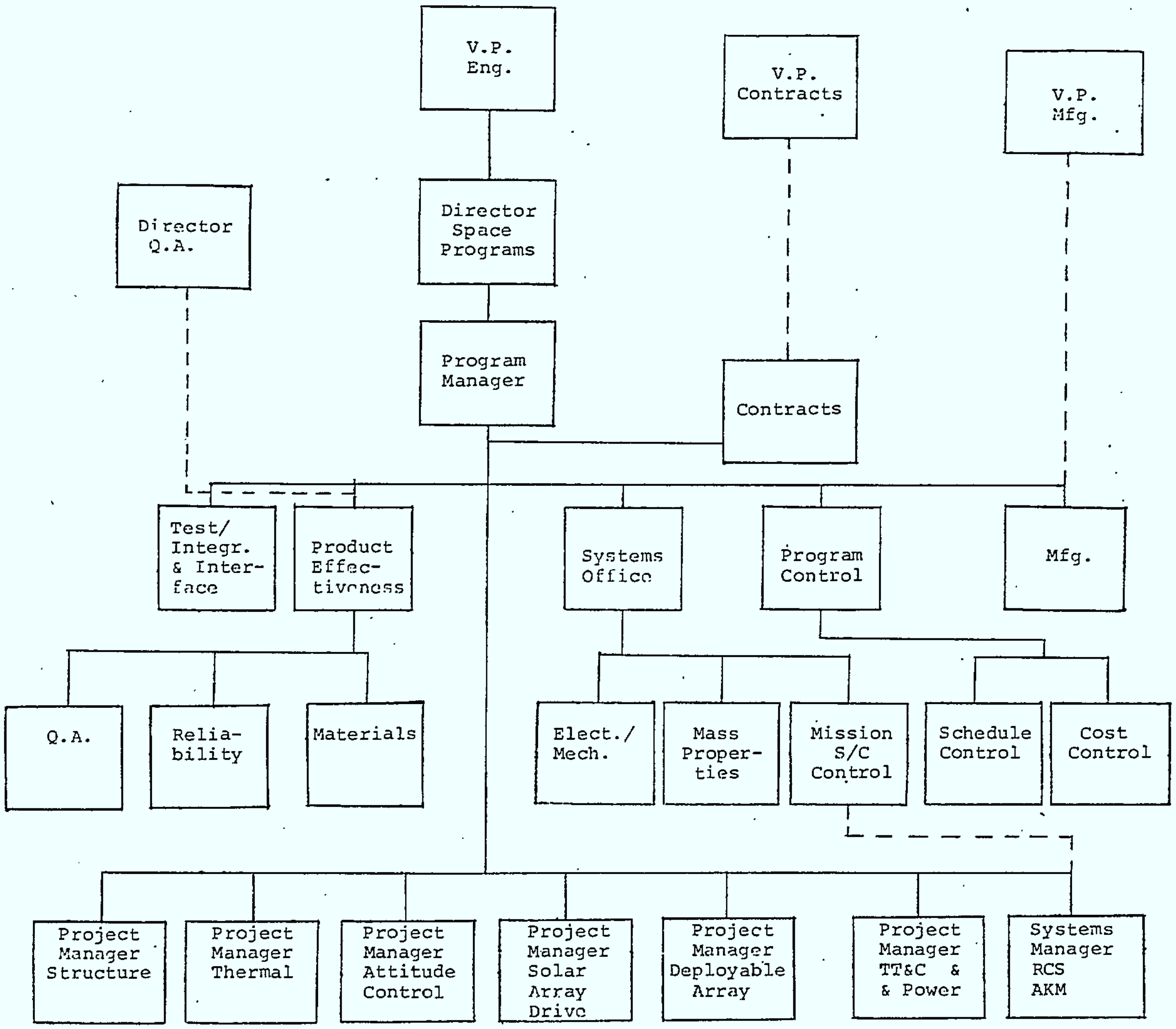

FIGURE 2-3

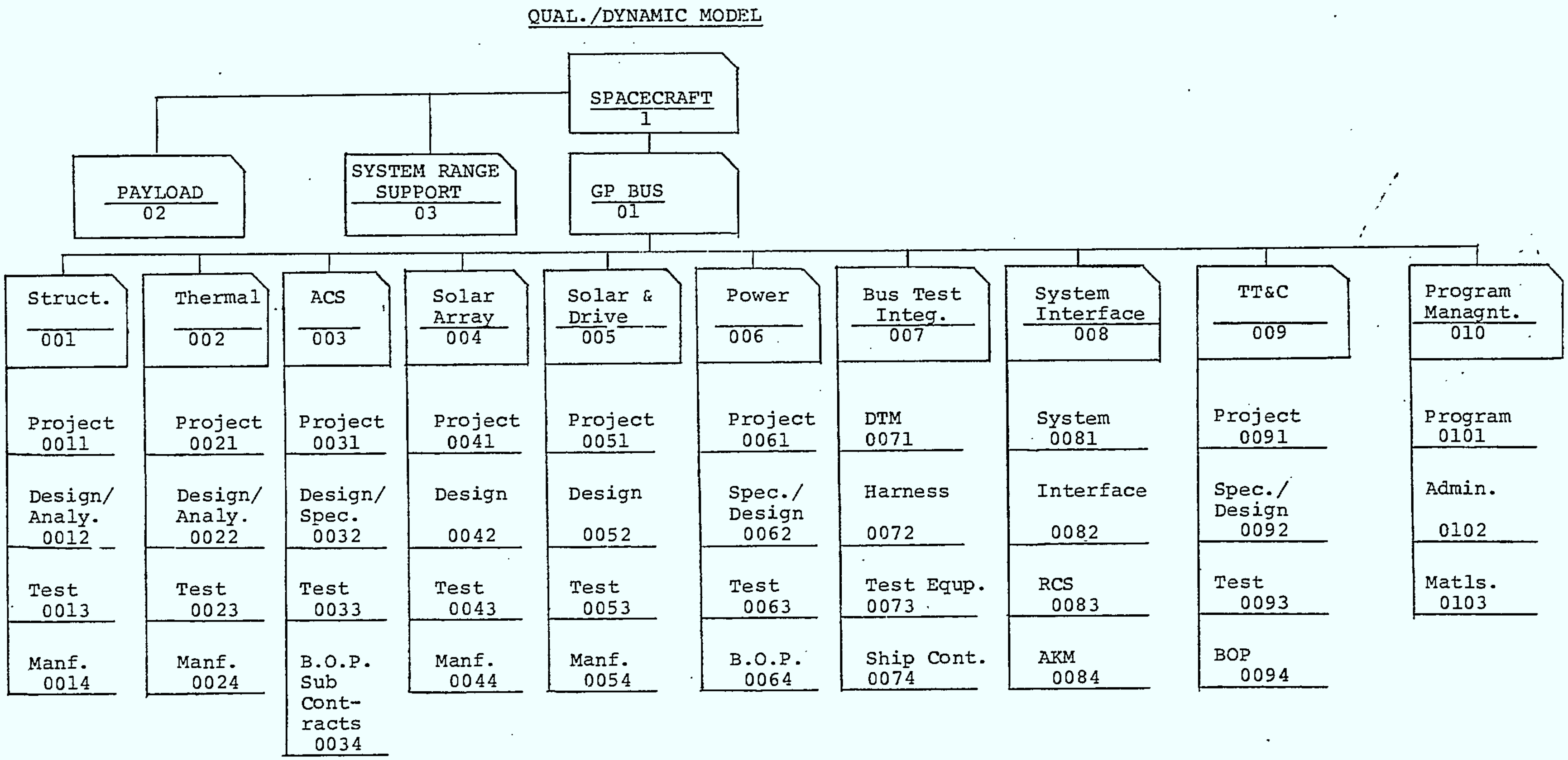
QUAL./DYNAMIC MODEL
SPACECRAFT
1
PAYLOAD
02
SYSTEM RANGE SUPPORT
03
GP BUS
01
Struct.
001
Project 0011
Design/ Analy. 0012
Test 0013
Manf. 0014
Thermal
002
Project 0021
Design/ Analy. 0022
Test 0023
Manf. 0024
ACS
003
Project 0031
Design/ Spec. 0032
Test 0033
B.O.P. Sub Cont-racts 0034
Solar Array
004
Project 0041
Design 0042
Test 0043
Manf. 0044
Solar & Drive
005
Project 0051
Design 0052
Test 0053
Manf. 0054
Power
006
Project 0061
Spec./ Design 0062
Test 0063
B.O.P. 0064
Bus Test Integ.
007
DTM 0071
Harness 0072
Test Equp. 0073
Ship Cont. 0074
System Interface
008
System 0081
Interface 0082
RCS 0083
AKM 0084
TT&C
009
Project 0091
Spec./ Design 0092
Test 0093
BOP 0094
Program Managnt.
010
Program 0101
Admin. 0102
Matls. 0103

Figure 2-4

(d) Liaison with the customer, in conjunction with the Contracts Administrators, to ensure that the contracted program requirements at all times meet the customer's needs.

2.2.2 Program Controller

The Program Controller will be responsible to the Program Manager for overall program planning, budgeting, cost, schedule control and reporting. This will inlude the necessary liaison and planning with the customer and the major subcontractors. In addition, he will be responsible for the following functions:

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(a) Highlighting program problem areas and provide cost and schedule visibility to the Program Manager, Subsystem Managers, and Spar management.

(b) Ensuring that program activities are in accordance with the authorized tasks.

(c) Ensuring that all reporting functions required by the contract are performed in a proper and timely manner.

(d) Ensuring that all applicable internal departments are aware of the program requirements.

(e) Ensuring that all detailed scheduling activities of the program have a well defined interface with the overall program plan.

(f) Ensuring that a constant surveillance is kept on all costs affecting the program, that the identification for such expenditures is related to and is in conformity with the agreed work packages and that only expenditures authorized are incurred.

(g) Interfacing between the customer and subcontractors on all administrative aspects of the program, excluding contractual matters.

In discharging the above responsibilities, the Program Controller will look to the Subsystems Project Managers for much of the detailed implementation.

Appendix A identifies typical program control procedures to be followed.

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2.2.3 Contracts Administrator

The Contracts Administrator will be responsible for:

(a) Ensuring that the program funding levels are properly negotiated with the customer.

(b) Ensuring that all contractual requirements are clearly defined both to the customer and to the Program Office.

(c) Resolving contractually any discrepancies that may arise between the work that needs to be done, and the work defined by the contract. Whereas ways and means may be discussed and formulated by other personnel in liaison with their customer counterparts, the official contractual channels to the customer will be through the Contracts Administrator. In this regard, it will be the Contracts Administrator's responsibility to ensure that no agreements (verbal or otherwise), which affect the scope of the task, schedule, or the cost shall be made with customer except through the Contracts Administrator.

(d) Reviewing and approving the contractual terms of all major subcontracts prior to their placement by the Procurement Department and obtaining customer consent where applicable.

2.2.4 Subsystem Project Managers

Project Managers will be appointed for the major Bus subsystems except the RCS and AKM Subsystems, namely:

- Thermal Subsystem
- Structure Subsystem
- Solar Array Subsystem
- Attitude Control Subsystem
- Power & TT&C Subsystem
- Solar Array Drive Subsystem

The RCS and AKM Subsystems are the responsibility of the Systems Manager.

The Subsystem Project Managers will be responsible to the Program Manager for:

(a) Meeting the technical requirements of the subsystem as defined by the contract within the budget and time constraints imposed by the Program Office.

(b) Defining and planning those subsystem tasks which are necessary to accomplish the objectives outlined above. This includes the responsibility of advising manpower and resource requirements to their appropriate Department Heads.

(c) Keeping the Program Office and the appropriate internal Department Head advised of the technical and schedule status of their subsystem, and highlighting any problem areas that require resolution in order that the program object may be met.

2.2.5 Systems Manager

The Systems Manager will be responsible to the Program Manager for:

(a) Spacecraft Bus technical compliance.

(b) Ensuring that clear definition exists for all technical interfaces between the subsystems which are the contractor's responsibility and all other areas which are the customer's responsibility.

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(c) Ensuring that all interfaces are clearly defined between the Bus subsystem.

(d) Assessing and highlighting to the Program Manager any discrepancies that exist between the spacecraft/mission technical requirements and the technical requirements of the Bus subsystem specification.

(e) Proposing to the Program Manager any studies and/or analyses which are not covered by the requirements of the subsystem specifications but which are considered necessary in order that the contracted task may be accomplished.

(f) Liaison on a continuous basis with the Subsystem Project Managers and the customer in pursuit of the tasks delineated in (a) through (d) above.

(g) Control of the AKM and RCS vendors.

2.2.6 Product Effectiveness Manager (Including QA)

The Product Effectiveness Manager will be responsible to the Program Manager for:

(a) Control of the "as designed" and "as built" configuration.

(b) Liaison with customer and subcontractors to ensure that all quality provisions required called up by the contract are understood and observed.

(c) Ensuring that the quality requirements of the contract are defined to, and observed by, all operating departments.

(d) Generating, in conjunction with appropriate line managers, those controls and procedures necessary to accomplish (a) through (c) above, and to implement such procedures.

(e) Generating reliability and quality assurance reports as may be necessary to meet the requirements of the contract.

(f) Negotiating with the customer and subcontractors a clear interpretation of the quality and configuration control provisions of the contract.

(g) Coordination of all Material Review Board activities related to the work contracted to Spar.

The Product Effectiveness Manager will receive day-to-day and long term assignments from the Program Manager. However, on all product assurance matters which impinge on, or may conflict with, company standard procedures and policies, he will take direction from the company Director of Quality Assurance and will advise the Program Manager of such direction. In case of conflict the Director of Quality Assurance will assume precedence.

2.2.7 Test/Integration Manager

The Test/Integration Manager is responsible to the Program Manager for:

(a) The test activities for all bus subsystems and for ensuring that meaningful test results are obtained. This includes development, acceptance, qualification and performance testing.

(b) Liaison with the Subsystem Managers (or their designates) in determining the test requirements and reviewing test results of subsystem components.

(c) Preparation of all test plans and test specifications.

(d) Preparation of test schedules and for ensuring that all necessary facilities are available when required.

(e) Carrying out those tests which are defined and agreed by the Subsystem Managers and Program Office under (b) and (c) above.

(f) Preparation of test reports.

(g) Determining and implementing the most cost effective way of meeting the test requirements.

(h) Responsible for the integration and acceptance testing of the Bus for delivery to the customer.

In addition the Test/Integration group will be responsible for the Bus harness design/manufacture, mass modules for the mechanical test model, and shipping containers. It is assumed that the CTS spacecraft shipping containers and handling dolly for spacecraft integration plus alignment equipment available at CRC will be used for this program.

2.3 Attitude Control Subsystem Implementation Plan

2.3.1 General

A work plan and schedule, Figure 2-5, for the production of a qualification model and three flight model Attitude Control Subsystem is presented herein.

Of the seven major subsystem components, two will require minor modification to meet the General Purpose Bus requirements. These components are:

(a) The control electronics unit, which will be, with minor modification, the Attitude Control Electronic Assembly (ACEA) used on the CTS Program.

(b) The momentum wheel which will be the CTS wheel except that a minor modification may be required to provide larger grease reservoirs for longer life.

The momentum wheel and control electronics development is minimal so that development/engineering models of those components will not be necessary.

A review of the attached component delivery schedule shows that due to the long lead times involved, particularly for the electronics unit, overlap between the qualification and flight programs will be necessary, thus introducing some risk. In addition, a Preliminary Design (or Definition) Phase will be required prior to letting subcontracts for the implementation phase.

The tasks required for the Preliminary Design Phase and Implementation Phase are identified below followed by a work plan and organization.

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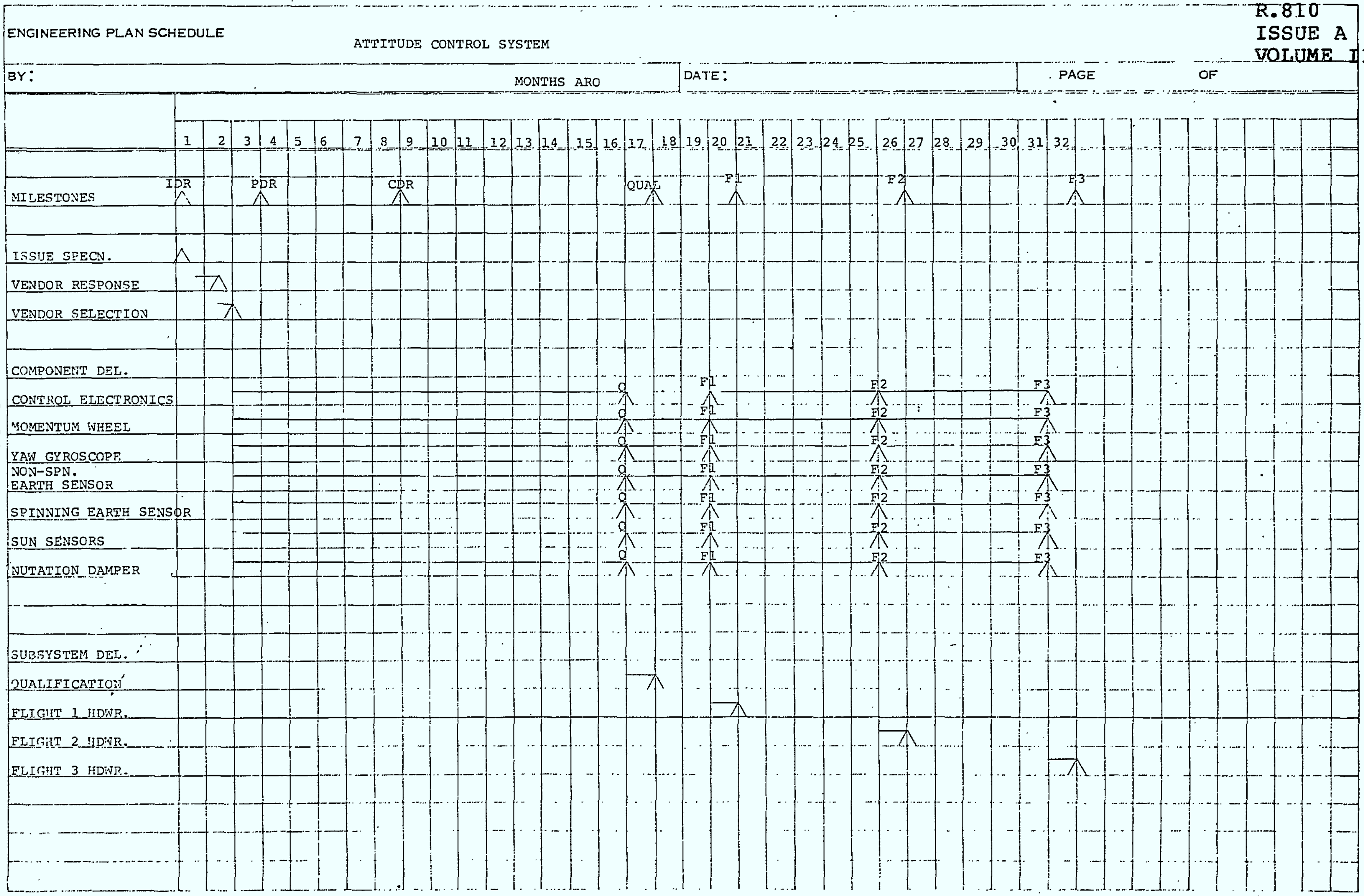

Figure 2-5

2.3.2 Preliminary Definition Phase

To accomplish the program as defined herein, a number of activities will be required prior to the component subcontract activities. These include:

(a) Control Electronics Design

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The control electronics will be the same as that of ACEA of the CTS program except for minor changes. These changes will be incorporated into a new set of drawings and specifications.

(b) Momentum Wheel

The momentum wheel will be the same design as that used on the CTS program. An investigation will be conducted on the sizes of the grease reservoirs. If this investigation proves that larger reservoirs are required, then this minor modification will be incorporated into a new set of drawings and specifications.

(c) Presubcontract Activities

Prior to letting subcontracts for the implementation phase, component specifications and bid packages require preparation followed by RFP actions and proposal evaluation.

(d) Systems Analysis

Systems analysis will be required to define critical component specification changes However, as in other systems/ detailed design tasks, every effort will be made to derive the maximum benefit from CTS experience.

It is estimated, that in order to complete the above tasks in preparation for the implementation phase, a period of three to four months will be required.

2.3.3 Implementation Phase

2.3.3.1 Component Model Deliverables

Component models for the Dynamic/Thermal spacecraft will be dummies; mass, footprint and thermal dissipation representative.

The qualification subsystem will consist of the following:

(a) Wheels - The qualification wheel.

(b) Electronics - The qualification unit.*

(c) Yaw Gyroscope - Flight unit.

(d) Non-Spin Earth Sensor - Flight units.

(e) Spinning Earth Sensor - Flight units.

(f) Sun Sensors - Flight units.

(g) Nutation Damper - Flight unit.*

* These qualification subsystem components will be considered the flight spare units.

2.3.3.2 Subsystem Integration and Test

The objective of the Attitude Control Subsystem test and performance demonstration is to assure equipment interface compatibility and verify system performance within the specified requirements. Tests will be performed at the component and subsystem level with dynamic flight performance verified by analysis and simulation.

2.3.3.2.1 Component Tests

2.3.3.2.1.1 Component Qualification Tests

Most of the attitude control subsystem components have undergone successful qualification for the CTS program and by similarity, may be considered qualified for the General Purpose Bus Satellite. Those components which require qualification are:

(a) Electronics
(b) Momentum Wheel (if modified)

For each of these components, a qualification test program will be conducted to verify that the qualification unit complies with the test requirements of the relevant specification. All qualification tests will be subject to quality assurance surveillance and all units will conform to the qualified design configuration with all changes or deviations formally approved.

2.3.3.2.1.2 Component Acceptance Testing

All flight components will be subjected to approved acceptance tests with all tests witnessed.

2.3.3.2.1.3 Component Inspection Testing

Inspection test procedures will be prepared based on the acceptance test procedures, except that environmental exposures will not be performed. These tests will verify correct operation of the units prior to installation in the subsystem and the results used as baseline against which any future degradation of performance can be measured.

2.3.3.2.2 Subsystem Testing

Subsystem testing of the integrated ACS will verify the operation and integrity of the subsystem. The tests will be performed with the components mounted on a full-scale spacecraft structure mock-up and interconnected with subsystem interconnect cables. Testing will include sensor operational tests, end-to-end checks, under/over voltage tests, power switching exercises and conducted powerline EMC tests.

2.3.3.3 Digital Simulation

Subsystem performance will be demonstrated through digital simulation using detailed component models and spacecraft dynamics.

2.3.3.4 Test Equipment

The major test equipment will consist of the following:

(a) Component peculiar test equipment supplied by the component vendors.

(b) ACS test set consisting of a test controller, signal and power supplies and test instrumentation.

(c) Test targets for stimulation of sensors.

2.3.3.5 Systems Engineering

The systems engineering activities include system definition, interface specification and control, analysis and simulation.

2.3.3.5.1 System Design

Through the system definition, close liaison will be maintained between the RCS and ACS systems. Systems design activities will include the preparation of subsystem component specifications and statements of work.

2.3.3.5.2 System Interfaces

System interfaces include electrical, mechanical and thermal for which the following activities are required.

(a) Electrical Interface and EMC

Support to component procurement and system design by way of preparation and review of documentation pertaining to electronic design integrity will be required as well as coordination of power, telemetry and command requirements and EMC control.

(b) Thermal Interface

Thermal engineering will support component procurement and manufacturing with responsibility for all thermal aspects of the subsystem, including preparation of thermal environment specifications and the negotiation of temperature limits with suppliers as well as definition of thermal test requirements.

(c) Mechanical Interface

Mechanical interface activities include the specification of mechanical envelopes and footprints, stress and dynamic analysis and specification of vibration test requirements as well as review of vendors' stress and dynamic analyses and tests.

2.3.3.5.3 Analysis and Simulation

The analysis and simulation requirements for the General Purpose Bus satellite program in the area of attitude control and orbit control are identified below. The attitude control aspects only will be dealt with. For orbit control, the necessary actuators and sensors will be available as part of the ACS/RCS subsystems. The software, analysis and simulation requirements for orbit control are also identified below on the assumption that the prime contractor will carry out these tasks, costs for which are not included in this study report.

The mission may be divided into the following operational phases:

(a) Launch
(b) Transfer Orbit Phase
(c) Apogee Injection
(d) Attitude Acquisition
(e) Station Acquisition

(f) On-Orbit Operation

i) Attitude Control
ii) Stationkeeping

The analysis and simulation requirements for the above are discussed below:

(a) Launch Phase

The launch phase is the responsibility of the launch authority. Launch constraints such as any guidance update requirements for the second stage for adjusting the transfer orbit apogee, apogee biasing schemes, transfer orbit node locations, launch window constraints due to power, thermal and transfer orbit attitude sensing, will require identification by the launch authority, the customer, and the appropriate subcontractor.

(b) Transfer Orbit Phase

For the transfer orbit phase, it is necessary to determine a suitable method of attitude determination, generate software for attitude determination, generate software to compute apogee motor firing attitude corrections based on transfer orbit parameter determination, simulate the spin axis reorientation manoeuvre.

(c) Apogee Injection

For this phase, it will be necessary to generate software for optimum apogee selection and for timing and firing the apogee motor.

(d) Attitude Acquisition

The attitude acquisition will consist of:

i) Despin
ii) Sun Capture
iii) Solar Array Deployment
iv) Pitch Manoeuvres and Wheel Spin Up
v) Precession Manoeuvre
vi) Transfer to On-Orbit Control

A small change will be necessary to the existing ground software.

(e) Station Acquisition

For this phase, it will be necessary to generate software for orbit determination in the near synchronous orbit and for the determination of the necessary drift requirements followed by circularization and synchronization at station.

(f) On-Orbit Operation

It will be necessary to perform detail design of the on-orbit attitude control laws including periods of stationkeeping perturbation and to generate detailed performance simulations.

2.3.3.5.4 Software

Results of the analysis and simulation activities will provide the logical operations and control laws required for the complete attitude control function.

2.3.3.6 Component Procurement

The major components for which the procurement activities will be carried out are:

(a) Non-spinning horizon sensor
(b) Momentum Wheel
(c) Yaw Gyroscope
(d) Sun Sensors
(e) Nutation Damper
(f) Spinning Horizon Sensor

A responsible equipment engineer (REE) will be assigned for each component. The primary responsibility of the REE is to ensure technical compliance of the subcontracted hardware to the specification requirements.

The defining documents will be verified and negotiated with the subcontractor so that they properly define the deliverable hardware. Once components are under contract, the REE will be responsible for:

(a) Continuously monitoring the progress of the subcontractor and determine problem areas with respect to design, manufacturing and testing as well as cost and schedule.

(b) Coordinating the review and approved of vendor documentation and technical data.

(c) Witnessing engineering, qualification and acceptance testing at the subcontractor's facility.

(d) Liaison with the integration and test engineers.

2.3.4 Project Organization

The project organization will consist of a project manager to whom will report a manager of component procurement and manufacture, and a manager of systems engineering and test.

The manager of systems engineering and test will be responsible for systems analysis, interface, design, simulation, integration and test.

The manager of procurement and manufacture will be responsible for product effectiveness, component procurement and manufacture.

Each of the above will supervise systems engineers, REE's, test engineers and technicians to accomplish the engineering tasks.

The project manager will report to the Program Manager and will obtain program office resources such as reliability engineering, quality assurance, materials and process engineering and program control from the program office.

2.4 RCS Implementation Plan

This implementation plan defines the tasks which will be performed by the mechanical prime contractor to define, procure and manage the contract for the Reaction Control Subsystem (RCS) for the General Purpose Bus (GPB) Satellite, and to ensure, at the spacecraft level, that the RCS models shall perform as intended throughout their ground and flight mission life. A schedule for accomplishing these tasks is shown in Figure 2-6.

2.4.1 Program Phases and Logistics

It is assumed that final systems design definition of the RCS and production of final RCS requirements specification and statement of work will be completed prior to GPB contract award. RCS RFP release will occur immediately upon receipt of GPB contract. With a 17- month program from GPB contract award to completion of RCS qualification, it is imperative to have all major RCS interfaces defined on day one of the contract.

Upon receipt of the GPB contract, Phase I, the RCS RFP will be released, proposals received, evaluated, negotiated and contract awarded by the end of month 2 ARO as shown in Figure 2-6. This schedule is predicated on the reasonable assumption that the potential RCS contractors would be knowledgeable and prepared to bid as a result of their own preproposal effort with the GPB prime.

The second phase will be the period from contract award at month 3 ARO to the completion of successful RCS qualification and FDR (approximately end of month 18 ARO).

ENGINEERING PLAN SCHEDULE   GENERAL PURPOSE BUS - REACTION CONTROL SUB SYSTEM

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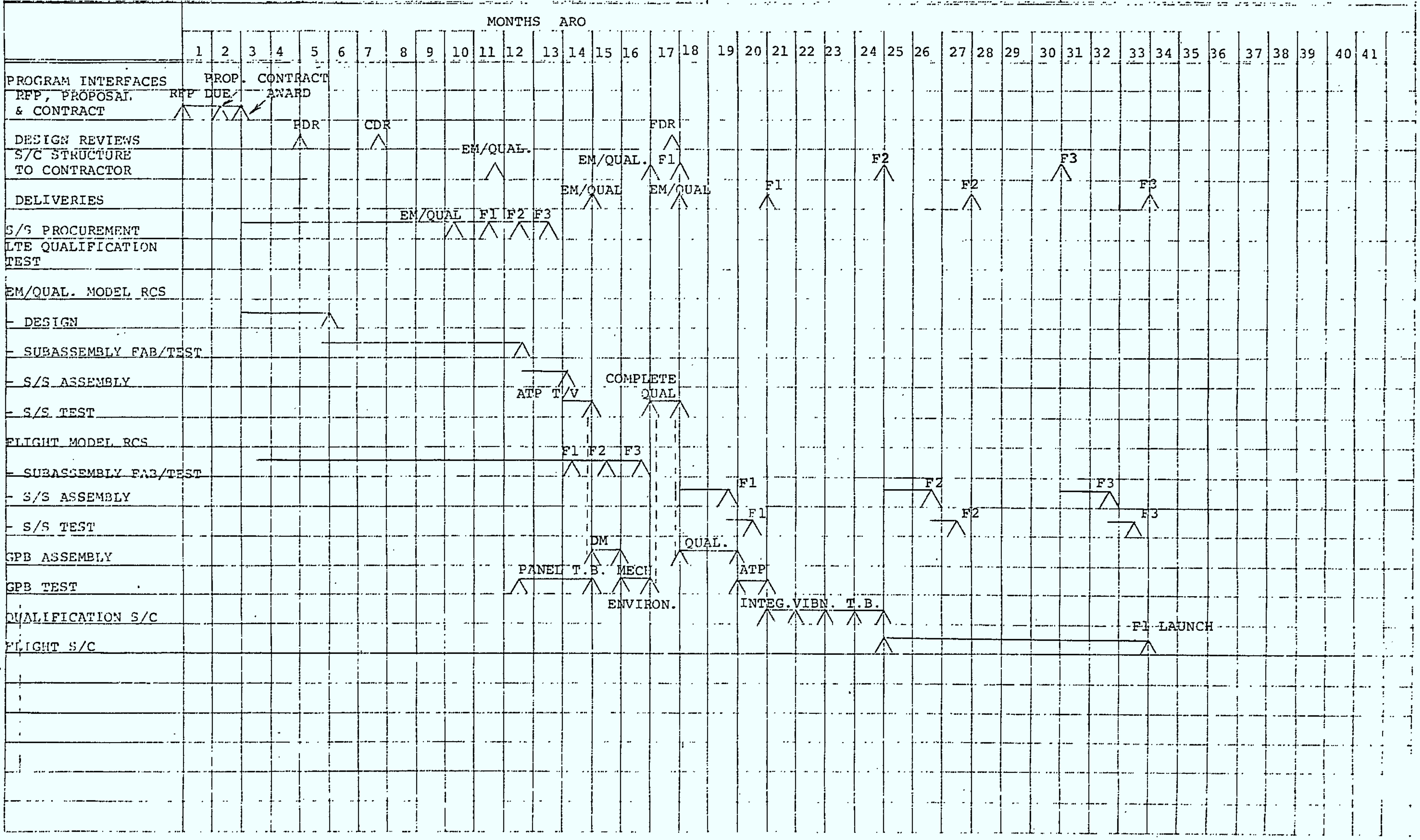

Figure 2-6

The third phase, the flight model production and test phase, will conclude the active RCS contract with availability for delivery of flight model 3 at month 33 ARO.

The fourth phase, bus level integration and test will continue through to delivery of flight model 3 bus at month 36 ARO.

2.4.1.1 Phase II

The design and qualification program for the RCS has been streamlined to minimize development hardware deliverables and to take advantage of GPB level testing as part of subsystem level qualification.

Potential RCS vendors have responded positively to the concept of a transfer to Canada of subsystem integration capability. This could take place over a 3 flight program such as the GPB. If implemented, this capability would reduce costs and simplify integration and test schedules on future programs. However, for the purposes of this study, a totally offshore prime integrated hardware program is baselined, since costing is available for this program responsibility only.

It is recommended that, for each of the three spacecraft models, the GPB primary structure including thrust tube, bulkheads (and non-flight strut supports for the bulkheads to simulate integrated structure stiffness) would be shipped to the RCS contractor's facility for direct integration, test and shipment of the RCS. This is dictated by the spacecraft structural design. It is also beneficial from the cost, schedule and RCS ease of integration points of view.

There was originally to be a DTM RCS plus a full qualification subsystem as defined in the RCS Statement of Work, SPAR-SOW.071 and it was based on this hardware requirement that the potential vendors provided budgetary costs. However, the requirements were subsequently reviewed to reduce unnecessary program scope and a budgetary quotation was received for the amended program, see Volume II, Section 2.4 of this report.

The state of development of the RCS hardware, combined with the need to provide flight configuration plumbing for the GPB development test model (DM) structural qualification and the difficulties encountered in performing mechanial environmental testing at the subsystem level, have led to the program shown in Figure 2-6.

The qualification (Engineering Model) RCS subsystem will be comprised of:

- a flight configuration half system
- a half system which is electrically, mechanically and thermally flight representative and which is capable of retaining fluids at full working pressure and
- an electrical control unit which is complete and flight quality, capable of controlling a full subsystem.

This model will be the first RCS subsystem hardware and will be built up on the GPB DM primary structure between month 11 and the end of month 13 ARO. Prior to this integration, components and modules will have been qualified.

During month 14 ARO, this subsystem will begin qualification including the following testing at the contractor's facility.

- o ATP
- o functional and electrical
- o leakage
- o proof
- o thermal vacuum
- o gas flow

At this point the engineering model RCS, mounted on the DM primary structure, will be returned to Spar for integration of the DM and structural environment qualification testing. This series of tests will also qualify the RCS structurally.

At the beginning of month 17 ARO, the DM, stripped to the primary structure plus EM/QUAL RCS, will be returned to the RCS contractor, where during this month, the RCS qualification will be completed. Included in this testing will be:

- o leakage
- o proof
- o performance mapping of all flight duty cycles
- o functional & electrical
- o gas flow

The subsystem will then be refurbished as necessary prior to delivery at the beginning of month 18 ARO to Spar for integration of the qualification GP Bus.

The only deliverable development hardware will be a thermal representation of the north station-keeping thrusters for the panel thermal vacuum test, planned for months 12 and 13 ARO. These thrusters, with high heat dissipation, represent the only significant thermal development task for the RCS, and their interaction with components on the north panel, notably the batteries and the mechanical drive unit, must be investigated as early in the program as possible.

The RCS preliminary design and development work will be completed at month 4 ARO culminating at the Preliminary Design Review. By month 7 ARO, the design will be complete and the subsystem Critical Design Review will be held. The RCS Final Design Review will be held at month 17 ARO after subsystem qualification has been successfully completed and reports presented.

2.4.2 Direct RCS Contractor Monitoring

2.4.2.1 Contractor Selection

The RCS engineers will interface with Purchasing at the time of RFP release. At least two competent RCS engineers will be required to evaluate the proposals and attend contractor negotiations, to arrive at the best choice for the RCS contract award.

2.4.2.2 Monitor at Contractor Facility

With a subsystem of the complexity of the RCS for GPB and with a parallel program effort, it is planned to employ two REEs, full time, to monitor the RCS through subsystem qualification. It is proposed that one engineer reside at the contractor's plant from the beginning of the contract through completion of RCS qualification and the RCS FDR. This engineer can perform many of the subsystem and system analysis tasks during this assignment (denoted by*) in task definition below. In addition, it is proposed to employ an RCS project engineer. He will be responsible for managing the RCS contract, performing systems analysis and monitoring spacecraft level testing. In addition, it is proposed that the RCS project engineer visit the RCS contractor's plant for direct monitoring every three weeks for approximately three days per trip up to completion of RCS final assembly; then once every two weeks during subsystem qualification. It is further proposed that both of these engineers visit the RCS contractor's facility once every three weeks during protoflight manufacture, test and buy-off.

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2.4.3.2 Subsystem Analyses

It will be necessary to ensure that the final design meets the spacecraft end-item requirements. Continuing analyses of the following will be required:

(a) Plume impingement analysis*,

(b) Thermal analysis (heat flux interactions, etc.),

(c) RCS performance analysis*,

(d) Alignment analysis*.

2.4.3.3 Review of Contractor Documents

All RCS contractor documents as defined below must be reviewed by both RCS engineers to ensure that all system requirements are being met.

(a) Subcontractor Specifications*,

(b) RCS Subassembly and Subsystem Test Plans and Procedures*,

(c) RCS Data Review Packages*,

(d) RCS Drawings*,

(e) RCS Test Reports*.

2.4.3.4 Subcontract Management

The RCS project engineer will handle the management of the RCS contract. This effort is estimated at two days per week throughout the active program.

2.4.4 Spacecraft Level RCS Tasks

2.4.4.1 Interface

Some continuing effort will be required for interfacing with other spacecraft subsystems after contract award. This is best accomplished by the project engineer resident at the mechanical prime.

2.4.4.2 RCS/Spacecraft Test Plans and Procedures

The RCS project engineer will prepare RCS and RCS/spacecraft test plans and procedures to perform incoming inspection, RCS integration and spacecraft compatibility and reference performance and special tests during spacecraft environmental tests. These will be prepared subsequent to RCS performance testing.

2.4.4.3 RCS and RCS/Spacecraft Tests

The RCS project engineer will be responsible for performing incoming testing of each RCS subsystem after delivered from the RCS contractor. These tests would be:

- functional and electrical tests using the electrical servicing cart (ESC)

- external and internal leakage checks using the propellant servicing cart (PSC)

NOTE: It has been assumed that the CTS PSC and DTM cart will be available for use during the GPB program. Hose fittings will have to be modified and age-critical components might have to be replaced.

A vacuum facility (such as the 8' x 8' vacuum chamber in the David Florida Laboratory, CRC) will be required for the external leakage test. A Veeco leak detector plus calibrated leak source will also be required for this test and for subsequent localized leakage sniffing if a leak is found. The internal leak check of latching valves can be done with the Veeco only. For the DTM, only simplified sniffer leakage and functional and electrical testing will be required.

During spacecraft integration and compatibility testing, reference performance and special compatibility tests will be performed which will require the participation of the RCS project engineer. The complexity of these tests (particularly those involving the ACS) remains to be defined.

Periodically throughout the ground life of each flight configuration RCS after integration within the spacecraft, valve leakage, functional and electrical and alignment tests will be performed and their results analyzed. For each model three series of these tests will be required - before vibration, before thermal vacuum and after thermal balance testing.

The RCS engineers will be required to participate in spacecraft environmental tests (vibration, thermal vacuum, thermal balance) for each model.

Incoming tests will be required to ensure that the propellant and electrical servicing carts are operating correctly.

2.4.4.4 Propellant Service Cart Operation and Cleanliness Control

The Bus contractor will require a contamination sampling station including ultrasonic cleaner (approximately two pints); cleaning guns, microscope, millipore sampling kit including filters, laminar flow bench and bagging equipment. Whenever fluids are being introduced into the Engineering Model or Flight Model subsystems, the output from the PSC hoses will be checked using this station. It will be necessary to fill and drain each RCS prior to and after each spacecraft vibration and thermal tests. The tasks to be performed are setting up a cleanliness facility, making contamination checks, and filling and draining operations.

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2.4.5 RCS Engineering Summary

Over the 18 months of Phases I and II, it will be necessary to employ two engineers full time to accomplish these tasks. A detailed breakdown of tasks during this phase has not been performed. However, the work flow from subsystem analysis through subsystem test, spacecraft RCS test procedures and spacecraft tests indicate a level loaded effort for two engineers.

The tasks described for the phase III and V, beginning at Month 18 ARO and terminating with S/C FM3 for launch at Month 45 ARO will require one engineer minimum. Many important tasks, such as RCS/spacecraft, post-test data analysis, RCS gas flow testing, preparation of RCS flight performance prediction documents and operating procedures for the subsystem will be performed during this period which has not been detailed in this plan.

2.4.6 Quality Assurance Participation

It is proposed that Bus contractor provide the following quality assurance assistance at the RCS contractor facility during the active RCS contract.

(a) Contract Award to Beginning of EM RCS Subsystem Assembly.

(b) During EM RCS Assembly and Subsystem Qualification and FM Assembly and Test.

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2.4.7 RCS Contractor Field Service Support

A quantitative estimate has not been made of the field support required from the RCS contractor. This effort would depend strongly upon the expertise within the mechanical Bus contractor. Should it be decided that the RCS contractor should monitor all major bus tests.

2.5 Deployable Solar Array (DSA) Implementation Plan

2.5.1 General

This section presents the work plan and schedule that would be needed to implement and produce three spacecraft sets of deployable solar array subsystems for the General Purpose Satellite bus.

It is assumed that a pre-proposal study phase and a proposal activity has preceded the program presented here. During these the main design features of the array would have been established in the context of an overall S/C design. As a consequence an Initial Design Review (IDR) is planned to take place at the beginning of the program, to identify and allow for any changes in the requirements that would impact the array. Subsequent to the IDR specification writing, vendor selection and preliminary design activity will commence with the objective of full design definition and orders for major components being placed at the PDR.

Therefore a review of the attached schedule Figure 2-7 will show that the program will not be completely risk-free, in that due to long procurement lead times, the order for the flight solar cell blanket would have to be placed before subsystem level qualification testing is completed; however, the design proposed has been subjected to qual level vibration during a government funded development contracted.

Also a certain amount of minor trade-off work, some development testing, a finalized performance specification and a preliminary design layout will need to be done early in the program, prior to starting the detailed design.

A section on the organizational and work breakdown structure that will be utilized is included. This is followed by recommendations to th customer regarding the purchase of test equipment for performance measurement and assessment of solar cell arrays.

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ENGINEERING PLAN SCHEDULE   GENERAL PURPOSE BUS SOLAR ARRAY

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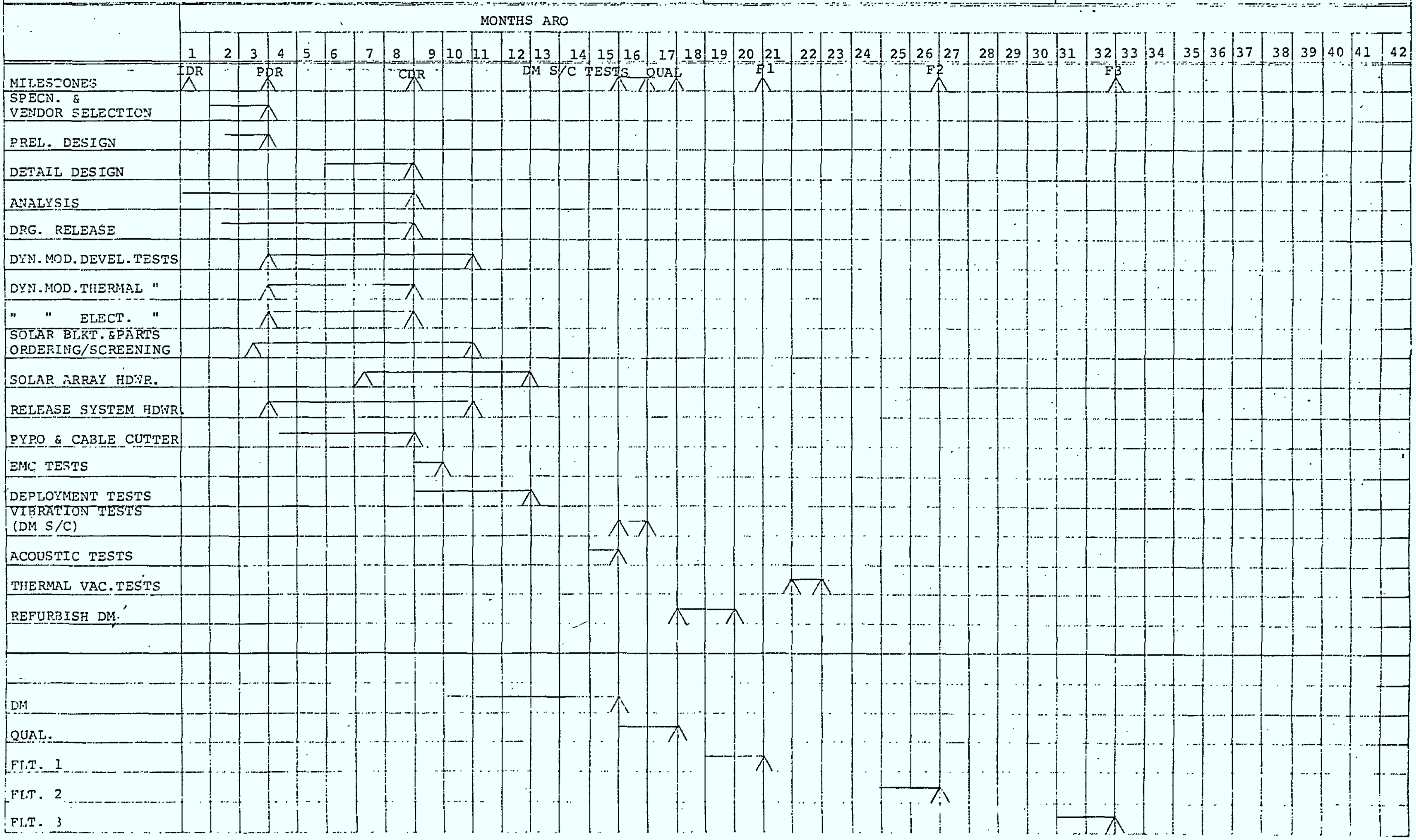

Figure 2-7

2.5.2 Design Phase

In order to accomplish the program as laid out in this document, the following activities with the respective outputs will be completed by the end of the Preliminary Design Phase:

(a) Trade-off study, including some development testing of the rigid frame/flexible substrate design particularly in the area of tie-down, release, deployment, latch-up and substrate mechanical properties.

Output - Basic design parameters of the stowage support, deployment, latch-up system and the substrate.

(b) Development testing above will include for the selected concept, the following:

Frame strength and stiffness, deployment mechanism spring rates and damping.

Stiffness properties, thermal conductance, thermo-optical properties of substrate.

Subunit level vibration, acoustic, thermal testing.

(c) Selection of tie-down/release system concept, i.e. trade-off between multi-point and single point release.

(d) Trade-off between pantograph and closed-cable system deployment method, including need or otherwise of rate control or dampers.

(e) Basic selection of cell/cover glass parameters and bus bar parameters.

(f) Selection of lubrication.

(g) Determination of a method for Ground Deployment testing of the subsystem, i.e., horizontal versus vertical. This trade-off should be done in conjunction with the deployment system trade-off (d), above.

(h) Preparation of an overall Test Matrix for the program.

It is estimated, that, in order to complete all of the above tasks in preparation for the Detail Design and Implementation phase, a period of three months will be required.

Subsequent to the Preliminary Design Review the array design and analysis will be carried out to the detail level required for producing qualification and flight hardware.

2.5.3 Development/Qualification

2.5.3.1 Program Philosophy

The subsystem has been divided into three major assemblies or sub-subsystems. These are:

- The Solar Cell Blanket,
- The Stowage and Deployment System,
- The Blanket Support Frame.

The overall plan will be to produce the following sets of hardware:

- A Development/Dynamic Model Subsystem (one wing)
- A Qualification Model Subsystem (one wing) subsequently upgraded to Flight Spare
- Three Flight Model Subsystems,
- Development Test Hardware as necessary,
- Test Equipment - Deployment Rig, Portable Test Set.

The philosophy of this program is based on utilizing state-of-the-art technology as much as possible, obtaining confidence in the structural characteristics by vibrating a dynamic model subsystem on the dynamic model spacecraft with a qualification model solar cell blanket on one side, qualifying on a component level in thermal-vacuum and vibration, and finally carrying out a complete system qualification vibration test on a complete spacecraft.

It is anticipated that flight system manufacture will start after completion of qualification system testing on the dynamic model spacecraft but before completion of the complete system/spacecraft qualification test. Also, procurement of the flight solar cell blanket will be initiated before completion of qualification testing.

Thermal-vacuum deployment at the subsystem level would be desirable, but has not been included in the program as it is anticipated that the cost of such a test could not be justified. Instead heavy reliance will have to be placed on adequate assembly level and/or component level thermal vacuum testing.

Acceptance testing of flight assemblies will include vibration and thermal vacuum tests on a component or assembly level.

2.5.3.2 Development/Dynamic Model Subsystem

The development/dynamic model subsystem will be structurally representative of the GPB DSA subsystem. The array orientation and power transfer assembly will be represented by mass modules. A simulated solar cell array using either glass chips or reject quality solar cells will be used on a representative substrate on one wing. The other wing will have a qualification model solar cell blanket which will be fully covered with flight quality solar cells. The deployment control devices may be represented by mass modules on one side.

Vibration and, if possible, acoustic testing on the Dynamic Model spacecraft will give confidence in the basic design concept.

Design and manufacture of this subsystem will start after the Preliminary Design Review (three months ARO) and will be completed eight months ARO with integration and testing on the dynamic model spacecraft taking place during months 15 and 16 ARO. A design review will be held following this test.

2.5.3.3 Qualification Model Subsystem

The first three months of the program will involve detail design and writing of detail component specifications. Design and procurement activities for the three major assemblies will start soon after the PDR.

The objective of these activities will be to design, develop and qualify at either the component or assembly level the three major assemblies. The amount of development and testing required will be different for each assembly. A period of about 12 months will be required to accomplish the above objective, with the solar cell blanket being the pacing item.

Qualification vibration of the solar cell blanket, the frame and stowage system will be done at the spacecraft level. The qualification model subsystem will have a half spacecraft set (one wing) and will be flight representative. The other half will have a mass representative solar cell blanket.

This subsystem will be subjected to performance, deployment, stowed static test and vibration tests. Qualification thermal vacuum testing will have been carried out at the component level as well at the complete system level.

A Final Design Review will be held following the completion of Subsystem level Qualification testing. This will give release for the manufacture of flight hardware, although certain long lead items such as the solar cell blanket will have been ordered earlier.

2.5.3.4 Flight Subsystems

The three spacecraft sets will be built in the staged sequence shown in the schedule. The F1 set (i.e. both F1-1 and F1-2) will be available for integration with the F1 bus by month 20, the F2 set by month 26 and the F3 set by month 32. One month has been allowed for integration with the flight buses before spacecraft integration and testing.

2.5.3.5 Flight Spare

One complete unit (the refurbished qualification model) will be available as a flight spare.

2.5.3.6 Development Test Hardware

In certain key areas such as mechanisms, a certain amount of development testing will be necessary. These areas will be determined early in the program and confidence established with early testing.

Development testing will be required in the area of the deployment control mechanism, hinges, and tie-down/ release system. A certain amount of module level testing of the solar cell blanket and frame assembly may also be required.

2.5.3.7 Test Equipment

The following major items of test hardware will need to be manufactured:

(a) Two deployment rigs - either vertical or horizontal.

(b) Two portable test sets for providing subsystem deployment commands.

For assessing performance and degradation of the solar array, it is proposed that both a Xenon arc flasher and an infrared imaging system (Thermo Vision) be used. The cost for these has not been included in this report and more is said in Section 2.5.5.

2.5.4 Organizational and Work Breakdown Structure

2.5.4.1 Project Organization

A project organization is shown in the attached chart Figure 2-8. Reporting to the Project Manager will be four engineers.

(a) The Systems Engineer with responsibility for Systems Analyses, Interface, Dynamics, Stress and Thermal analyses and Electrical/EMC analyses.

(b) The Integration and Test Engineer with responsibility for system integration and test planning conduct, test equipment and documentation.

(c) A Project Engineer - Solar Cell Blanket with the detailed design, procurement and test responsibilities for the solar cell array.

TYPICAL ORGANIZATION - DSA PROGRAM

GENERAL PURPOSE BUS PROJECT

PROJECT MANAGER

SYSTEMS ENGINEER	SYSTEM INTEGRATION & TEST ENGINEER	PROJECT ENGINEER SOLAR CELL BLANKET	PROJECT ENGINEER STOWAGE & DEPLOYMENT, FRAME STRUCTURE
- Dynamics	- System Integn.& Test Planning	- Design	- Design
- Stress	- Test Conduct	- Procurement	- Development
- Thermal	- Reporting	- Testing	- Procurement
- Electrical/EMC			- Testing
- Interface			

Assumptions:

Program Control, product effectiveness and mass properties covered under program office.

Figure 2-8

(d) A Project Engineer - Stowage, Deployment System and Frame Structure.

Each of the above will supervise development engineers, designers, draftsmen and technicians to accomplish the engineering tasks.

The Project Manager will report to the Bus Program Manager and will draw on the resources in the Program Office for the functions of Product Effectiveness such as Reliability Engineering, Materials and Processes Engineering and Quality Engineering. Program Control will also be effected by the Program Office.

2.5.4.2 Work Breakdown Structure

Control of the program will be effected by means of the work breakdown structure proposed herein.

This allows an effective control of costs and schedule by breaking the program in discrete subprograms with defined boundaries. Each Work Package is under the direct control of a single engineer or manager for execution and cost control.

2.5.5 Solar Array Test Equipment Recommendations

There are presently two types of test equipment available in the industry that are very suitable for measuring the performance and assessing the degradation of a large solar cell array. These are the Xenon Arc Flasher and the Thermo Vision systems. The two are mutually complementary. The former is used for obtaining I-V curves of the solar cell strings and the latter provides infrared image maps of a reverse-biased array and can be used to spot open circuits, short circuits and faulty individual cells.

The Xenon arc flasher can be rented for about $500/day. However, not many units exist and there is a reluctance on the part of owners to ship the units to various locations. The cost of a unit is between $70,000 and $100,000. The Thermo Vision systems cost between $20,000 and $30,000. Past experience has shown that renting of these units however is difficult.

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The budgetary price does not include costs for rental or purchase of the above hardware.

It is recommended here that the Government consider the purchase of the above two units of test equipment for the testing of solar cell arrays, particularly since there will be the need for testing up to 8 spacecraft sets in the foreseeable future, allowing amortization of the capital expenditure.

2.6 Structure Subsystem - Implementation Plan

The following is a description of the implementation plan for the General Purpose Bus Structure subsystem. The schedule for this implementation plan is shown in Figure 2-9 and it is assumed a competitive proposal phase has occurred prior to contract award.

5/HC.15 The Structure Subsystem, due to its similarity to the CTS configuration requirements, is able to draw heavily on the analysis and techniques of that program. The program plan, costs and schedule reflect this benefit.

2.6.1 Preliminary Design Period

This period will be dedicated to the confirmation of the equipment configurations, structure configuration and structure design, consistent with the particular subsystem and the overall spacecraft requirements. This phase will be concluded with a Preliminary Design Review.

2.6.1.1 Initial Design Review

Initial design review will be conducted to confirm the overall configuration specification requirements, payload configuration and interface data.

In this phase, preceding the main design phase, the configuration of the spacecraft/payload will be established and layouts showing equipment location will be completed and supplied as interface data. This task will require continuous interfacing between the interface control, design, and mass properties control groups to ensure that the overall spacecraft centre of mass location and moment of inertia ratio requirements are met.

2.6.1.2 Structure Configuration

2.6.1.2.1 Design Approach

The structure will be configured to provide a stable platform for all equipment during launch and all subsequent phases of life.

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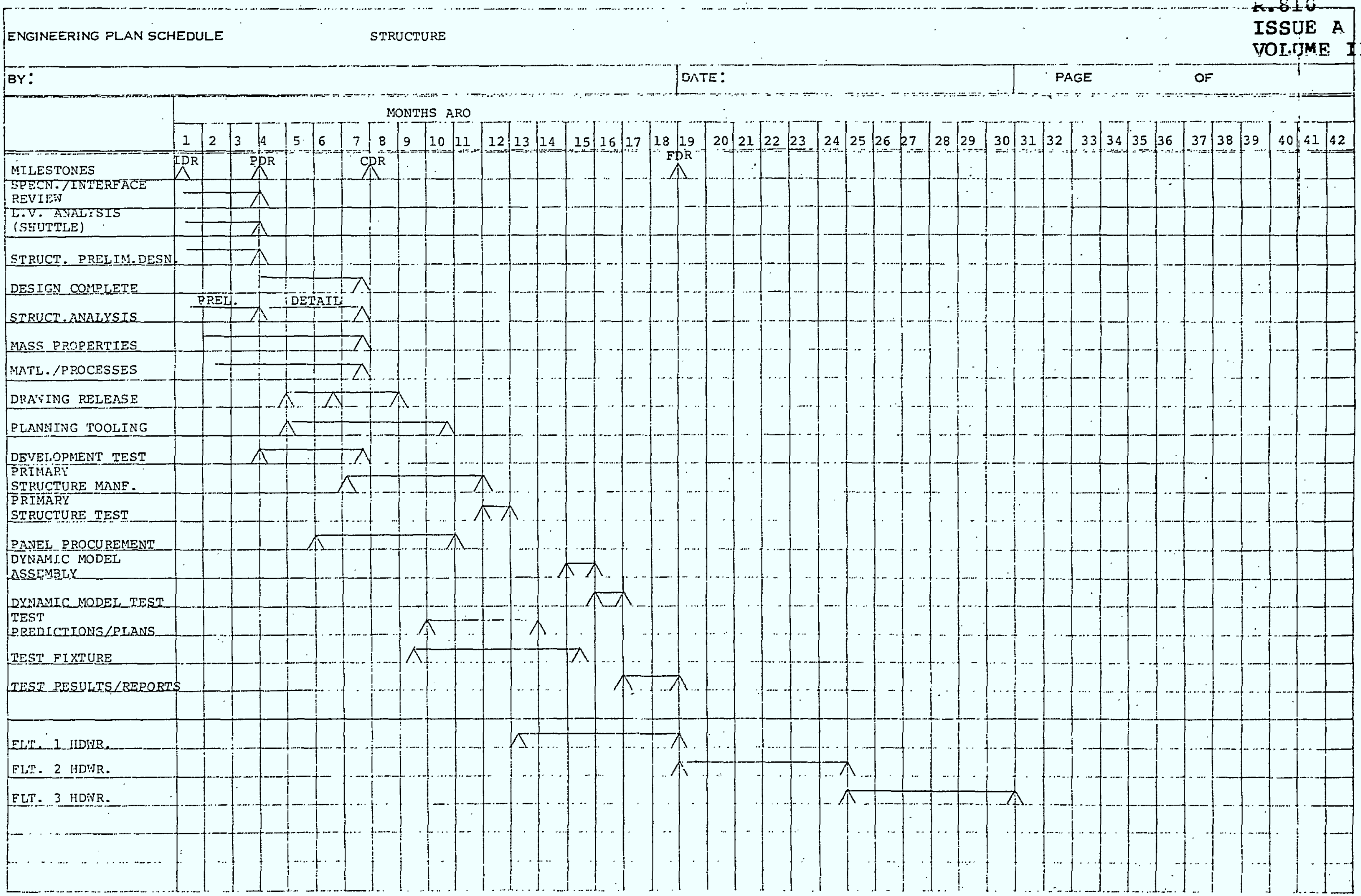

Figure 2-9

Ready access during integration will be provided by configuring a stable central thrust structure with cruciform ribs and detachable forward and peripheral equipment panels.

One risk that should be noted at this time, is the adaptability of the GP Bus design to the Shuttle launch environment. The Shuttle environments are not yet firm and in some cases are undefined. They are dependent on the structural design of the spacecraft supporting cradle which has not yet been flight proven. The dynamic environment of the structure and of the spacecraft supported equipment may be significantly different from that which is now envisaged. Any change in the shuttle launch environment subsequent to the Initial Design Review (IDR) could therefore seriously impact both on the design of the structure and equipment. No allowance has been made in this program for such changes subsequent to the IDR.

Design requirements will be met or exceeded by designing for: stability, rigidity, strength, high reliability and low weight. Particular attention will be paid to provide adequate panel support so that panel natural frequencies are well separated from both the spacecraft and the launch vehicle natural frequencies. Panel vibration response will thereby be minimized.

At the end of the preliminary design phase, an overall structure configuration will have been decided upon, including all major structural component sizes and thicknesses.

2.6.1.3 Interface Data

The following interface data will be required at the beginning of this phase in order to be able to design a structure responsive to the overall spacecraft and individual subsystem requirements.

(a) Launch Vehicle: Adapter restraints and structural dynamic characteristics (e.g., stiffness, damping at resonance) fairing restraints. Launch vibration, acoustic and sustained acceleration environments. Third stage spin rates and accelerations, separation shocks.

(b) Apogee Kick Motor: Envelope (cold and hot), weight, moments of inertia. Details of attachment of the spacecraft, strength and stiffness of attachment flange. Alignment requirements. Normal modes of vibration, natural frequencies damping at resonance, when supported at the mounting flange. Accelerations and vibration spectra during the apogee motor burn phase.

(c) Individually Mounted Units: Size, especially footprint dimensions, weight, centre-of-mass location, moments of inertia for larger size units, details of attachment. Alignment requirements, thermal and electrical grounding requirements. Structural dynamic characteristics (normal modes, natural frequencies, damping at resonance) if components can be expected to be dynamically active during spacecraft vibration testing. These will be particularly important for large items having pronounced structural dynamic characteristics of their own, such as the stowed solar array, antennas, RCS tanks, momentum wheels, etc. Harness and waveguide configurations shall be available.

2.6.1.4 Structural Design Activity

Drawings generated in this preliminary design phase will consist of:

- Equipment Layouts
- Structure Layouts
- Test Sample Detail Drawings
- Sample Test Fixture Drawings

The structure layouts will be used to provide Manufacturing with the information required to begin design of primary and peripheral structure tooling and spacecraft integration fixtures and to permit the ordering of long lead items.

2.6.1.5 Structural Analysis Activity

A coarse, three-dimensional dynamic computer model of the structure with concentrated masses representing the payload will be generated to determine the basic natural frequencies of the spacecraft and estimate the magnitude of overall responses at the basic resonances. Simplified models of dynamically active units such as the antennas, the RCS tanks, the solar arrays, etc., will be included.

Hand stress analysis will be used to calculate the required panel facesheet and core thicknesses, dimensions of panel fastening members (attaching panels to each other and to the cruciform ribs), etc. Each panel will be designed based on an envelope load case which will include the effect of the worst payload configuration for the panel.

Structure thermal distortion analysis will performed for all signficant thermal gradients in order to assure that the structure accuracy remains within the required levels.

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2.6.1.6 Mass Properties Control Activity

The main thrust of this activity during this phase will be employed so as to ensure that:

(a) The structural layout allows for the distribution of equipment consistent with all other subsystems and spacecraft constraints while maintaining the required CoM limits and MoI ratio constraints.

(b) The choice of structural element sizes and materials, the material and process specifications, the manufacturing processes and tolerances are consistent with the maximum weight constraints.

A mass Properties Control Plan will be prepared.

A preliminary weight estimate for the structure will be prepared.

2.6.1.7 Materials and Process Control Activity

Testing will be conducted on all processes proposed for use when sufficient background information is not available. These tests will be designed to be representative.

2.6.1.8 Test Program

2.6.1.8.1 Development Tests

A development test program will be implemented at the start of the main design phase, will be define during the preliminary design phase. This will include development tests for:

- thin face sheet honeycomb panel and inserts
- attachment of panels
- struts

2.6.1.9 Manufacturing Activity

Manufacturing plans will be prepared using the drawings prepared by the Design Group.

The material for panel blanks and thrust tubes will be ordered, as well as forgings for thrust tube rings. Development test samples will be ordered.

The design of tooling for all structural components will have begun, to be followed in the next phase by their fabrication.

2.6.1.10 Design Reviews

2.6.1.10.1 Preliminary Design Review

A preliminary design review will be held to present and discuss the equipment layout configuration, the proposed overall structure configuration, and design solutions as justified by the results of preliminary structural and weights analysis. Process control specifications, a Mass Properties Control Plan, a Development Test Plan, a Manufacturing Plan and some results of materials tests will be available for review.

2.6.2 Detail Design Phase

First four month period from the third to and including the seventh month ARO.

2.6.2.1 Main Activities During the Period

With agreements reached on equipment configurations, the structural configuration and design, this phase will be dedicated to working out the design solutions for the structure

A multi-mass computer model of the spacecraft will be made available for the combined spacecraft/launch vehicle launch dynamics analysis.

2.6.2.2 Configuration and Specification Status

The payload configuration and the structure configuration will have been firmed up at the beginning of this phase.

Agreement will have been reached on the specification to which the structure design and performance will comply.

2.6.2.3 Interface Activity

Interface activity will continue to concentrate on the precise definition of all items outlined in Secton 2.6.1.3.1.

2.6.2.3.1 Interface Data

Of particular importance will be the firming up of interface data and dynamics of large and dynamically active items of equipment: e.g., stowed solar arrays, antennas, RCS tanks, etc.

2.6.2.3.2 Combined Spacecraft/Launch Vehicle Launch Dynamics Analysis

A multi-mass model of the spacecraft will be made available for this analysis which is particularly significant for establishing the notching levels during spacecraft vibration testing of large cantilevered appendages; see Section 2.6.2.5 for further details.

2.6.2.4 Structural Design Activity

Detail drawings of the primary structure will be prepared and issued for thrust tubes, rings, cruciform ribs, forward and peripheral equipment panels, the removable closure panels (east/west panels in Option A&C) and aft closure panel.

Drawings for panel and primary structure tooling test and spacecraft integration fixtures, as well as ground handling equipment, will be issued at the end of this phase.

Also included in the structure subsystem drawing set will be:

(a) The assembly drawings complete with instructions required for integration testing of the Bus.

(b) Mass module detail and installation drawings for the Dynamic/Thermal model spacecraft. Whereas these drawings will be complete and comprehensive, it is assumed that the Communications payload modules, the inert Apogee Kick Motor will be supplied by the customer.

2.6.2.5 Structural Analysis Activity

A detailed dynamic computer model of the whole spacecraft, including representative modelling of dynamically active units such as the antenna, the RCS tanks, the solar arrays, etc., will be created. This model will contain a sufficient number of plate elements and mass nodes to obtain a realistics estimate fo the first bending mode and frequency of each spacecraft panel.

Quasi-static and vibration load cases will be analyzed by computer. The generated output will consist of:

- overall structure and local panel resonant frequencies and mode shapes.

- resonant frequencies of dynamically active components.

- interface loads between thrust tubes, cruciform ribs and panels and major items of equipment and structure.

Near the end of this three month period, a detailed stress analysis of spacecraft panels and attachments will begin, based on the loads determined from the computer analysis results. A comparison between newly determined design loads and loads assumed in the preliminary defintion phase will immediately indicate which structure components appear critically loaded; detail analysis will begin with these parts, especially those belonging to the primary structure.

The simple model generated in the Preliminary Design Phase will be updated in light of the results obtained with this model and be made available for the first combined spacecraft/launch vehicle launch phase dynamic analysis. The results of this analysis will be required for establishing the notching criteria during the spacecraft vibration testing, especially for controlling the responses of large cantilevered appendages such as antennas, etc.

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2.6.2.6 Mass Properties Control Activity

CoM and MoI constraints for various equipment layouts will be confirmed.

Weight limits will be established for the main structural components and a weight contingency plan established.

The weight estimate for the structure will be updated and firmed up.

2.6.2.7 Materials and Process Control Activity

Process control documents and material procurement specifications will be identified and prepared.

Support will be given to Quality Assurance in assessing the capabilities of vendors who will be supporting Spar Manufacturing.

2.6.2.8 Test Program

2.6.2.8.1 Development Tests

Samples defined in Section 2.6.1.8.1 will be manufactured and tested. Test results will service to determine the optimum configuration for the DM panel bonding, foam blocks and attachment members.

Test plans will be generated for panels, the designs of which require careful verification because of the numerous cut-outs essential for a light-weight structure. Test fixtures will be designed.

2.6.2.9 Manufacturing Activity

Test samples defined in Section 2.6.1.8.1 task will be fabricated along with any required test fixtures.

Manufacturing of ground handling equipment for the complete structure and various subassemblies will start. Primary and peripheral structure tooling will be designed and fabricated.

Thrust tubes, ring forgings and panel blanks will be in the process of being completed.

2.6.2.10 Critical Design Review

A critical design review will be held to present and discuss the detail andd final equipment layout. Final structural drawings and analyses will be presented along with the plans and procedures for the static and dynamic tests. The mass property calculations, vehicle dynamic analysis and the results of the development tests will be discussed. This review will be used to confirm the interface data and requirements. It will be held at the end of month 7 ARO.

2.6.3 DM Test Program

2.6.3.1 Primary Structure Static Test

A test plan will be prepared for the structure static test.

The structure will be loaded to qualifications level quasi-static loads. Both the MECO and POGO and maximum lift-off conditions will be tested for. North/south and east/west panel loads will be realistically applied along the outboard edges. The primary structure, including the aft closure panel, will be completely flight representative. The apogee motor loading will be realistically applied to the thrust tube apogee motor ring.

2.6.3.2 Manufacturing Activity

Manufacturing of the panels, and the primary structure tooling and ground handling equipment will be completed during this period. Manufacture of thermal and mass modules will start, all structure tooling will have been fabricated.

The complete structure of the DM will be manufactured and assembled so as to become available for static testing.

2.6.3.3 DM Spacecraft Assembly and Design Confirmation

This phase will be dedicated to the completion of the fabrication and to the assembly of the DM Spacecraft structure. The static test which will confirm the design of the structure will have taken place.

Analysis will continue in the area of thermally induced structural deformations.

2.6.3.4 Configuration and Specification Status

The configuration will have been firmed up. The specification will have been agreed upon. Test levels will have been set. There will be no significant on-going activity in this area.

2.6.3.5 Interface Activity

Contact with other subsystems will be maintained.

2.6.3.6 Structural Design Activity

The final structure assembly drawings for the DM, including mass module installations, will be issued.

2.6.3.7 Structural Analysis Activity

The results of the primary static test will be evaluated and a report written comparing predicted and measured stresses.

A thermal distortion analysis of the complete spacecraft structure will be carried out, using a finite element computer model and the temperature distributions supplied by the thermal analysis group. All temperature cases which may lead to significant thermal distortion of some portion of the structure will be examined.

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2.6.3.8 Mass Properties Control Activity

The complete weight statement for the structure including a comparison of calculated versus actual weights will be available.

2.6.3.9 Materials and Process Control Activity

Monitoring activity will be continued in this phase.

Support will be given to Reliability Engineering in the analysis of failures and in making recommendations in preventing their recurrence.

2.6.3.10 DM Dynamic Test Program

A test plan for sinusoidal and random qualification vibration of the DM will be prepared.

2.6.3.11 Manufacturing Activity

Manufacture and integration of all structure components will be completed during this period. Mass module manufacturing will be completed; the assembly of the spacecraft structure and integration of mass modules will begin.

2.6.3.12 DM Spacecraft Integration and Qualification Test

This phase will be dedicated to the qualification testing of the DM spacecraft structure. The structure will be fully equipped with mass modules. Vibration sensitive components will be as near as possible to flight hardware.

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2.6.4 Qualification Phase

2.6.4.1 Structural Design Activity

The design group will generate any drawings showing structural modifications, as required from the DM vibration test and post-analysis results.

2.6.4.2 Structural Analysis Activity

The results of the DM vibration tests will be evaluated and compared with analytically predicted behaviour.

Any design deficiencies identified during the test will be corrected.

Calculated margins of safety which have been based on analytical predictions will be updated to reflect the test results.

2.6.4.3 Materials and Process Control Activity

Support will be given to Reliability Engineering in the analysis of failures and in making recommendations in preventing their occurrence.

2.6.4.4 Manufacturing Activity

Manufacturing will refurbish the DM structure up to a qualification model structure and will introduce any modifications into the structure that were the result of the DM testing. Qualification model equipment boxes, RCS, one half of the solar array (one wing) and a dynamical active payload will be installed into the spacecraft. The other half of the solar array will be the DM dummy.

2.6.4.5 Qualification Model (QM) Test Program

2.6.4.5.1 Vibration Test

The QM spacecraft, which will use the refurbished DM structure, will be subjected to sinusoidal and random qualification level vibration inputs, applied at the base of the spacecraft adapter.

Qualification equipment or dynamically active subsystems will be used.

2.6.4.5.2 Acoustic Test

Acoustic testing of the entire QM Spacecraft will be performed.

2.6.4.5.3 Test Facilities

It is assumed that test facilities and personnel conversant with equipment will be negotiated and supplied by the customer.

2.6.4.6 Manufacturing Activity

No manufacturing activity for the QM Spacecraft, other than required for possible repairs is foreseen.

2.6.4.7 Design Reviews

2.6.4.7.1 Final Design Review

This design review will take place after the evaluation of all QM test data has been completed and drawings showing structure modifications ensuing from the vibration test results have been prepared.

The results of the analysis predicting the thermally induced deformations of the structure will also be presented.

2.6.5 Flight Spacecraft Structure Design Phase

Any modifications or refurbishment to the QM design resulting from the vibration test will be introduced after the thermal vacuum test.

A intensive analysis and design phase will take place following the completion of the QM testings. During this period, interface data will be reviewed, the spacecraft dynamic model will be updated to the current payload distribution, margins of safety will be revised to reflect the current configurations. Minor structural changes such as added doublers and foam blocks may then be introduced.

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The design group will review the detail drawings for structure, the analysis group will sign-off revisions to these drawings after the review.

Manufacture will following the planning introduced for the QM.

2.7 Thermal Subsystem Implementation Plan

The following is a description of the implementation plan for the General purpose Bus thermal Subsystem, and is written against each of the tasks listed in the implementation plan schedule, Figure 2-10.

The plan assumes that the concept of the General Purpose Bus must be verified for the thermal control subsystem for the SHF spacecraft payload.

The Thermal Subsystem is one which, because similarity with the CTS configuration/requirements, is able to draw heavily on the analysis and techniques, performed/developed for that program and flight experience data obtained to date. The program plan, costs and schedule reflect this benefit.

2.7.1 Data Definition Phase

Prior to program commencement, payload parameters (for subsystems which are not the responsibilities of the contractor) will require definition. It is assumed that support will be provided by the contractor for this activity. It is further assumed that finalization of all specification data will be achieved four weeks after program commencement.

2.7.2 Thermal Analysis/Design

2.7.2.1 Identification of Critical Mission Phases

This activity involves the generation of a "gross" or "bulk" spacecraft thermal model for the identification of, and design for, the thermally critical mission phases (max/min. temperature/power phases) from launch to end-of-life based on specified performance/design/interface requirements for the thermal subsystem and the specified environmental requirements.

SPAR FORM 2423. FOR USAGE SEE EPP. 2-34, 2-38, 2-40 AND CP038.

ENGINEERING PLAN SCHEDULE GENERAL PURPOSE BUS - THERMAL SUBSYSTEM IMPLEMENTATION PLAN

BY: DATE: MARCH 10, 1977 PAGE 1. OF 1

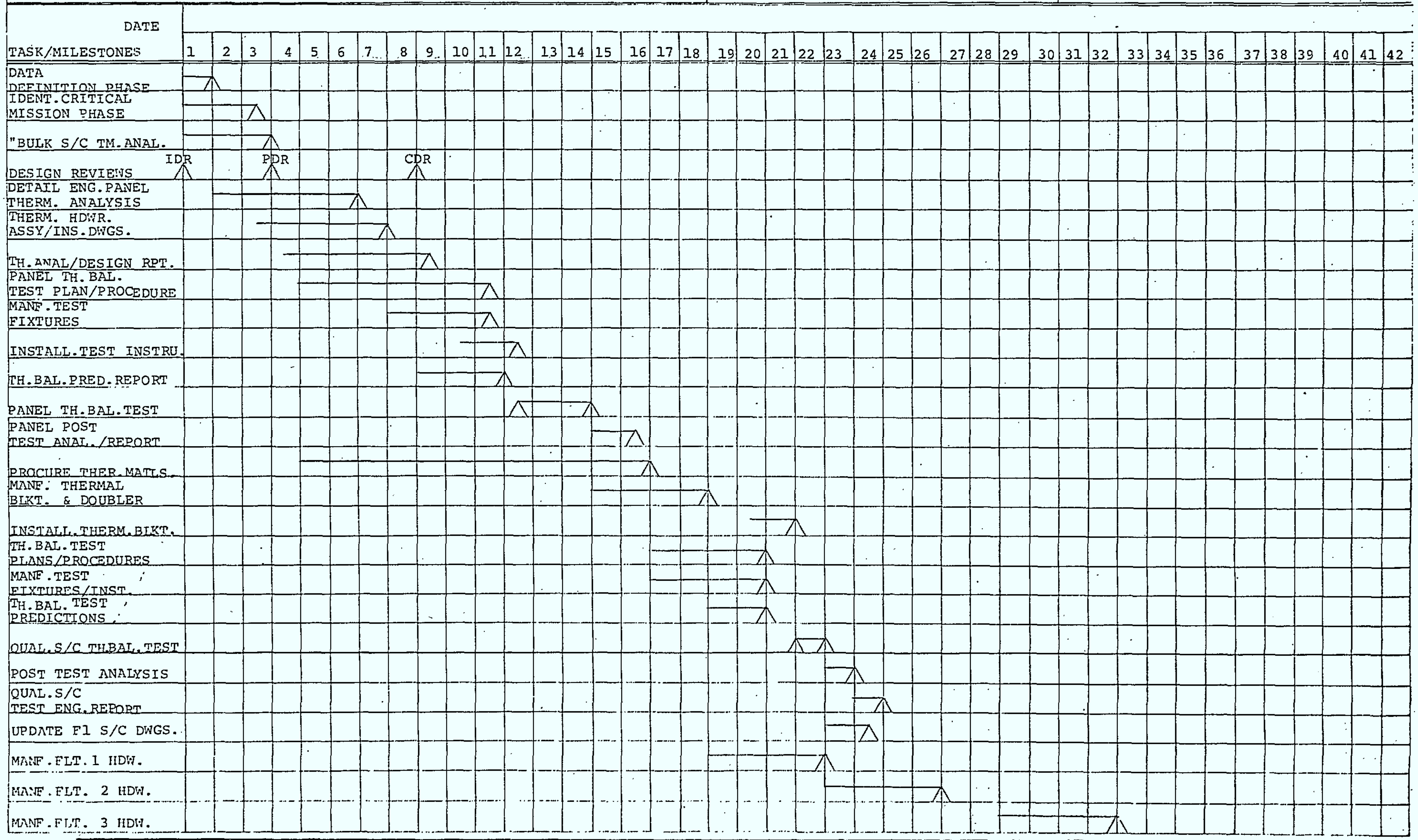

Figure 2-10

Refinement of the "bulk" thermal model may be required depending on the conflicting requirements or locations of the spacecraft components.

2.7.2.2 "Bulk" Spacecraft Thermal Model Analysis

The thermal analysis philosophy to be adopted will be the use of a "bulk" spacecraft thermal model (more detailed than that used in 2.7.2.1), to predict temperatures for various areas of the spacecraft (common location and/or approximately isothermal) which in turn will be used as a boundary temperatures in the detailed thermal analysis of equipment platforms, subsystems, etc.

Temperature predictions, using the bulk spacecraft thermal model will be made for all the thermally critical mission phases identified in 2.7.2.1.

2.7.2.3 Detailed Equipment Platform/Area Thermal Model Analysis

As indicated above, this task is the design of the spacecraft equipment platforms, equipment areas, subsystems, etc., using detailed thermal models of these locations (but treating electronic components etc. as being isothermal), and using as inputs those boundary temperatures for the other spacecraft locations, generated by the bulk spacecraft thermal model.

Should the final thermal design configuration for the spacecraft invalidate the assumptions made in the bulk spacecraft model analysis, one or more iterations (of the procedures in 2.7.2.1, 2.7.2.2, and 2.7.2.3) will be required to arrive at the final spacecraft thermal design.

2.7.2.4 Thermal Hardware Assembly/Installation Drawings

On finalization of the spacecraft thermal hardware configuration, detailed assembly and installation drawings will be produced for each item of thermal hardware and for each distinct equipment platform and/or subsystem.

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Drawings detailing standard blanket fabrication techniques are already in existence.

2.7.2.5 Thermal Analysis/Design Report

A detailed report on the analysis conducted and the final design arrived at for the thermally most critical condition will be presented.

The report will identify the temperature predictions for the spacecraft components for all critical mission phases, together with the power requirements for thermal control heaters during these phases. The thermal design configuration will be presented (complete with installation drawings) and a detailed weight breakdown for the hardware will be identified.

2.7.2.6 Thermal Subsystem CDR

The purpose of the CDR is:

(a) For the contractor to present the thermal design produced for the general purpose bus and in detail discuss the design for the SHF payload configuration (complete with analysis and assembly/installation drawings).

(b) For the contractor to outline the manufacturing techniques and program for the thermal hardware and to present the preliminary test plan for the spacecraft thermal balance test.

(c) For the customer to accept the adequacy of the design based on the analytical temperature predictions and to agree to the contractor proceeding with the manufacture and installation of the thermal hardware and with preparations for the thermal balance test.

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2.7.3 Thermal Hardware Manufacture and Installation

2.7.3.1 Procurement of Thermal Materials

As soon as sufficient design definition and confidence exists procurement of the following thermal hardware items will take place:

(a) Raw Material for the manufacture of a thermal multi-layer insulation blanket.

(b) Thermal radiator surfaces (silvered teflon, paint, tapes, etc.) (electric resistance Kapton film heaters will be substituted for second surface mirrors for cost and test reasons for the Qual model spacecraft).

(c) Raw material for manufacture of thermal doublers.

(d) Electric resistance heaters and thermostats.

(e) Other material as required.

Due to lead-time requirements, item (a) would be ordered in sufficient quantity for the qual spacecraft and the three flight spacecraft. Other items would be ordered immediately after the north panel thermal balance test, depending on cost/delivery lead time factors.

2.7.3.2 Manufacture Thermal Blankets and Doublers

This task involves:

(a) The fabrication of individual thermal blankets based on standard fabrication techniques, installation drawing definition and using a full size mock-up of the spacecraft to generate thermal blanket form and fit. The spacecraft mock-up will be representative of the actual qual model spacecraft in those areas that affect blanket form and fit.

5/HC.34 The finished blankets will be check fitted on the spacecraft mock-up to ensure adequacy.

(b) The manufacture of the thermal doubler plates to the applicable detailed drawings.

2.7.3.3 Install Thermal Doublers and Radiators

Installation of the thermal doubler plates will be performed to the applicable installation drawings and process specifications. Ultrasonic measurements will be performed to ensure the adequacy of the thermal bond between doubler and honeycomb panel facesheet. Electrical grounding will also be verified.

The adhesive backed silver teflon, paints and tapes, etc. will be installed as per the applicable installation drawings and process specifications.

As indicated previously, electric resistance Kapton film heaters will be substituted for second surface mirrors.

2.7.3.4 Install Thermal Multi-Layer Insulation Blankets

Installation of thermal blankets will be performed according to the applicable installation drawings and process specifications. Grounding requirements will be verified on each and every blanket. Final thermal seal-off of the spacecraft will be under the direction of engineering personnel.

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2.7.4 North Panel Thermal Balance Test

2.7.4.1 Panel Thermal Balance Test Plan

This document will define the objectives, philosophy. requirements, test cases and test article configurations of the qualification model panel thermal balance test program. It will also describe the environmental conditions, panel power dissipations, data acquisition requirements and inter-agency responsibilities (customer, contractor, test facility subcontractor).

2.7.4.2 Panel Thermal Balance Test Procedures

This document will specify the step-by-step procedures required to carry out the panel thermal balance test program, and will, together with the referenced procedures, become the instrument by which the test will be conducted.

2.7.4.3 Manufacture of Thermal Modules

The philosophy adopted for the panel test program will be the testing of representative panel and thermal subsystem using mass and thermal modules respectively for the panel components. This procedure allows qualification of these subsystems to be performed independently and hence without their associated schedule restrictions.

Hence the task for the thermal test is the manufacture of thermal modules, representative in the following respects to the qualification/flight model components:

- power dissipation (using electric resistance heaters)

- thermal mass (using a combination of materials if necessary)
- approximate size
- mounting configuration

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NOTE: It may be possible to either eliminate or group together zero power dissipation/small mass components. Recommendations regarding this will be made by the contractor, to be reviewed by the customer.

2.7.4.4 Manufacture and Test Fixture

This task involves the manufacture of test fixture(s) required for supporting the panel in the thermal vacuum chamber during the various test phases of the panel thermal balance test program.

Definition of the interface between the test fixture and test chamber will be required. The complexity of this interface should not be significant.

2.7.4.5 Install Thermal Modules

This activity simply consists of the installation of the thermal modules into their respective locations in the panel. Particular attention has to be paid to ensure that the thermal interface is correctly simulated (use of thermal interface materials etc.).

2.7.4.6 Install Test Instrumentation

Test instrumentation will be located on the panel consistent with the requirements of the test prediction analysis and the test procedures. Instrumentation will also be located on the test fixture and chamber to monitor/control their effect on panel temperature.

2.7.4.7 Thermal Balance Test Predictions

The philosophy adopted regarding acceptance of thermal subsystem design/hardware performance will be the testing of the design in an environment as flight representative as possible (within cost/schedule limitations) and comparison of test data with pretest predictions. Criteria for acceptance will be adequate correlation between test data and pretest predictions (with suitable corrections for any test conduct discrepancy) and the existence of positive design margin when the test data is corrected to the flight environment.

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The following describe the tasks involved in performing the pretest predictions.

2.7.4.7.1 Model Test Environment

This activity involves the generation of radiation and conduction couplings between the test article panel and the test chamber (shrouds, solar/IR sources, test fixture, cabling) for all the applicable isothermal "nodes" of the north panel thermal model.

2.7.4.7.2 Test Predictions - Detail Thermal Models

The detailed north panel model is exercised to predict component isothermal temperatures during all test phases (the model being updated for the test environment).

2.7.4.8 Test Prediction Report

The test prediction report details the method of analysis of the panel in the test environment for all the applicable test phases, and lists the temperature predictions against thermal sensor number/location for all test phases.

Graphs will describe the predicted temperature response for instrumented areas during transient test phases.

A complete list of all assumptions made (power dissipation, properties, etc.) will be included in the report.

2.7.4.9 Panel Thermal Balance Test

This activity involves the running of the panel thermal balance test. Should the test facilities be subcontracted then the subcontractor will be responsible for the operation of the facilities and assist the contractor in the performance of the test.

Required task facilities will be a vacuum chamber capable of accommodating the panel.

All activities will be specified in the test procedures.

2.7.5 Panel Post Test Evaluation

2.7.5.1 Post Test Analysis

This task involves the complete post test analysis of the qual model thermal balance test and the resolving of all anomalies experienced in the test.

All anomalies in component temperatures will require a re-evaluation of their flight temperatures based on test data corrected to the flight environment.

2.7.5.2 Post Test Analysis and Engineering Report

The post test analysis section of this report will detail the findings of the post test analysis indicating:

- resolution of design critical anomalies
- unresolved nondesign critical problem areas (if any)
- design changes made (if any) to meet specification
- updated flight predictions for all components

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The post test engineering section of this report will detail the following:

- a definitive source listing to describe execution of the tests, panel and chamber configurations, and environment
- configuration changes
- instrumentation changes
- other deviations from the original test plans and procedures
- highlights of anomalous occurrences/results during the tests
- qualitative summary of major results
- recommendations for conducting the qualification spacecraft tests.

2.7.6 Qualification Spacecraft Design/Manufacture

2.7.6.1 Update Thermal Subsystem Assembly/Installation Drawings

This task involves the updating of the panel assembly and installation qualification drawings to reflect the thermal hardware improvements as the need may be shown by the results of the panel test.

2.7.7 Qualification Spacecraft Thermal Balance Test

2.7.7.1 Thermal Balance Test Plan

This document will define the objectives, philosophy, requirements, test cases and test article configurations of the qualification model spacecraft thermal balance test program. It will also describe the environmental conditions, spacecraft power dissipations, data acquisition requirements and inter-agency responsibilities (customer, contractor, test facility subcontractor).

2.7.7.2 Thermal Balance Test Procedures

This document will specify the step-by-step procedures required to carry out the qualification model spacecraft thermal balance test program, and will, together with the referenced procedures, become the instrument by which the test will be conducted.

2.7.7.3 Manufacture and Test Fixture

This task involves the manufacture of test fixture(s) required for supporting the spacecraft in the thermal vacuum chamber during the various test phases of the qual model spacecraft thermal balance test program.

Definition of the interface between the test fixture and test chamber will be required. The complexity of this interface should not be significant.

2.7.7.4 Install Thermal Modules

This activity simply consists of the installation of the thermal modules into their respective locations in the spacecraft. Particular attention has to be paid to ensure that the thermal interface is correctly simulated (use of thermal interface materials etc.).

2.7.7.5 Install Test Instrumentation

Test instrumentation will be located on the qual model spacecraft consistent with the requirements of the test prediction analysis and the test procedures. Instrumentation will also be located on the test fixture and chamber to monitor/control their effect on spacecraft temperatures.

2.7.7.6 Thermal Balance Test Predictions

The philosophy adopted regarding acceptance of thermal subsystem design/hardware performance will be the testing of the design in an environment as flight representative as possible (within cost/schedule limitations) and comparison of test data with pretest predictions. Criteria for acceptance will be adequate correlation between test data and pretest predictions (with suitable corrections for any test conduct discrepancy) and the existance of positive design margin when the test data is corrected to the flight environment.

The following describe the tasks involved in performing the pretest predictions.

2.7.7.6.1 <u>Model Test Environment</u>

This activity involves the generation of radiation and conduction couplings between the test article (qual spacecraft) and the test chamber (shrouds, solar/IR sources, test fixture, cabling) for all the applicable isothermal "nodes" of the "bulk" and "detailed" thermal models.

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2.7.7.6.2 <u>Test Prediction - Bulk Spacecraft Thermal Model</u>

Procedure for generation of pretest predictions has to be identical (wherever possible) to the method of generation of flight predictions. Hence the same "bulk" spacecraft thermal model is again employed to generate boundary temperatures for use in the detailed thermal models, for all distinct test phases.

2.7.7.6.3 <u>Test Predictions - Detail Thermal Models</u>

The detailed equipment platform/area, subsystem, etc. models are again exercised (using boundary temperatures from the bulk model) to predict component isothermal temperatures during all test phases (all models being updated for the test environment).

2.7.7.7 <u>Test Prediction Report</u>

The test prediction report details the method of analysis of the spacecraft in the test environment for all the applicable test phases, and lists the temperature predictions against thermal sensor number/location for all test phases.

Graphs will describe the predicted temperature response for instrumented areas during transient test phases.

A complete list of all assumptions made (power dissipation, properties, etc.) will be included in the report.

2.7.7.8 Thermal Balance Test

This activity involves the running of the thermal balance test. Should the test facilities be subcontracted then the subcontractor will be responsible for the operation of the facilities and assist the contractor in the performance of the test.

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Required task facilities will be a vacuum chamber capable of accommodating the spacecraft and having an adequate solar simulation source for irradiating the spacecraft.

All activities will be specified in the test procedure.

2.7.8 Post Test Evaluation

2.7.8.1 Post Test Analysis

This task involves the complete post test analysis of the qual model thermal balance test and the resolving of all anomalies experienced in the test.

All anomalies in component temperatures will require a re-evaluation of their flight temperatures based on test data corrected to the flight environment.

2.7.8.2 Post Test Analysis and Engineering Report

The post test analysis section of this report will detail the findings of the post test analysis indicating:

- resolution of design critical anomalies
- unresolved nondesign critical problem areas (if any)
- design changes made (if any) to meet specification
- updated flight predictions for all components

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The post test engineering section of this report will detail the following:

- a definitive source listing to describe execution of the tests, spacecraft and chamber configurations, an environment
- configuration changes
- instrumentation changes
- other deviations from the original test plans and procedures
- highlights of anomalous occurrences/results during the tests
- qualitative summary of major results
- recommendations for conducting the flight spacecraft tests

2.7.8.3 Thermal Subsystem Qual Model FDR

The objective of this final design review are for:

(a) The contractor to present the post test analysis and engineering report and to demonstrate the adequacy of the thermal design and hardware as verified by pre- and post- test predictions for the as tested payload configuration.

(b) The contractor to list qual model deliverables to the customer and demonstrate the completion of delivery of these.

(c) The customer to buy off the thermal subsystem design/hardware for the general purpose bus based on information presented and to accept the completion of the qual model phase.

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2.7.9 Flight Spacecraft Design/Manufacture

The following procedure will be identical for all flight spacecraft.

2.7.9.1 Update Thermal Subsystem Assembly/Installation Drawings

This task involves the updating of assembly and installation drawings to reflect the thermal hardware improvements as the need may be shown by the results of the qualification test.

2.7.9.2 Manufacture of Flight Hardware

This task involves the manufacture and/or procurement of all flight thermal hardware (blankets, thermal radiators, heaters, etc.).

2.7.9.3 Install Flight Hardware

This final activity involves the installation of the above hardware on the flight spacecraft.

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2.8 Apogee Kick Motor Implementation Plan

The Implementation Plan submitted in this study depicts that submitted by Thiokol.

Schedules ARO in this text refer to ARO the GPB contract. At the award of GPB contract, the RFP for the AKM would be released and vendor contract award would occur at the end of month 2 ARO.

Following the delivery of the DTM Thiokol will qualify motors to Spar Specification SPAR-SG.356 Issue B. Their plan basically falls into the following phases, and can comply with the overall implementation program plan with a launch of flight one at month 33 ARO.

The Thiokol plan consists of a two batch approach. The first batch will consist of a three motor build. One motor would be an inert and the other two would be qualification motors which would be fired. The second batch would consist of four motors, one would be fired to qualify the batch and the other three would be flight. The timing of the second batch build would be geared to the flight need dates.

(a) Design Analysis phase covering three month period.

(b) Inert motor deliveries by 12 months ARO for spacecraft vibration and thermal balance tests.

(c) Manufacture two motors for test (one with nominal loading and one offloaded), complete tests of the first motor by 14 months ARO and of the second 17 months AR.

(d) Deliver a fired motor (engineering model) with fired (nonfunctional/safe-and-arm device by 19 months ARO.

(e) Manufacture four motors, one batch qualification motor and three flight motor and qualify the batch by 27 months ARO.

(f) Delivery a flight motor by month 30 ARO.

(g) Deliver a flight motor by month 36 ARO.

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(h) Be ready to deliver a flight motor by month 42 ARO.

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2.9 Telemetry, Tracking and Command (TT&C) Subsystem Implementation Plan

General

A work plan and schedule for the production of a mass and thermal model, a qualification model and three flight models of the Telemetry, Tracking and Command Subsystem are presented herein.

Of the major subsystem components, only the TT&C antennas will require development to meet the General Purpose Bus requirements. The other major units; the command decoder and encoder, and the transmitter and receiver electronics, will be modifications of existing standardized S band designs.

A development model antenna will be fabricated and mounted onto a spacecraft metal mock-up fitted with representative payload (stowed and deployed) communications antennas. Antenna test patterns will be measured in order to assure that the concept will be compatible with the General Purpose Bus configuration.

A review of the attached schedule Figure 2-11 shows that the program will be compatible with the overall bus requirements. Minor overlapping of the qualification tests and the flight fabrication poses a slight risk. A list of tasks that needs to be done is presented along with the months required to accomplish each task.

2.9.1 Initial Design Phase

2.9.1.1 Command Decoder and Encoder Preliminary Design

This task will establish the preliminary design of the Command Decoder and Encoder. It will also complete the trade-off study between packaging these units separately or with the Attitude Control Electronics. Preliminary analyses, layouts and specifications will be completed. A test philosophy will also be established.

SPAR FORM 2423. FOR USAGE SEE EPP. 2-34, 2-38, 2-40 AND CP 038.

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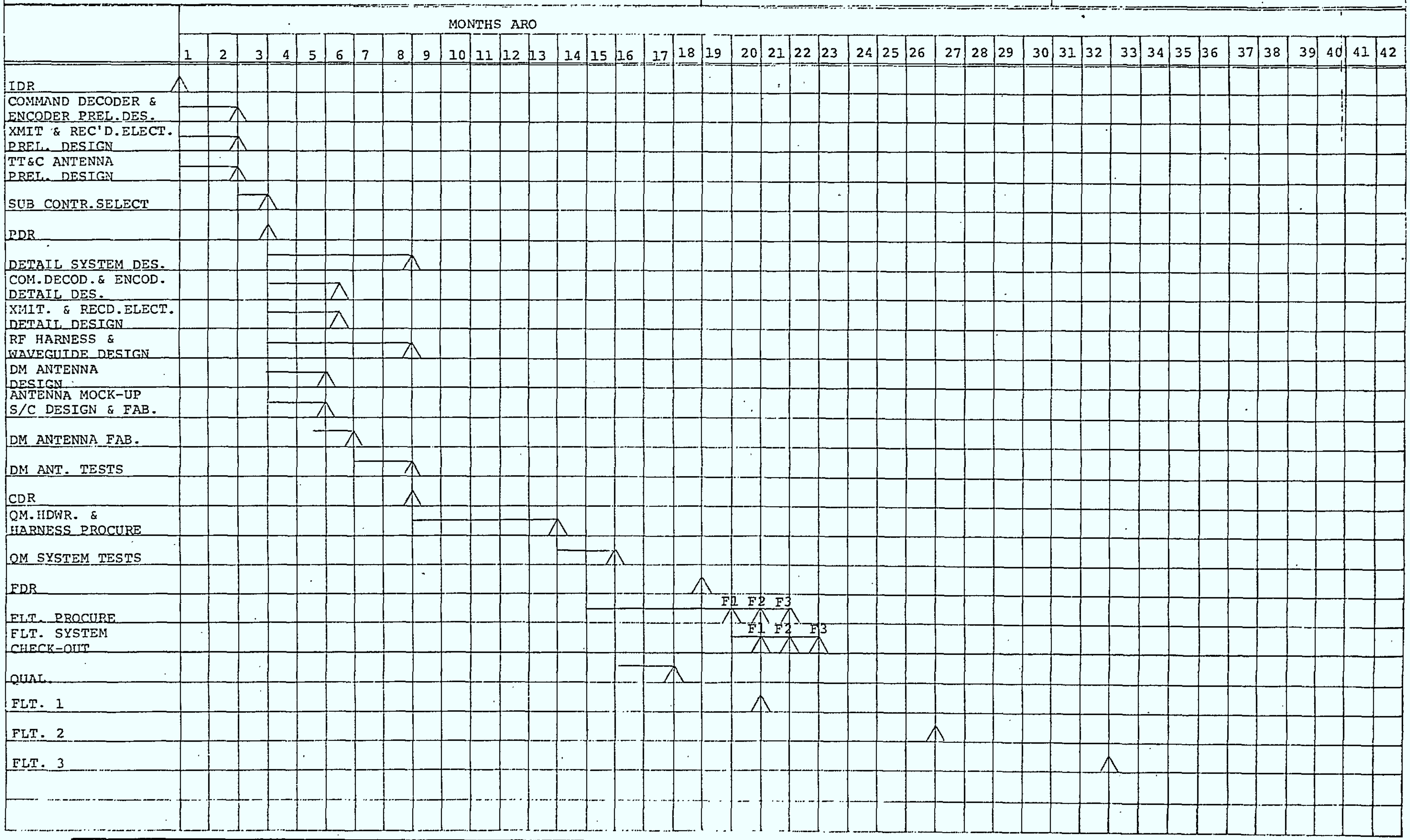
ISSUE A
VOLUME III

ENGINEERING PLAN SCHEDULE

GENERAL PURPOSE BUS - TT&C SUBSYSTEM - IMPLEMENTATION PLAN

BY: DATE: PAGE OF



2-89

Figure 2-11

2.9.1.2 Transmitter and Receiver Electronics Preliminary Design

This task will define the preliminary design of the Telemetry Transmitter and Command Receiver Electronics. Trade-off studies, selection of hardware, preliminary analyses, layouts and specifications will be completed. A test philosophy will also be determined.

5/HC.49

2.9.1.3 TT&C Antenna Preliminary Design

During the phase, several configurations will be investigated and traded-off against each other. Preliminary analyses, layouts and interface requirements will be established. At the conclusion of this phase, a particular antenna configuration will be selected as the one that best meets the requirements of the General Purpose Bus. The test philosophy and test methods will be determined. Preliminary hardware specifications will be written and potential hardware vendors listed.

2.9.1.4 Subcontractor Selection

At GPB contract award, the TT&C subsystem RFPs will be released to potential vendors. Evaluation and selection of vendor(s) will be completed with contract award at the end of month 3 ARO.

2.9.1.5 Telemetry, Tracking and Command Systems PDR

The purpose of the PDR is:

(a) For the contractor to present the preliminary design produced for the General Purpose Bus and to show that the selected system and subsystems best meets the requirements and constraints of the spacecraft. System analyses, layouts, power requirements, efficiency and compatibility with other spacecraft subsystems will be presented.

(b) For the contractor to present the preliminary design of the major subsystems and to show where major CTS components and subsystems have been used in the design. The preliminary subsystem analyses, layouts, requirements and compatibilities will also be presented.

(c) For the contractor to outline the plans for the engineering model antenna testing and development. Methods of measurements, and the hardware and materials to be used in the fabrication of the test antenna will be outlined.

(d) For the customer to accept the adequacy of the preliminary design and method of antenna testing so that the contractor can proceed with the program.

The PDR will be held at the end of month 3 ARO.

2.9.2 Detail Design Phase

2.9.2.1 Detail System Design

This activity involves the detail analyses, layouts, establishing the system requirements, assuring compatibility with other spacecraft systems and the writing of the final systems specifications. During this phase the subsystem interface, location within the spacecraft and interface with ground based equipment will be established. Detail trade-off studies and allocations of functions will be completed.

2.9.2.2 Command Decoder and Encoder Detail Design

This task will cover the detail and final design of this subsystem. The final analyses, drawings and specifications will be completed. The test methods and test equipment will be selected.

2.9.2.3 Telemetry Transmitter and Command Receiver Detail Design

This activity will cover the detail and final design of this subsystem. The final analyses, drawings and specifications will be completed. During this phase the methods of testing and the test equipment will be selected.

5/HC.51

2.9.2.4 RF Harness and Waveguide Design

This activity involves the detail design, analyses and hardware selection which best meets the system requirements and which will be compatible with the overall spacecraft bus. Layouts and drawings will be completed in order to establish the lengths, sizes and/or quantity of various elements.

2.9.2.5 Development Model (DM) Antenna Design

This activity will cover the detail design of the engineering model TT&C antenna array. Drawings, calculations and material selection will be done during this phase. These documents will be the same as those used to fabricate the qualification and flight antennas. Substitute hardware and/or components which do not affect antenna performance may be used in the DM antenna due to cost and/or schedule constraints.

2.9.2.6 Antenna Mocked-Up Spacecraft Design and Fabrication

This task will cover the design and fabrication of an antenna mock-up spacecraft. This mock-up will be a simple metal covered wooden structure which will simulate the effects of the real spacecraft. It will be used to mount the antenna and its associated hardware during the antenna tests.

2.9.2.7 Development Model TT&C Antenna Fabrication

This activity will cover the fabrication of the development model TT&C antenna. This antenna will closely approximate the design of the qualification and flight model antenna. This antenna will be built in the most economical and expeditious manner possible.

Either due to cost or schedule considerations, substitute hardware will be used where possible where it does not affect the electrical performance of the antenna.

5/HC.52 2.9.2.8 Development Model TT&C Antenna Tests

This activity involves the field testing of the engineering model TT&C antenna. From the results of this test, either modifications will be required or the basic concept will be verified. If tests indicate that modifications are necessary, then these modifications will be incorporated into the engineering model antenna and the field tests repeated. The data will be gathered and a test report written. These tests will be performed during months 7 and 8 ARO at the contractor's facilities.

2.9.2.9 Telemetry, Tracking and Command Systems CDR

The purpose of the CDR is:

(a) For the contractor to present the TT&C design produced for the general purpose bus and to review the detail analyses, trade-offs, drawings and specifications. The contractor will also present the results of the engineering models TT&C antenna test.

(b) For the contractor to present the plan for the manufacturing and testing of the TT&C system. The capability of the vendors will also be discussed.

(c) For the customer to accept the adequacy of the design based on the analytical and test data presented so that the procurement of the qualification system can proceed.

The CDR will be held at the end of month 8 ARO.

5/HC.53

2.9.3 Qualification Phase

2.9.3.1 Qualification Hardware and Harness Procurement

This task covers the procurement and fabrication of the qualification subsystems and harness. During this phase, flight specifications and controls shall be imposed on all vendors. Long lead items needed to complete the flight systems will be procured.

2.9.3.2 Qualification Model TT&C System Tests

This activity will cover the system qualification test on the qualification model. Test plans, test procedures and specifications will be generated for this task. Test reports will review the results of the tests and the flight drawings, where necessary, will be updated. Configuration control will be maintained throughout the qualification build.

2.9.3.3 Telemetry, Tracking and Command Systems FDR

The purpose of the FDR is:

(a) For the contractor to present the results of the qualification tests and to review the flight drawings, analyses and specifications.

(b) For the customer to accept the adequacy of the data obtained from the qualification tests and to give permission to proceed with the procurement and fabrication of the flight systems.

The FDR will be held during month 18 ARO.

2.9.4 Flight Phase

2.9.4.1 Flight System Procurement

This activity covers the procurement, fabrication and control of the three flight TT&C systems. Configuration control will be maintained throughout this program.

5/HC.54

2.9.4.2 Flight System Acceptance Test

This task involves the acceptance tests of the three flight TT&C systems. Also covered in this activity are the subsystem and/or vendor tests.

2.9.4.3 Flight Support

This activity covers the engineering and technical support throughout the flight spacecraft integration and test, on an as needed basis. Although required by most prime contractors, it has not been costed in this study report.

2.10 Power Control Subsystem Implementation Plan

General

A work plan and schedule for the production of an engineering model, a qualification model and three flight models of the Power Control Subsystem are presented herein.

This subsystem consists of four distinct units; a three battery subsystem including conditioning, a Main Bus Power Conditioning Unit (PCU), a Power Distribution Unit (PDU) and an Auxiliary Power Unit (APU). The design and the components of these units will be based on existing state-of-the-art designs and components.

A review of the attached schedule, Figure 2-12, shows that the program will be compatible with the overall bus requirements. A list of tasks that need to be done is presented along with the months required to accomplish each task.

2.10.1 Initial Design Phase

2.10.1.1 Component Design

This task will establish the preliminary design of the battery subsystem, the PCU, the PDU and the APU. It will complete the sizing, and the selection of the major components. Preliminary analyses, layouts and specifications will be completed. A preliminary test plan will be established for each component in the subsystem.

2.10.1.2 Subcontract Selection

At GPB contract award, the power control subsystem RFPs will be released to potential vendors. Evaluation and selection of vendor(s) will be completed with contract award at the end of month 3 ARO.

SPAR FORM 2423. FOR USAGE SEE EPP.2-34, 2-38, 2-40 AND CP038.

SPAR

R.810
ISSUE A
VOLUME III

ENGINEERING PLAN SCHEDULE   GENERAL PURPOSE BUS - POWER SUBSYSTEM

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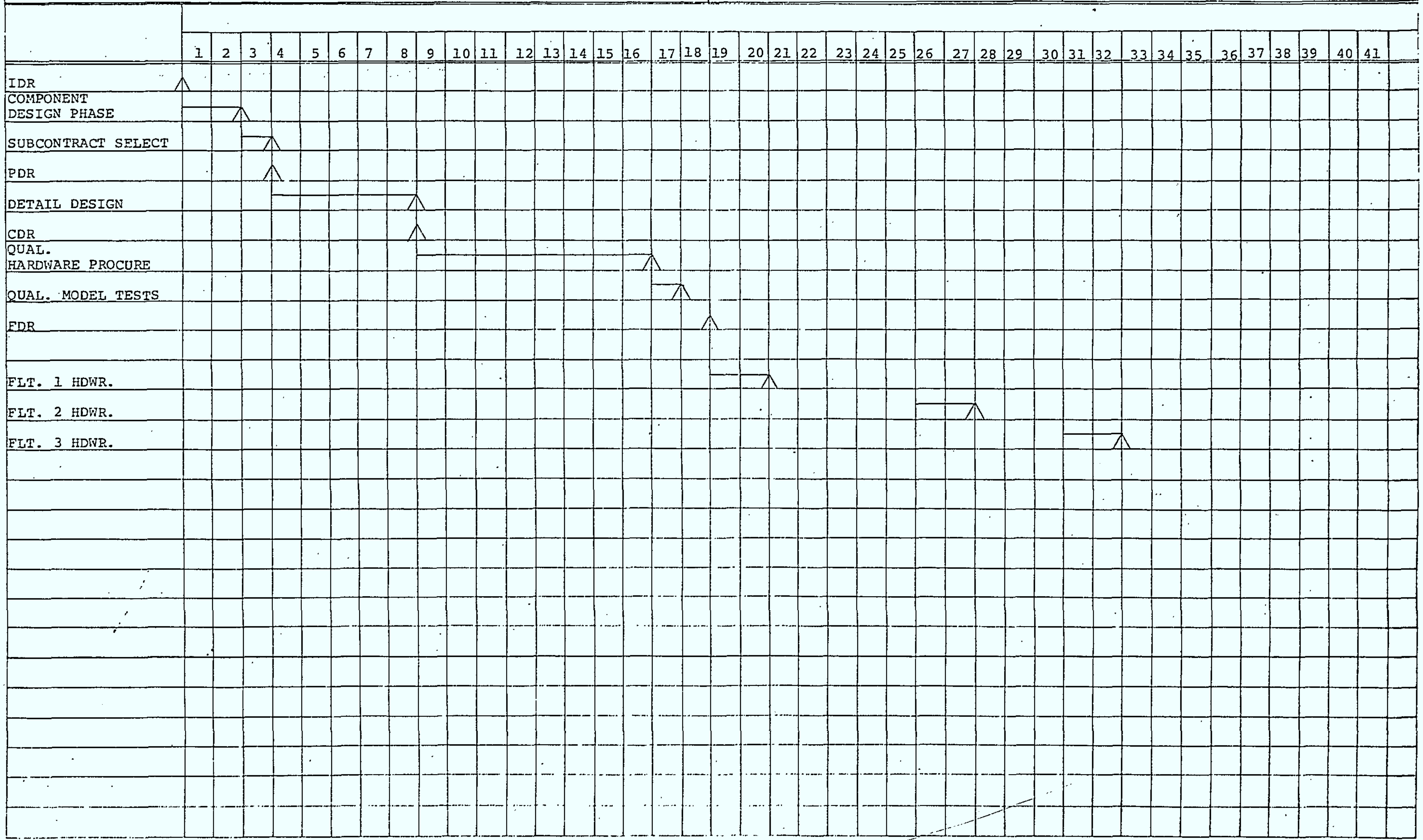

Figure 2-12

2.10.1.3 Power Control Subsystems PDR

The purpose of the PDR is:

(a) For the contractor to present the preliminary design produced for the General Purpose Bus and to show that the selected system and subsystems best meet the requirements, and constraints of the spacecraft. System analyses, layouts, power budgets, efficiency and compatibility with other spacecraft subsystems will be presented.

(b) For the contractor to present the preliminary design of the major subsystems and to show where major components and subsystems of existing designs have been used in the design. The preliminary subsystem analyses, layouts, requirements and compatibilities will also be presented.

(c) For the customer to accept the adequacy of the preliminary design and the power available to run the payload at the end of life so that the contractor can proceed with the program.

PCS PDR will take place at the end of month 4 ARO.

2.10.2 Detail Design Phase

2.10.2.1 Detail System Design

This activity involves the detail analyses, power budgets for all environments, establishing system requirements and layouts of the power subsystem which will assure its compatibility with the other spacecraft systems. The final system specifications will be completed during this phase. The subsystem interface, location within the spacecraft, detail trade-off studies and the important interfaces with the D&T and DSA will be completed.

2.10.2.2 Detail Component Design

This task will cover the detail and final design of the battery, the PCU, the PDU and the APU. The final analyses, drawings and specifications will be completed. The test methods and test equipment will have been selected. The selection of the hardware, components and the vendors that will fabricate various elements will have been completed. Component schedules, acceptance criteria, component life and component temperature limitations will be established.

2.10.2.3 Power Control Subsystem CDR

The purpose of the CDR is:

(a) For the contractor to present the Power Subsystem design produced for the general purpose bus and to review the detail analyses, trade-offs, drawings, power budgets and specifications.

(b) For the contractor to present a plan for the manufacturing and testing of the power subsystem. A presentation will also be made of the major components and vendors selected for the subsystem hardware.

(c) For the customer to accept the adequacy of the design and the end of life power available for the payload so that the procurement of the qualification and flight units can proceed.

The CDR will be held at the end of month 8 ARO.

2.10.3 Qualification Phase

2.10.3.1 Qualification Hardware Procurement

This task covers the procurement and fabrication of the qualification subsystem. During this phase, flight specifications and controls will be imposed on all vendors. Long lead items needed for the flight units will also be procured.

The qualification subsystem hardware will be built wherever possible, with high reliability parts. Where lead time prohibits this, the contractor may request the use of non high reliability components.

2.10.3.2 Qualification Model Power Control System Tests

5/HC.58

This activity will cover the system and component qualification tests on the qualification model. Test plan, test procedures and specifications will be generated for this task. Test reports will review the results of the tests and the flight drawings, specifications will be updated. Configuration control will be maintained throughout this phase.

Prior to delivery of the qualification unit at month 17 ARO and prior to integration into the qualification model GP Bus, it will have undergone bench testing both on the unit and at the subsystem levels plus thermal vacuum, vibration and EMC qualification level testing.

Batteries of flight configuration will be subjected to ground life testing including flight representative charging and discharging cycles as well as periodic reconditioning and results will be used to help define flight operational procedures and limitations.

2.10.3.3 Power Control System FDR

The purpose of the FDR is:

(a) For the contractor to present the results of the qualification tests and to review the flight drawings, analyses and specifications.

(b) For the customer to accept the adequacy of the data obtained from the qualification tests and to give permission to proceed with the procurement and fabrication of the flight systems.

The FDR will be held at month 18 ARO.

2.10.3.4 Qualification GPB Integration

As a service subsystem, the qualification PCS will be the first subsystem, other than the RCS, to be integrated into the qualification Bus.

2.10.4 Flight Phase

5/HC.59

2.10.4.1 Flight System Procurement

This activity covers the procurement, fabrication and control of the three flight Power Control Subsystems. Configuration control will be maintained throughout this program. Production and delivery of these units will be timed to meet the GPB flight models integration schedule.

2.10.4.2 Flight System Acceptance Test

This task involves the acceptance tests of the three flight Power Control Systems. Also covered in this activity is the subsystem and/or vendor tests.

2.10.4.3 Flight Battery Selection and Installation

Flight battery cells will be carefully selected and matched into battery packs. Spar recommends that flight packs will not be utilized during ground testing, being integrated with each PCS just prior to prelaunch checkout and that acceptable but not superior cell batteries be used, where necessary, for the majority of ground testing. Costs presented do not include these non-flight "workhorse" battery packs.

2.10.4.4 Flight Support

This activity covers the engineering and technical support throughout the flight spacecraft integration and test, on an as needed basis. It is required by most prime contractors; however, it has not been costed in this study report.

5/HC.60

2.11 Solar Array Drive (SAD) Subsystem Implementation Plan

General

A work plan and schedule for the production of a development model, a qualification model and three flight models of the Solar Array Drive Subsystem are presented herein.

Each subsystem consists of two major elements, the Array Orientation Electronics (AOE) and two Mechanical Drive Units (MDU's). A minor element in the system is the harness that connects all three units. The major units will be derivation of the existing CTS design, hence considered space qualified and low risk.

The qualification model subsystem will consist of one development model MDU, to be used as a mass module for spacecraft dynamic test, one qualification model MDU, a qualification model AOE and a qualification model harness.

A review of the attached schedule Figure 2-13 will show that the program will be compatible with the overall bus requirements. A list of tasks that needs to be done is presented along with the months required to accomplish each task.

2.11.1 Initial Design Phase

2.11.1.1 Initial Design Review

This initial phase will be used to confirm the appropriate information about the requirements, constraints, hardware compatibility and operational activity relating to the SAD subsystem contractual documents issued. This information will be compared to similar information available from the CTS program. This will help guide the selection of hardware, indicate the size and type of modification required of the potential useable sections of the CTS design and indicate areas where development test must be done.

SPAR FORM 2423. FOR USAGE SEE EPP. 2-34, 2-38, 2-40 AND CP 038.

ENGINEERING PLAN SCHEDULE

GENERAL PURPOSE BUS - SOLAR ARRAY DRIVE

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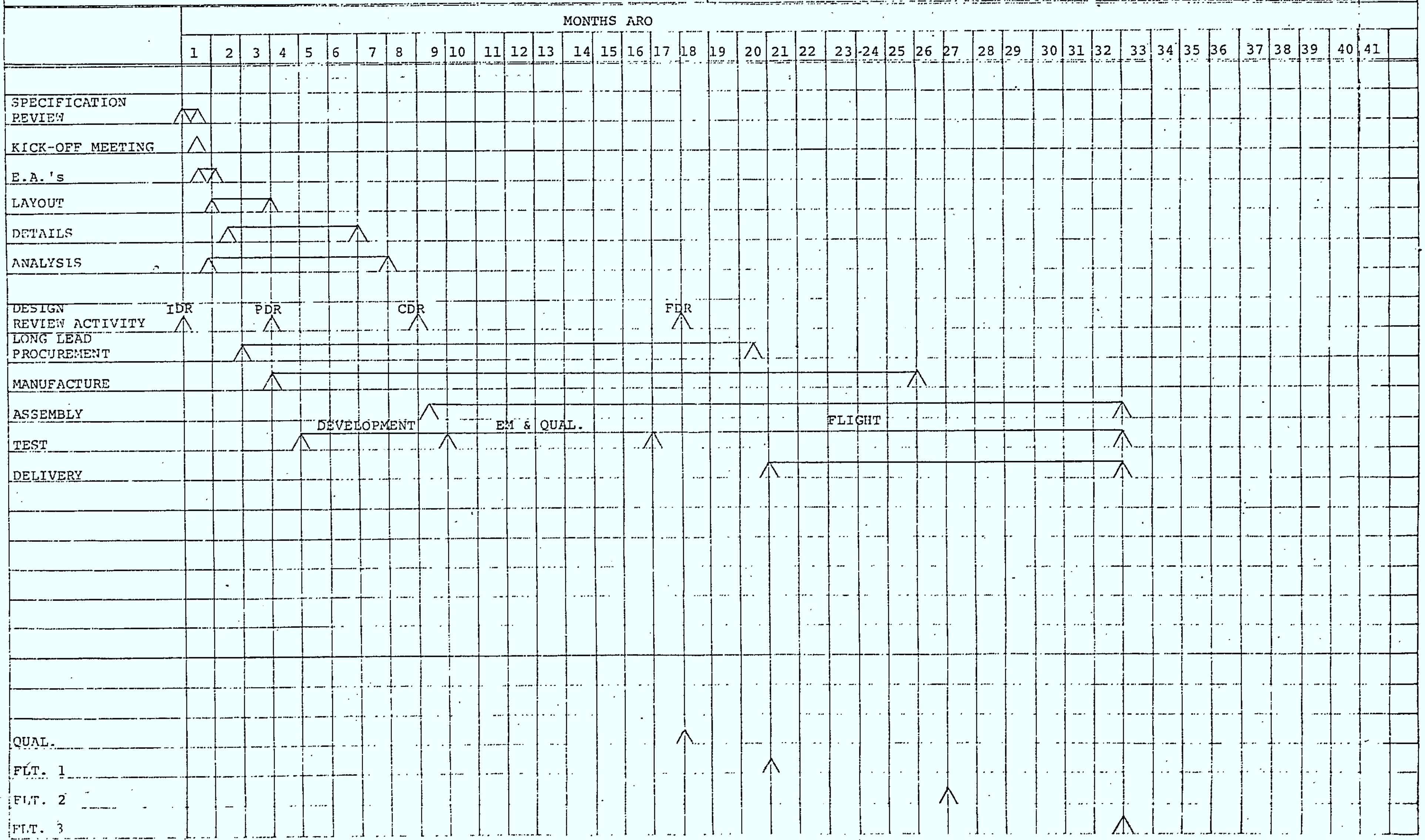


Figure 2-13

5/HC.61

2.11.1.2 Preliminary System Design

In order to accomplish this task preliminary system layouts and calculations will be done. Trade-off studies, preliminary selection of hardware, and preliminary spacecraft compatibility studies will be done. This task will last three months. At the end of this phase a system baseline will be established.

2.11.1.3 Array Orientation Electronics (AOE) Preliminary Design

This task will establish the preliminary design of the AOE. It will establish which CTS components can be used without change, which will need minor modifications and which will need major modifications. It will also identify all the new elements which must be designed. Preliminary analyses, layouts and specifications will be completed. A test philosophy will also be established.

2.11.1.4 Mechanical Drive Unit (MDU) Preliminary Design

This task will establish the preliminary design of the MDU. It will establish which CTS components can be used without change, which will need minor modifications and which will need major modifications. All new elements will be identified. Preliminary analyses, layouts and specifications will be completed. A test philosophy will also be established.

2.11.1.5 Solar Array Drive PDR

The purpose of the PDR is:

(a) For the contractor to present the preliminary design produced for the General Purpose Bus and to show that the selected system and subsystems best meet the requirements, and constraints of the spacecraft. System analyses, layouts, power requirements, efficiency and compatibility with other spacecraft subsystems will be presented.

(b) For the contractor to present the preliminary design of the major components and to show where major CTS components have been used in the design. The preliminary component analyses, layouts, requirements and compatibilities will also be presented.

(c) For the customer to accept the adequacy of the preliminary design so that the contractor can proceed with the program.

The SAD PDR will be held at the end of month 3 ARO.

2.11.2 Detail Design Phase

2.11.2.1 Detail System Design

This activity involves the detail analyses, layouts, establishing the system requirements, assuring compatibility with other spacecraft systems and the writing of the final system specifications. During this phase the subsystem interface location of the AOE within the spacecraft and harness lengths will be established. Detail trade-off studies will be completed.

2.11.2.2 Array Orientation Electronics

This task will cover the detail and final design of this subsystem. The final analyses, drawings and specifications will be completed. The test methods and test equipment will be selected. Make or buy decisions will be made.

2.11.2.3 <u>The Mechanical Drive Unit Hardware and Vendor Selection</u>

This task will cover the selection of the hardware, components and the vendors that will fabricate various elements. Request for proposal will be sent to several vendors. When the proposals are received, they will be evaluated and the best vendors selected. Schedules, cost, acceptance criteria will be established.

5/HC.63

2.11.2.4 <u>Harness Design</u>

This activity involves the detail design, analyses and hardware selection which best meets the system requirements and which will be compatible with the overall spacecraft bus. Layouts and drawings will be completed in order to establish the lengths, sizes and/or quantity of various elements. Various vendors will be contacted so that cost, delivery schedules and specifications can be agreed upon.

2.11.2.5 <u>Engineering Model MDU</u>

This task covers the engineering model development tests. One MDU will be built and driven by breadboard electronics. Various tests will be conducted and the data obtained will be used to complete the detail design of the qualification and flight units.

2.11.2.6 <u>Solar Array Drive Systems CDR</u>

The purpose of the CDR is:

(a) For the contractor to present the SAD design produced for the general purpose bus and to review the detail analysis, trade-offs, drawings and specifications. The contractor will also present the results of the engineering model tests.

(b) For the contractor to present the plan for the manufacturing and testing of the SAD system. The capability of the potential vendors will also be discussed.

(c) For the customer to accept the adequacy of the design based on the analytical and test data presented so that the procurement of the qualification system can proceed.

The SAD CDR will be held at the end of month 8 ARO.

2.11.3 Qualification Phase

2.11.3.1 Qualification Hardware and Harness Procurement

This task covers the procurement and fabrication of the qualification subsystems and harness. During this phase, flight specifications and controls shall be imposed on all vendors. Long lead items needed to complete the flight systems will be procured.

2.11.3.2 Qualification Model SAD System Tests

The activity will cover the system qualification test on the qualification model. The qualification system will consist of one engineering model MDU, one qualification model MDU and a qualification model AOE. Test plans, test procedures and specifications will be generated for this task. Test reports will review the results of the tests and the flight drawings, where necessary, will be updated. Configuration control will be maintained throughout the qualification build.

2.11.3.3 SAD Life Test

This activity will cover the procurement and fabrication of one SAD life test unit. An accelerated life test of three months will be performed on this unit under environmental conditions which will simulate the actual space conditions. A test report will be issued at the conclusion of the test.

5/HC.65

2.11.3.4 Solar Array Drive Systems FDR

The purpose of the FDR is:

(a) For the contractor to present the results of the qualification tests and to review the flight drawings, analyses and specifications.

(b) For the customer to accept the adequacy of the data obtained from the qualification tests and give permission to proceed with the procurement and fabrication of the flight systems.

The SAD FDR will be held at the end of month 18 ARO.

2.11.4 Flight Phase

2.11.4.1 Flight Systems Procurement

This activity covers the procurement, fabrication and control of the three flight SAD systems. Configuration control will be maintained throughout this program.

2.11.4.2 Flight System Acceptance Test

This task involves the acceptance tests of the three flight SAD systems. Also covered in this activity is the subsystem and/or vendor tests.

2.11.4.3 Flight Support

This activity covers the engineering and technical support throughout the flight spacecraft integration and test, on an as needed basis. Although required by most prime contractors, it has not been costed in this study report.

5/HC.66

3.0 COST DETAILS

Budgetary cost estimates provided in the attached letter are related to a Bus Contractor developing and qualifying an Engineering (Qualification) Model Spacecraft Bus, and delivering to the customer or spacecraft prime contractor this Bus plus 3 flight assemblies with the Bus contractor's subassemblies fully integrated and acceptance tested. To this Bus will be integrated the Transponder and Antenna Assembly, for compatibility testing and eventual vibration and TV testing of the integrated spacecraft by the selected prime spacecraft contractor.

In addition, the costs include the manufacture of the dynamic model (DM) spacecraft, manufacture of mass models for the Bus subsystems for the DM, and support required for testing the DM. It is assumed that payload mass models will be provided by the customer or spacecraft prime contractor.

The exercise to examine and identify the costs associated with procuring subsystems from US and other international countries was not conducted due to:

- o difficulty in preparing sensible drawing and bid packages within the time and study budget constraints
- o slight reluctance on the part of US companies to respond to a paper study when they are extremely busy on live programs such as TDRSS, ANIK C, SBC, DISC III, AEROSAT, etc.
- o Alignment of space companies in Canada under one house altered the original thinking where American companies may have supported such an activity (considered likely when the SOW was initially prepared).

Consequently the budgetary costs submitted reflect more a maximized Canadian content GPB with other divisions within Spar supplying the TT&C and power subsystem to procurement specifications.

5/HC.67

The costs have been prepared against the schedule and integration/implementation plans discussed in Section 2.0, the attached drawing family tree and, in keeping with the companies control techniques, are related to the work breakdown structure plan identified in Appendix A and given in Figure 2-4. They are broken down into:

- Development/Qualification Costs,

- Flight Systems Costs

Details on the costs will be forwarded in a separate letter to DOC.

During this implementation/cost exercise each subsystem has been costed independently along with the main management staff line functions such as systems integration and test and overall program management and administration. Not identified in this plan are the costs related to personnel supporting the spacecraft (with BUS and Payload integrated) qualification tests, nor the flight spacecraft support activity required during test and launch.

The costs submitted are considered to be a responsive cost effective program by a company bidding competitively and having conducted a proposal activity phase to a prime contractor. In addition it reflects a low cost approach by using wherever possible existing Communication Technology Satellite (CTS) designs (with minor changes) and assumes certain ground equipment from the CTS program will be made available; these include the S/C shipping container to be used for shipping the BUS (not the complete S/C), the handling dolly which can be used for integrating the GPB and available alignment equipment for complete spacecraft integration.

In areas where improved technology is being considered, the subcontractors have either been placed on contract or have demonstrated satisfactory results on other spacecraft programs. Any areas that may be considered a risk at this time will be fully developed and qualified prior to manufacture of the flight hardware and available for a launch in the 33 month. (Assuming start is early 1978 this will result in a launch by late 1980).

As mentioned previously, these costs do not include Mechanical Ground Support Equipment (MGSE), Electrical Ground Support Equipment (EGSE), Alignment Equipment and In-Orbit Ground Control Equipment. The reasons for excluding these items are:

5/HC.68

- It is assumed that MGSE such as handling dollies, S/C shipping container, slings, etc. used on CTS will be made available. If for logistic reasons it is considered necessary to have available a second shipping container to the CTS design, an estimate for this is provided in the attached letter.
- EGSE has not been costed since this is usually required and supplied by the payload subcontractor.
- It is assumed that Alignment Equipment will also be available from the CTS program.
- Ground Control Equipment currently exists at CRC or Telesat's control centre, and again it is assumed that the existing equipment will be made available to a Canadian contractor.

3.1 Existing CTS Spacecraft Designs

In keeping with this low cost approach the CTS subsystems which have minimum design/engineering content are discussed:

3.1.1 Solar Array Drive (SAD) and AOE

The costs here reflect those changes associated with integrating the CTS SAD to the North or South panel and upgrading the DM unit to include dry lubricating to achieve 7-8 year mission life. No engineering changes have been identified on the AOE, the assumption being that unit can this be used as is.

5/HC.69

3.1.2 Attitude Control System

Assumptions made here are that the spin phase components used for CTS can be used as is. Similarly the hardware used for the acquisition phase do not require major engineering design changes. For the 3 axis stabilized phase it is recognized that design modifications will be required to include north-south stationkeeping, and the changes associated with doing this have been included. No other major changes have been identified to the components operation during 3 axis phase with the exception that an additional momentum wheel, which has been included, to achieve mission life and provide redundancy.

4.0 SPARES PHILOSOPHY

The general spares philosophy which has been adopted for the GP Bus program is to provide dedicated spares for electromechanical components and low cost items and to refurbish qualification electronics units, if required for flight backup. A list of components, showing the suggested flight spares, is defined below:

UNIT	QUANTITY OF DEDICATED FLIGHT SPARES
Attitude Control Subsystem	
sun sensor assembly	1 spin sensor, 2 non-spin sensor & 1 electronics unit
analog sun sensors	1
momentum wheel	1
non-spinning earth sensors	1
spining earth sensors	1
yaw gyro	1
nutation damper	0
attitude control electronics assembly	0*
Drive Mechanical Unit	
stepper motor	1
optical encoder	1
slipring assembly	1
Array Orientation Electronics	0*
Solar Array Blanket Assembly	0*
Power Subsystem	
battery	1

5/HC.71

<u>Telemetry, Tracking & Command</u> 0*

<u>Apogee Kick Motor</u> 0**

<u>Reaction Control Subsystem</u>

propellant tank	1
low thrust engine assembly	2
latching valve	1
filter	1
pressure transducer	1
electronic circuit board	1 of each design

* qualification units refurbished if necessary, to flight status

** AKM - sufficient propellant from flight batch retained by contractor to enable casting of another flight motor, if required.

The total cost of the deliverable dedicated flight spares is provided in the attached letter. No costs have been included for the potential refurbishment of qualification units.

APPENDIX A

BUDGET COST AND SCHEDULE CONTROLS

MANAGEMENT SERVICES

ORGANIZATION

PLANNING

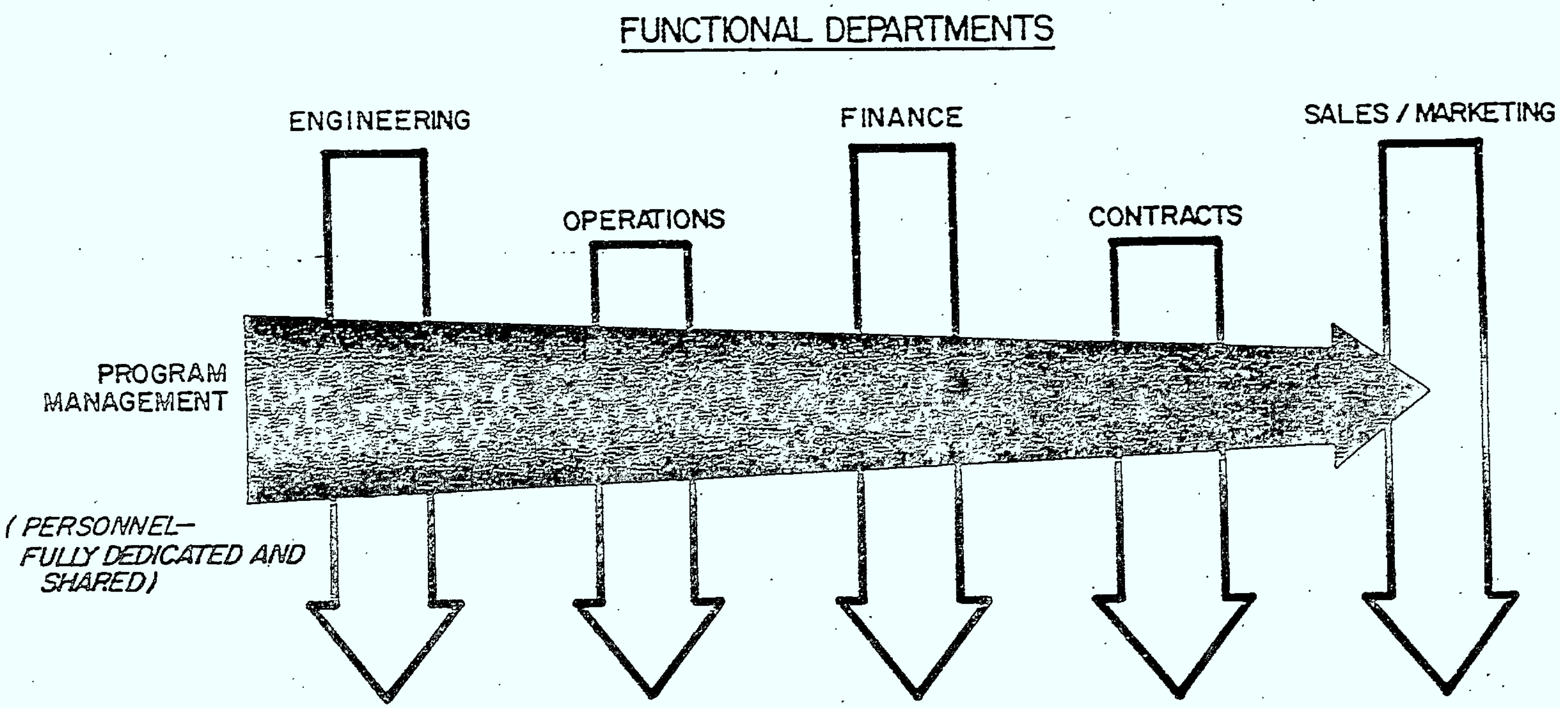
CONTROL

SCHEDULING

COST

REPORTING & ANALYSIS

CHANGE (CONTROL)



PROGRAM MANAGEMENT / LINE MATRIX ORGANIZATION

PLANS PROVIDE:

- BASIS FOR DIRECTION OF THE WORK

  ie. OBJECTIVES - TECHNICAL : SPEC. & SOW
  - TIME: SCHEDULE
  - COST: ESTIMATES & BUDGETS

- COMPARATIVE BASIS FOR

  ACHIEVEMENT ASSESSMENT

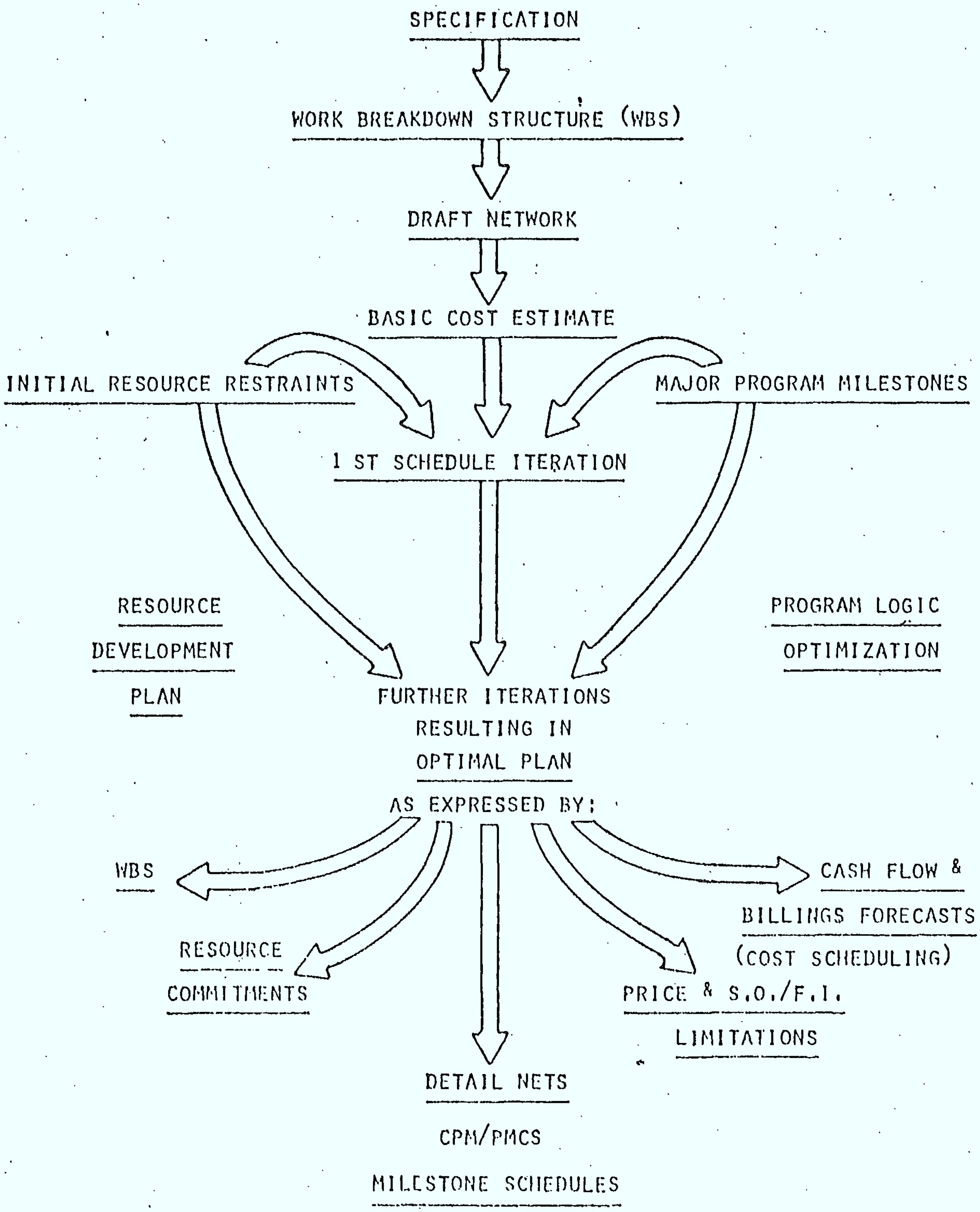
- FOUNDATION ON WHICH TO DEVELOP

  PROBLEM WORK-AROUNDS

- BASIS ON WHICH TO ASSESS & INTEGRATE

  CUSTOMER REDIRECTIONS

PLANNING PROCESS



WORK BREAKDOWN STRUCTURE

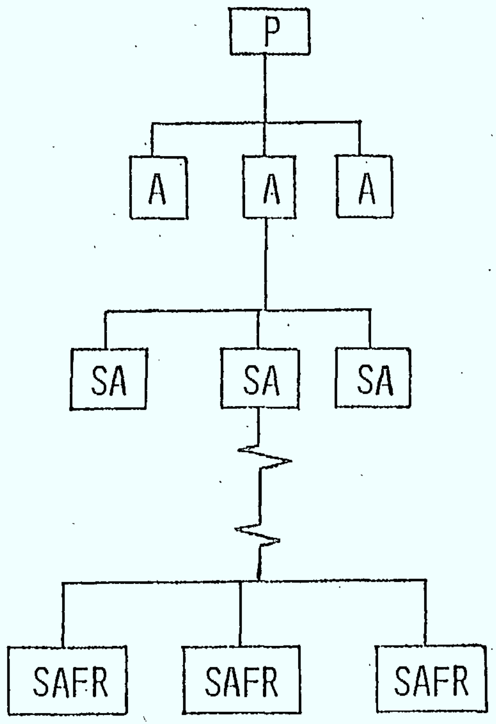
PRODUCT ORIENTED

PROJECT

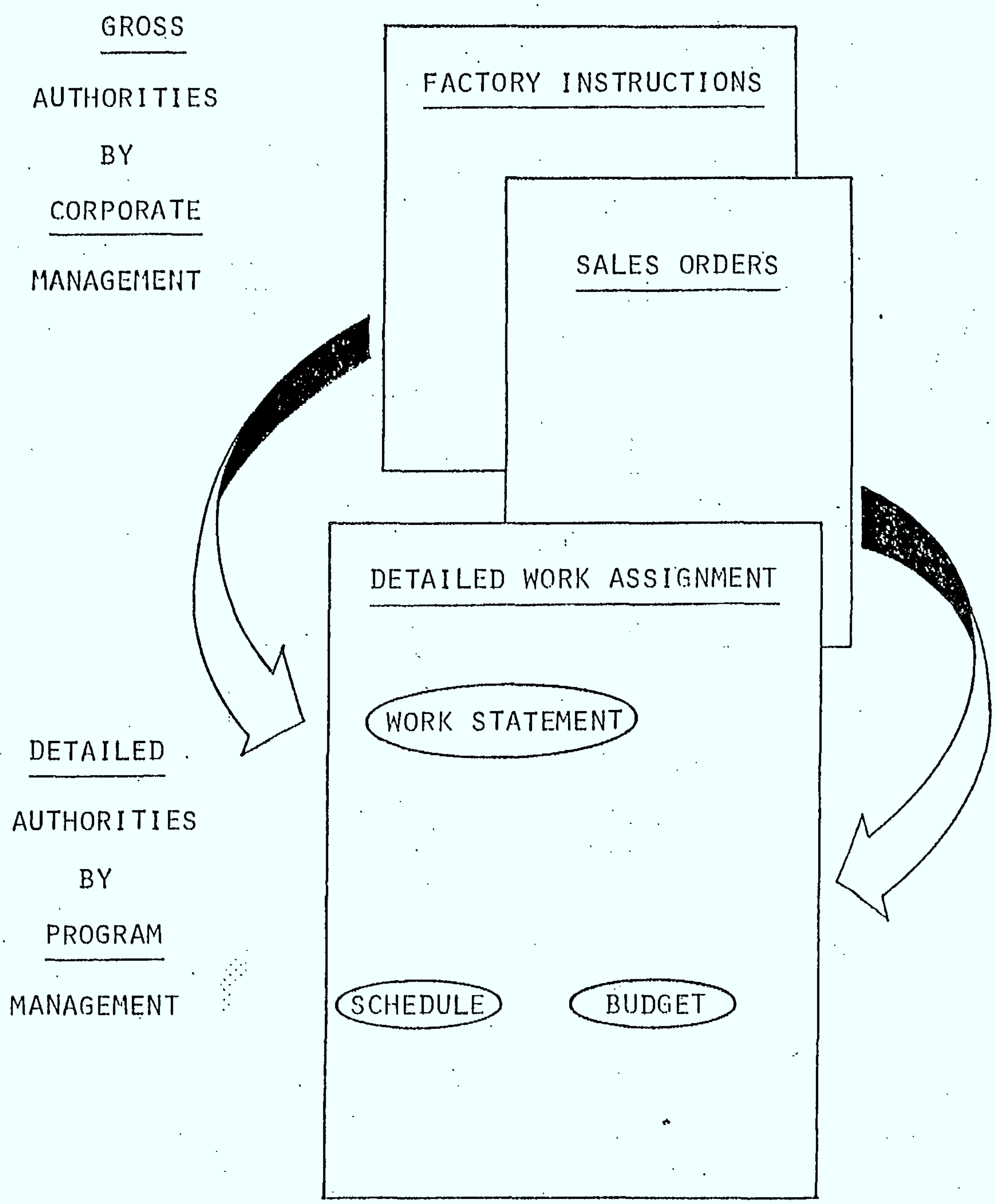
MAJOR ASSEMBLY OR
SYSTEM

SUBASSEMBLY OR
SUBSYSTEM

FUNCTIONAL
RESPONSIBILITY



INTERNAL AUTHORIZATIONS



CONTROL

AUTHORIZATIONS TO DO WORK
- FACTORY INSTRUCTION
- SALES ORDER
- DETAILED WORK ASSIGNMENT

COMMUNICATIONS	CONTRACTUAL	-	CONTRACTS OFFICER
	TECHNICAL	-	PROGRAM MANAGER
	MAJOR SUBCONTRACTS	-	S/C ADMINISTRATOR

CONTROL ROOM

ACTION BOARDS
AUTHORITIES
WBS
NETWORKS - PMCS/CPM
MILESTONE/GANTT CHARTS
COST GRAPHS - ACCOUNTING DATA

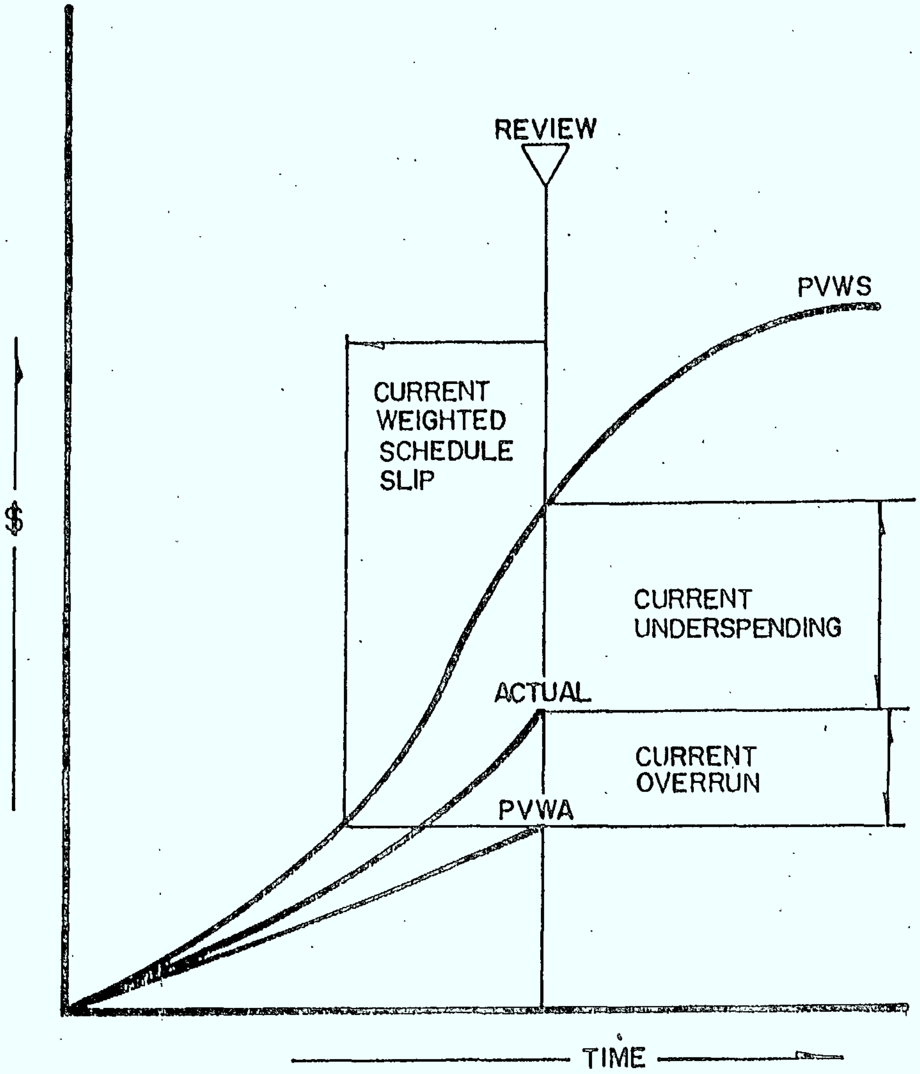
- A DISCIPLINE & TOOL FOR MIDDLE MANAGEMENT
- VISIBILITY FOR TOP MANAGEMENT

NETWORKS

AN EXCELLENT DISCIPLINE TO ENSURE INCLUSION OF ALL ACTIVITIES AND RECOGNITION OF IMPORTANT INTERDEPENDENCIES.

- FRAGNETS
- SUMMARY NETS
- COMMITMENTS
- CPM ANALYSIS - PMCS
  - FLOAT
  - BAR CHARTS
  - SORTS by Departments
    - Work Centres
    - Milestones
    - WBS levels
    - Time period
  - PRODUCTION CONTROL

PVWS — PLANNED VALUE OF WORK SCHEDULED
PVWA — PLANNED VALUE OF WORK ACCOMPLISHED
ACTUAL — DISBURSEMENTS + DELAYED BILLINGS



POSITION DISPLAY

ESTIMATE – DISTRIBUTION

(BASIC MAN HOURS – MATERIAL ACQUISITION DOLLARS)

NOTE: FOR BASIC ESTIMATE – SEE 'ESTIMATE TASK BASIC' (SPAR FORM 2278A)

DETAILS:

TASK:						IDENT. NO.	
WORK PACKAGE: NO..						ESTIMATE SUMMARY:	
SUBSYSTEM:						START DATE:	END DATE
ISSUE	1	2	3	4	5	SPAR TORONTO, CANADA	
DATE							
SIG							
DATE							
SIG							
DATE							
SIG							

			YR. TOTAL	YR. TOTAL	YR. TOTAL	YR. TOTAL
	YEAR					
	MONTH					
	WEEKS PER MONTH					
	TYPE CODE					
MFG. LABOUR	SHOP LABOUR					
	METH. ASSY. LABOUR					
	INSTRUMENT LABOUR					
	TOOL ROOM LABOUR					
	MANF. ENG. LABOUR					
	Q.A. LABOUR					
	NSP LABOUR					
ENG. LABOUR	ENG. TA LABOUR					
	ENG. DI LABOUR					
	ENG. CI LABOUR					
	ENG. TO LABOUR					
	TECH LABOUR					
NON LABOUR	RAW MATERIAL					
	B.O.P.					
	SPAR MANF. PARTS IN STORES					
	STORES ISSUE					
	CAPITAL EQUIP					
	T & L					
	TEST FACILITIES					
	TRANS. & PACK					
	SUBCONTRACT REGULAR					
	SUBCONTRACT ORDR SUM					
	COMPUTER SERVICES					
	CONSULTING SERVICES					
	PURCHASE SERVICE					
	STANDARD B.O.P. TOOLING					
	SUBCONTRACT TOOLING					

FORM NO. SPAR 2278

SPAR AEROSPACE PRODUCTS LTD

SPAR

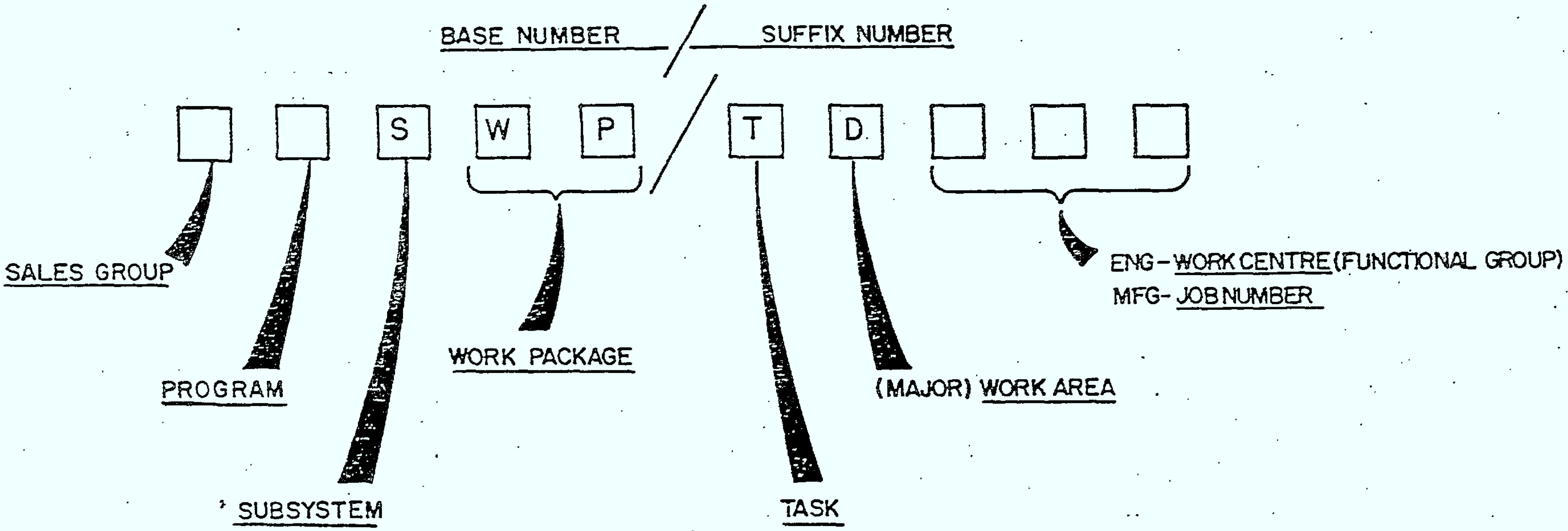
SPAR-R.810
VOLUME III
APPENDIX A

PVWS

(ESTIMATE TO COMPLETE)

FIPAC - FINANCIAL PLANNING AND CONTROL SYSTEM

- INPUTS
  - ACTUALS FOR:
    - ENG. LABOUR
    - MFG. LABOUR
    - NON-LABOUR
  - ESTIMATES TO COMPLETE
    - BY MONTH
    - BY TYPE CODE
    - IN MAN HOURS AND NON-LABOUR $
  - RATES
    - BY TYPE CODE
    - BY FISCAL YEAR
    - BY COST ELEMENT
- COMPUTATIONS
  - APPLICATION OF RATES
  - SUMMATION OF TYPE CODES
  - SUMMATION OF TIME PERIODS
  - SUMMATION OF WBS LEVELS
- OUTPUTS
  - INPUTS, PLAYBACK OF
  - FISCAL DATA
  - MONTHLY & QUARTERLY DATA
  - ESTIMATE TO COMPLETE
  - ESTIMATE AT COMPLETION

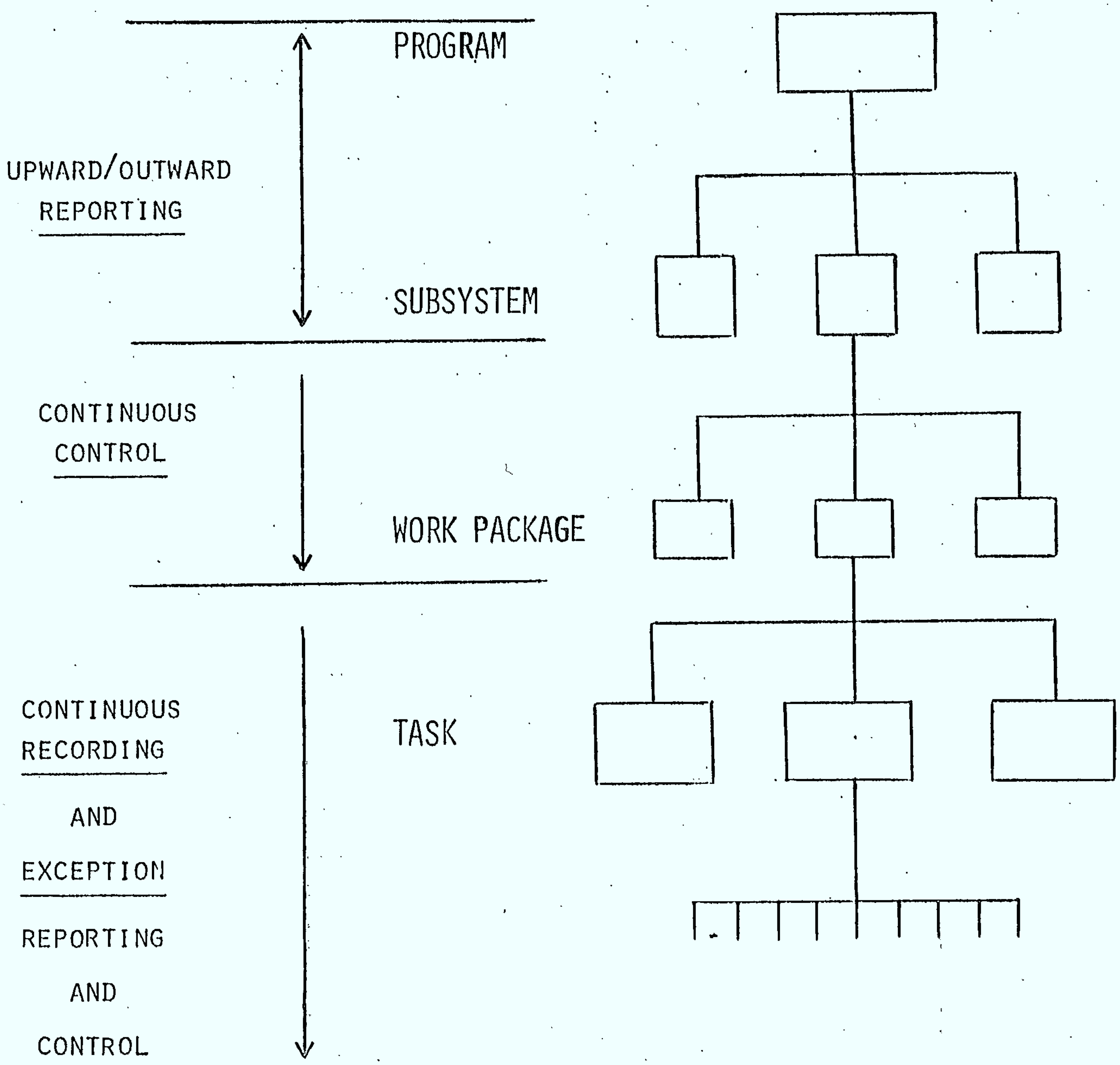


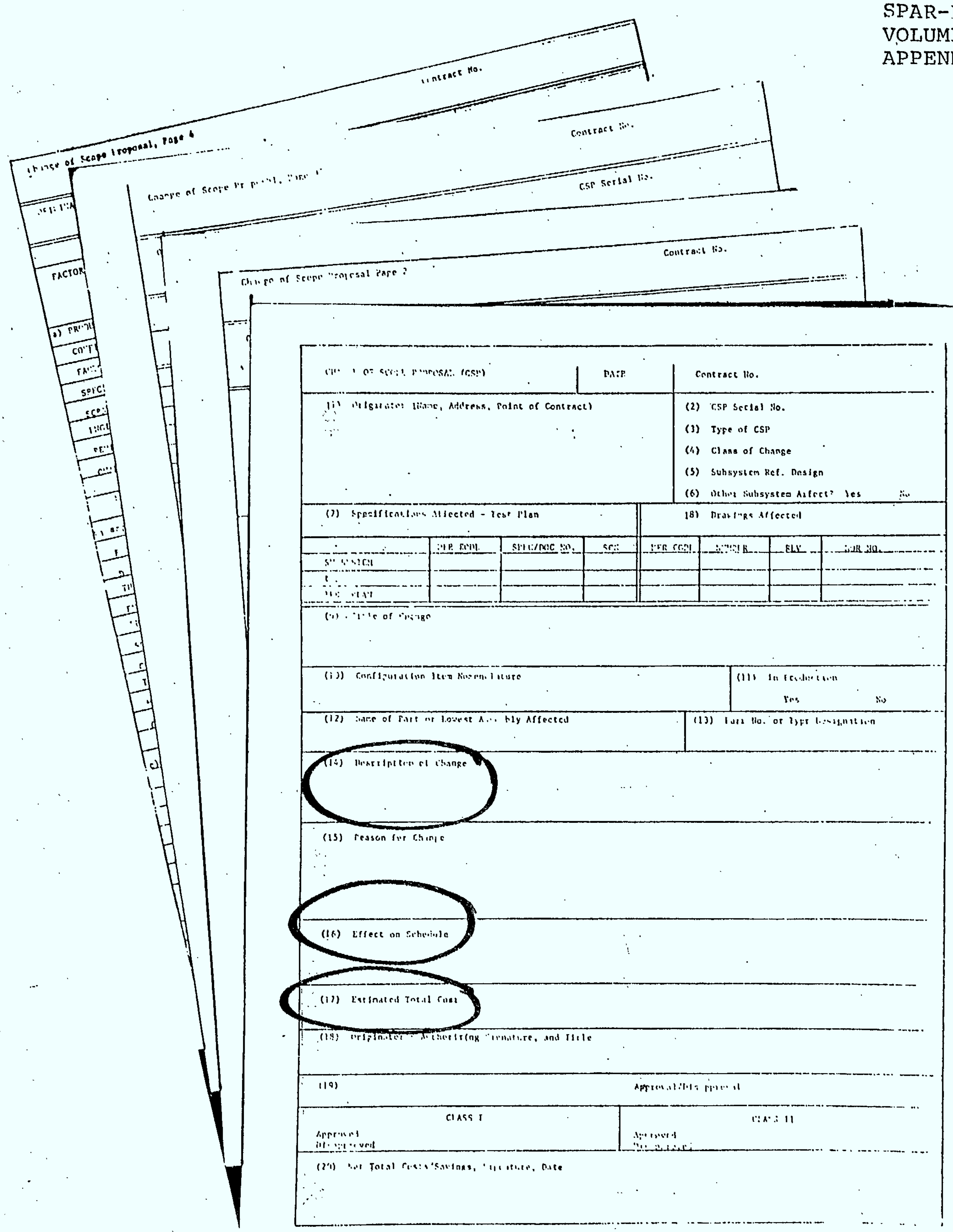
SYSTEMATIC WORK ORDER NUMBER STRUCTURE

ACTUAL COSTS

- TYPE CODES
- WORK ORDER NUMBERS
  - SYSTEMATIZED
  - WBS RELATED
- COST ACCOUNTING TABULATIONS
  - MAN HOURS
  - COST AT OVERHEAD
  - CURRENT PERIOD & CUMULATIVE
  - AUTHORITY LIMITATIONS
  - FOR INDIVIDUAL AND GROUPS OF TYPE CODES
  - TO AND BELOW ALL LEVELS OF WBS

WORK BREAKDOWN STRUCTURE




Change of Scope Proposal, Page 4
Contract No.
Contract No.
CSP Serial No.
Contract No.
DATE
Contract No.
(1) Originator (Name, Address, Point of Contract)
(2) CSP Serial No.
(3) Type of CSP
(4) Class of Change
(5) Subsystem Ref. Design
(6) Other Subsystem Affect? Yes No
(7) Specifications Affected - Test Plan
(8) Drawings Affected
Yes No
(12) Name of Part or Lowest Assembly Affected
(13) Part No. or Type Designation
(14) Description of Change
(15) Reason for Change
(16) Effect on Schedule
(17) Estimated Total Cost
(19)
CLASS I
Approved
Disapproved
Approved
(20) Net Total Costs/Savings, Signature, Date

SPAR

- MAKES EFFECTIVE USE OF COMPUTERS IN THE GENERATION OF TIMELY & ACCURATE SCHEDULE & COST INFORMATION.

- APPROACH THE MANAGEMENT TASKS OF PLANNING, DIRECTION & CONTROL IN A SYSTEMATIC & EFFECTIVE WAY.

- GENERATES MANAGEMENT INFORMATION USING ENLIGHTENED SYSTEMS WHICH INCORPORATE CTS 1104.

- PLANS & MEASURES PERFORMANCE IN DETAIL AND HAS ABILITY TO GET A PERSPECTIVE ON THE PROGRAM, TO FOCUS ON SIGNIFICANT CURRENT & POTENTIAL PROBLEMS, & ON AN EXCEPTION BASIS, TO PENETRATE TO THE CAUSAL FACTORS.

- PRACTICES A MANAGEMENT PLANNING & DATA SYSTEM CONSISTENT WITH THE REQUIREMENTS OF THE PROGRAM.

APPENDIX B

TYPICAL SUBSYSTEM WORK BREAKDOWN STRUCTURE

(DSA SUBSYSTEM WORK BREAKDOWN STRUCTURE)

TYPICAL SUBSYSTEM WORK BREAKDOWN STRUCTURE

(DSA SUBSYSTEM WORK BREAKDOWN STRUCTURE)

Work Package No.	Task
10	Project Management
- 1	Program Administration
- 2	Photography
- 3	Travel and Living
11	Systems Engineering
- 1	Systems and Interface
- 2	Dynamics
- 3	Stress
- 4	Thermal
- 5	Electrical/EMC
20	Dynamic Model Subsystem
- 1	Design
- 2	Procurement and Manufacture
- 3	Integration and Test
21	Qual. Model Solar Cell Blanket
- 1	Design
- 2	Procurement and Manufacture
- 3	Testing
22	Qual. Model Stowage and Deployment System
- 1	Design
- 2	Procurement and Manufacture
- 3	Testing
23	Qual. Model Orientation and Power Transfer System
- 1	Design
- 2	Procurement and Manufacture
- 3	Testing

D4/R.677/10

Work Package No.	Task
24	Qual. Model Subsystem Integration and Testing
	- 1 Planning
	- 2 Integration and Testing
	- 3 Report
	- 4 Test Equipment Design and Manufacture
31	Flight Solar Cell Blankets
	- 1 Design Update
	- 2 Manufacture, Procurement
	- 3 Acceptance Testing
32	Flight Stowage and Deployment Systems
	- 1 Design Update
	- 2 Manufacture, Procurement
	- 3 Acceptance Testing
33	Flight Orientation and Power Transfer Systems
	- 1 Design Update
	- 2 Manufacture, Procurement
	- 3 Acceptance Testing
34	Flight Subsystem Integration and Testing
	- 1 Planning
	- 2 Integration and Acceptance Testing
	- 3 Report

G.P. BUS FAMILY TREE

H J TAYLOR. ISSUE A – 25 FEB '77
B – 1 MAR '77

LEGEND

① —— QUANTITIES PER NEXT ASSY.

2E —— DWG SHEET QTY. AND SIZE.

IMPLEMENTATION PLAN AND COST FOR
GENERAL PURPOSE BUS.