FINAL REPORT
SYSTEM DESIGN OF THE PIONEER VENUS SPACECRAFT

VOLUME 12
INTERNATIONAL COOPERATION

By

R. S. KELLY

July 1973

Prepared Under
Contract No. [redacted] NAS2-7250
By
HUGHES AIRCRAFT COMPANY
EL SEGUNDO, CALIFORNIA
For
AMES RESEARCH CENTER
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION

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PREFACE

The Hughes Aircraft Company Pioneer Venus final report is based on study task reports prepared during performance of the "System Design Study of the Pioneer Spacecraft." These task reports were forwarded to Ames Research Center as they were completed during the nine months study phase. The significant results from these task reports, along with study results developed after task report publication dates, are reviewed in this final report to provide complete study documentation. Wherever appropriate, the task reports are cited by referencing a task number and Hughes report reference number. The task reports can be made available to the reader specifically interested in the details omitted in the final report for the sake of brevity.

This Pioneer Venus Study final report describes the following baseline configurations:

- "Thor/Delta Spacecraft Baseline" is the baseline presented at the midterm review on 26 February 1973.
- "Atlas/Centaur Spacecraft Baseline" is the baseline resulting from studies conducted since the midterm, but prior to receipt of the NASA execution phase RFP, and subsequent to decisions to launch both the multiprobe and orbiter missions in 1978 and use the Atlas/Centaur launch vehicle.
- "Atlas/Centaur Spacecraft Midterm Baseline" is the baseline presented at the 26 February 1973 review and is only used in the launch vehicle utilization trade study.

The use of the International System of Units (SI) followed by other units in parentheses implies that the principal measurements or calculations were made in units other than SI. The use of SI units alone implies that the principal measurements or calculations were made in SI units. All conversion factors were obtained or derived from NASA SP-7012 (1969).

The Hughes Aircraft Company final report consists of the following documents:

<u>Volume 1 - Executive Summary</u> - provides a summary of the major issues and decisions reached during the course of the study. A brief description of the Pioneer Venus Atlas/Centaur baseline spacecraft and probes is also presented.

Volume 2 - Science - reviews science requirements, documents the science-peculiar trade studies and describes the Hughes approach for science implementation.

Volume 3 - Systems Analysis - documents the mission, systems, operations, ground systems, and reliability analysis conducted on the Thor/Delta baseline design.

Volume 4 - Probe Bus and Orbiter Spacecraft Vehicle Studies - presents the configuration, structure, thermal control and cabling studies for the probe bus and orbiter. Thor/Delta and Atlas/Centaur baseline descriptions are also presented.

Volume 5 - Probe Vehicle Studies - presents configuration, aerodynamic and structure studies for the large and small probes pressure vessel modules and deceleration modules. Pressure vessel module thermal control and science integration are discussed. Deceleration module heat shield, parachute and separation/despin are presented. Thor/Delta and Atlas/Centaur baseline descriptions are provided.

Volume 6 - Power Subsystem Studies

Volume 7 - Communication Subsystem Studies

Volume 8 - Command/Data Handling Subsystems Studies

Volume 9 - Altitude Control/Mechanisms Subsystem Studies

Volume 10 - Propulsion/Orbit Insertion Subsystem Studies

Volumes 6 through 10 - discuss the respective subsystems for the probe bus, probes, and orbiter. Each volume presents the subsystem requirements, trade and design studies, Thor/Delta baseline descriptions, and Atlas/Centaur baseline descriptions.

Volume 11 - Launch Vehicle Utilization - provides the comparison between the Pioneer Venus spacecraft system for the two launch vehicles, Thor/Delta and Atlas/Centaur. Cost analysis data is presented also.

Volume 12 - International Cooperation - documents Hughes suggested alternatives to implement a cooperative effort with ESRO for the orbiter mission. Recommendations were formulated prior to the deletion of international cooperation.

Volume 13 - Preliminary Development Plans - provides the development and program management plans.

Volume 14 - Test Planning Trades - documents studies conducted to determine the desirable testing approach for the Thor/Delta spacecraft system. Final Atlas/Centaur test plans are presented in Volume 13.

Volume 15 - Hughes IR&D Documentation - provides Hughes internal documents generated on independent research and development money which relates to some aspects of the Pioneer Venus program. These documents are referenced within the final report and are provided for ready access by the reader.

Data Book - presents the latest Atlas/Centaur Baseline design in an informal tabular and sketch format. The informal approach is used to provide the customer with the most current design with the final report.

CONTENTS

1. SUMMARY

A spectrum of plans has been prepared to illustrate the range of practical sharing possibilities available so as to assist Ames Research Center (ARC) and European Space Research Organization (ESRO) in selection of a program meeting mutual goals. Five plans are described showing increased participation by ESRO with ascending plan number. Each of these has sharing properties fulfilling particular requirements such as available ESRO budget level, extent of ESRO program responsibility, matching particular ESRO capability, and cost saving to ARC through sharing. All plans apply to orbiter sharing only.

A sharing plan based on the model Plan 4 may offer the most attractive division of Pioneer Venus between ARC and ESRO. This plan allows ESRO to bear primary responsibility for the orbiter and to avoid an extensive financial burden. Savings to ARC are commensurate with ARC loss of program control. Duplication of effort is avoided by using orbiter subsystems that are common to the probe bus and orbiter.

A summary verbal report on this international cooperation task was given to ARC during the midterm progress report, 26 February 1973. The conclusions presented here are the same as presented at midterm. However, some additional elaboration of the study work is presented in this report.

2. INTRODUCTION

European participation in the Pioneer Venus program has been under consideration. The purpose of the study task reported on here was to prepare material to assist Ames Research Center in interface discussions and planning.

The Systems Design Study has been largely directed to development of a low cost baseline which can meet the mission requirements of the program.

Familiarity with the overall system, subsystems, integration, testing, and assembly requirements is used here to structure suggest alternate approaches to a joint effort by Ames, with the aid of the Ames prime contractor and by the ESRO. Effects of a possible interface on the Ames prime contractor can then be discussed in terms of system requirements, costs, and schedule.

There is no attempt to identify precise roles of the ESRO community organizations. The references to ESRO include by implications the European Space Technology Center (ESTEC) and vice-versa.

This study task examines some aspects of sharing the Pioneer Venus program with the European scientific community through the sponsorship of ESRO. In addition to technology sharing, cost sharing will occur because ESRO will finance the work it undertakes.

In the contemplated sharing plan, it is presumed that the designs of the probe bus spacecraft and the orbiter spacecraft will have many subsystems and major components, which are nearly identical (as suggested by present and earlier studies). These are referred to as "common" subsystems. Primarily these common subsystems will comprise the "bus," or basic spacecraft, on which the science instruments are the payload.

In the contemplated sharing plan, the general design of both the probe and the orbiter will be prepared by the NASA contractor in order to maximize the commonness, hopefully, thereby reducing total project cost. The NASA contractor will make the specific design for the probe and will manufacture it and those common items required for the orbiter. The common items will be provided to ESRO for use in the specific orbiter design for which ESRO may take responsibility.

3. AMES/ESRO RESOURCES

Alternate plans for the sharing of the construction and flying of the hardware will be based on breaking down or segmenting the overall effort into specific separate tasks. Before doing this, it is necessary to establish the resources commanded by Ames and the Ames prime contractor (APC) and ESRO and the ESRO prime contractor.

Two spacecraft, an orbiter and a probe bus comprise the major elements of the Pioneer Venus system. It has been agreed by ESRO and NASA that ESRO activity be confined to orbiter-unique matters. This analysis, therefore, is restricted to the resources available to ESRO, in both subsystems as well as a full scope orbiter program.

Resources are defined here to consist of funds, manpower, time, and physical activities and are to be allocated to design, development, test, assembly, integration, and management tasks.

The ESRO interest in a substantive program relates to its science program policy. Presently, ESRO policy precludes sponsorship of an independent ESRO planetary program. ESRO policy presently provides about $27 million per year for science programs. This budget allows a new project start once in about 2 to 3 years, depending on project costs. It is more likely that ESRO would desire to commit this budget to a major worthwhile sharing program or to a complete new-start program than that it would desire to break the budget into parts to support secondary pieces of programs.

ESRO contracts basic spacecraft hardware and functional tasks to ESRO community industry. The classical ESRO approach is to solicit bids from each of its three major bidding consortia (industrial groups represented by contractors in all leading ESRO supportive countries). Generally this bidding process takes about 2 years or more for those programs wherein the basic satellite design must be evolved. This process has to satisfy political considerations, balance of payments, redistribution in proportion to contribution (to ESRO financing), and has to bend to other pressures engendered by the nature of the ESRO organization.

ESRO has sponsored some preliminary studies, through ESTEC, by several leading European companies participating in space work. These studies were conducted in 1972 and familiarized the ESRO community with the requirements of Pioneer Venus so that an ESRO procurement can proceed with dispatch. Continued study effort by the ESRO community keeps its industrial and scientific community abreast of and interested in the Pioneer Venus program.

With respect to the assembly, integration, and test work package, some comments may be in order on the size deficiencies in ESRO test chambers:

1) With the spin axis oriented perpendicular to the sun axis, the dimension of the Thor/Delta launched orbiter spacecraft in the direction of the spin axis is presently 2.77 m, which is greater than the 2.6 m illuminated diameter of the ESTEC test chamber (HBF-3).

2) The axial dimension of the Atlas/Centaur launched orbiter is 3.3 m, which is significantly greater than the test volume diameter of ESTEC's HBF-3 (3 meters).

Unless this deficiency can be remedied without unacceptable consequences, other test facilities of adequate dimensional capacity will be required. AIT at ESTEC is a key element in any sharing program. The incompatibility of spacecraft and ESTEC facilities, unless remediable, could jeopardize the entire sharing program.

4. SHARABLE WORK PACKAGES

To formulate alternate plans with different levels of ESRO participation, it is necessary that separable work packages or tasks be defined. These packages should have certain characteristics if they are to qualify for assignment to ESRO. The scope of work packages must, of course, be consistent with the degree of program responsibility assumed by the assignee.

By way of illustration, certain subsystems with simple interfaces may be assigned for design and construction according to performance and interface specifications prepared by the organization responsible for the spacecraft overall design. The assignee's product, so long as it conforms to these specifications, will not significantly impact the remainder of the spacecraft design. Therefore, the work can be assigned with assurance and limited supervision to a subcontractor.

On the other hand, thermal control, for example, is a pervasive aspect of spacecraft design, impacting the various subsystems as well as the conception and configuration of the spacecraft itself. This task should remain the responsibility of the prime contractor/designer because it cannot be effectively assigned as an independent work package. Other work packages in the nature of system design must also be a direct responsibility of the prime contractor.

This situation is recognized in the sharing plans subsequently described. Under some sharing plans involving assignment of system design work packages to ESRO or its contracting community, ESRO takes all system design tasks and full spacecraft design responsibility because system design responsibility cannot be split between ARC and ESRO.

In those sharing plans where ARC retains spacecraft design responsibility, the work packages assigned to the ESRO community have the following characteristics:

- Clean and clearly described interfaces
- Manageable and economical coordination requirements
- Schedule compatibility
- Minimum of duplicated effort

Work packages can be classified as hardware packages (subsystems and major units) or function packages (sometimes called software). The hardware packages listed are the noncommon subsystems of the orbiter; the function packages are all orbiter unique.

1) Hardware

   Despun antenna system

   Orbit insertion propulsion subsystem

   Command memory

   Solar power subsystem

   Data storage unit

   Miscellaneous components

   Science instruments

   Orbiter unique structure

   Modification kits for converting probe test vehicles to orbiter configuration

   Modification kits for common hardware

2) Functions

   Mission analysis and design

   Qualification and acceptance testing

   Assembly and integration of qualification and flight spacecraft

   Science instrument integration

   Design of probe-to-orbiter modification kits for test vehicles

   Vibration and thermal design verification tests

   Direct purchase of common hardware from Hughes

   Responsibility for orbiter design beyond baseline

The ESRO community should have prior experience with major orbiter unique subsystems for which it accepts responsibility. ESRO experience is available on despun antennas, orbit insertion motors, data storage subsystems, and solar power panels. The Pioneer Venus despun antenna, command memory, and data storage unit have counterparts in the Helios satellite, which might fulfill the orbiter requirements. The orbit insertion propulsion might be accomplished by a version of the Symphonie liquid propellant engine. These possibilities may be verified by more detailed study. An illustration of spacecraft arrangement with these subsystems in place is shown in Figure 4-1.

The first five hardware packages are relatively independent subsystems for which performance, physical characteristics, and interface requirements can be defined with relative unambiguity precision. Little familiarity with contiguous systems of the spacecraft is required. These subsystems can be subcontracted by the prime contractor with relative ease. These remarks also can be applied to the first three of the functions packages, since their content and scope can be defined and their general inter-relations with the spacecraft are minimal.

The last four hardware items and the last four functions items are of a different nature. To accomplish these work packages successfully, an extensive overall knowledge of the mission, the spacecraft and its subsystems, and the concepts underlying its design are necessary, as none of these tasks could be successfully accomplished from the narrow subsystem point of view. Whatever group takes responsibility for the last four hardware packages must be prepared to take responsibility for the orbiter design beyond the baseline.

Orbiter science packages may be convenient elements for ESRO to provide, particularly those prepared in the ESRO community where interface coordination can be local to ESRO.

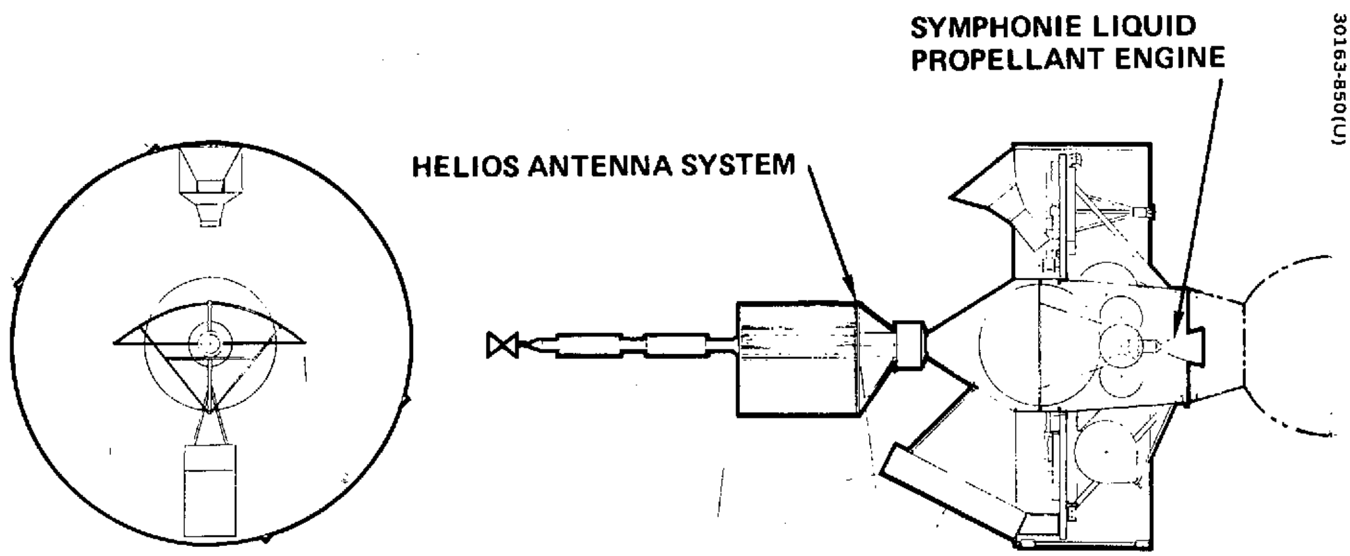


FIGURE 4-1. POSSIBLE ESRO ORBITER CONFIGURATION

5. PROGRAM MANAGEMENT CONSIDERATIONS

ARC performs the vital role in the international cooperation program. It serves as sponsor and organizer of the U. S. part of the cooperative program, arranging with ESRO a program suitably structured for mutual benefit. It will manage and fund the U. S. effort, directing the U. S. contractor in his ESRO support efforts. Third, it provides a formal conduit for U. S. originated information and hardware pertinent to the orbiter program.

The ARC described baseline for the Pioneer Venus international cooperation program is shown in Figure 5-1. It shows the semi-independent flow paths of the probe and orbiter spacecraft. Important features of the plan suggested by this flow diagram are:

1) ARC exerts heavy influence on the design of the orbiter spacecraft to assure maximum commonality in common subsystems. This role requires extensive mission analysis by ARC, although in the chart the orbiter mission analysis is shown as an ESRO primary task.

2) Coordination is required among NASA (ARC) and ESRO (ESTEC) and their leading contractors. (This coordination is not shown on the flow chart, but is discussed elsewhere in this report.)

3) Extensive import/export activity will be required to comply with the customs laws of various countries. The impact of this activity may be increased cost of performance and a slower schedule than is ordinarily associated with a U. S. domestic program.

From the viewpoint of the prime contractor, it is important that design integrity be assured. This requirement implies that either ARC or the ARC prime contractor be the originator (via a baseline design) and keeper of the design configuration, including keeping records up to date and assessing the impact of ESRO work on orbiter design integrity. This task can be effectively conducted by the contractor. The approach could be to prepare a proper baseline design for each configuration (probe and orbiter) and (with support of ARC) to maintain knowledgeability about its evolution. Also, baseline interfaces could be prepared as well as interface specifications for furnished packages (science) and for non-common hardware.

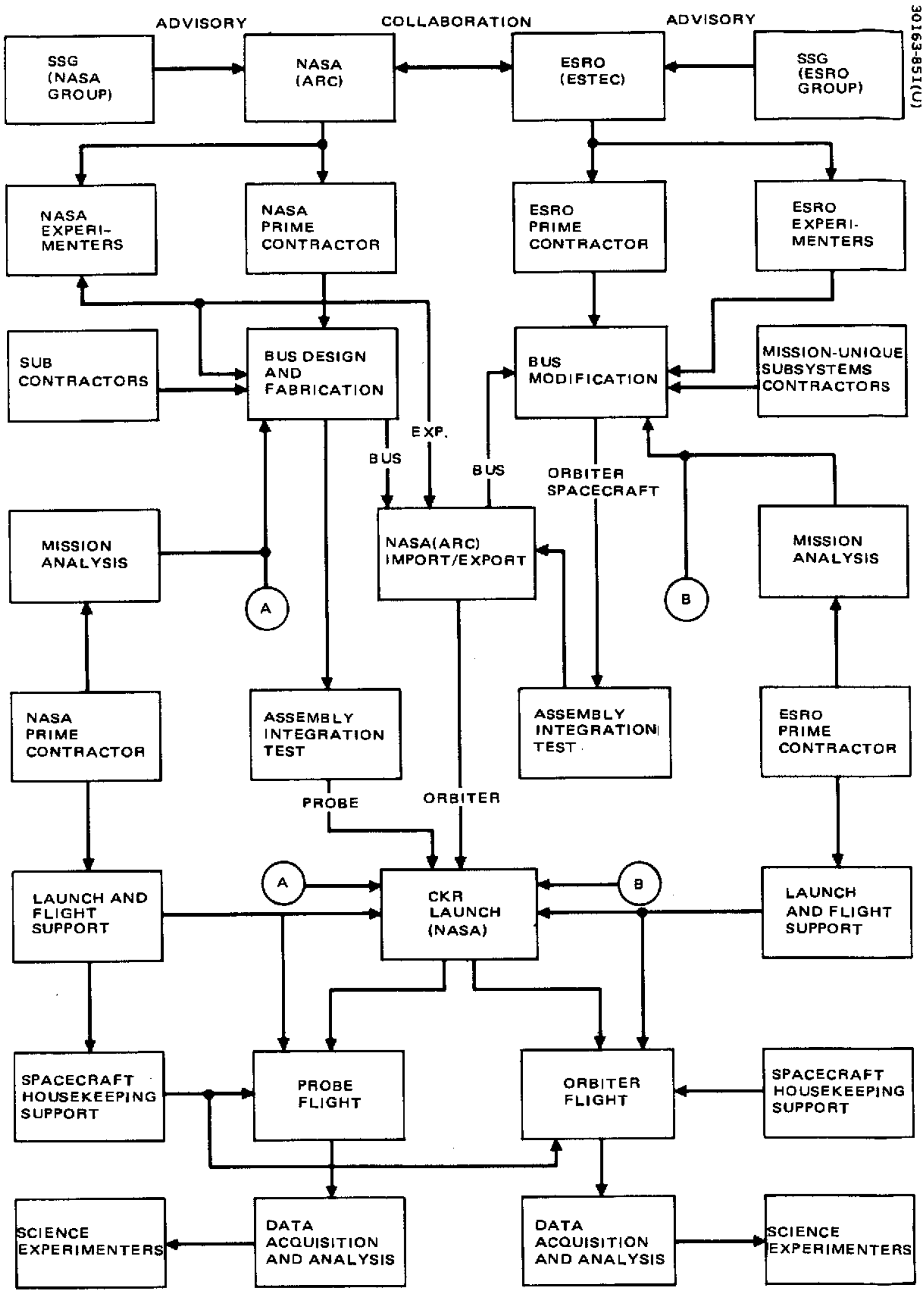


FIGURE 5-1. PIONEER VENUS ORBITER SUMMARY FLOW DIAGRAM

Again, from a contractor's point of view, responsibility trails must be clear. Buyers and sellers should deal directly with each other to assure satisfactory project performance; divided projects should have clear interfaces and responsibility trails. In the selection of alternative sharing plans to be studied, any sharing approaches that do not have responsibility trails defined by contractual mutual obligations between the contractors and the sponsoring agencies, or between the contractors when the latter are mutually obligated in the work distribution tree, have been eliminated.

The responsibility trail is established by the contracting procedure. Presuming that ESTEC and ARC will arrive at a cooperation agreement which adequately establishes their mutual responsibilities, the following described contracting approaches illustrate two possible contracting schemes.

5.1 APPROACH A

All obligations are to ARC. All deliveries are nominally made to ARC. ARC asserts all requirements and specifications, supervises the contract, and pays for all contract work. No obligations to other parties relative to the project are undertaken by the contractor. Within this framework, design, hardware manufacturing, testing, and technical assistance to ESRO and ESRO contractors can be arranged according to ARC requirements by definition in the work statement and its ancillary documents. This work is done to ARC satisfaction.

5.2 APPROACH B

With respect to basic orbiter design and common hardware subsystems, the contracting conditions would be the same as Approach A, all such work being done to ARC satisfaction. However, by agreement among the parties, the Ames prime contractor could sell, as a subcontractor to the ESRO prime contractor, the common subsystems (with negotiated hardware modifications where necessary) and technical assistance for support of this hardware. Such work would be done to the satisfaction of the ESRO prime contractor, and payment would be by the ESRO prime contractor. General technical assistance for the orbiter program would be separately contracted with ARC for nominal delivery to ARC and this assistance would be done to the satisfaction of ARC.

Technical support and assistance to ARC is desirable because it helps preserve the technical integrity of the orbiter design needed to assure that the orbiter will fulfill its intended mission. This support can be contracted under either approach described above.

5.3 EXPORT AND IMPORT FACTORS

Export and import factors impinge significantly on the cost of the cooperation program. Export license may be required under the Munition Control Act. For the Pioneer Venus program, this is formality only, but should be done carefully to avoid subsequent burdensome complexities of detail procedure. Import is the costly aspect of the cooperation, amounting to about 5 percent of the value of imported spacecraft items (which valuation must include the values of any assistance supplied, whether paid for by ESR(or not). There are myriad details involved in duty "management" including some which are cost reducing. An important question unsettled at this writi is whether or not NASA/ARC can avail itself of duty-free imports. This question could be investigated by ARC and a determination made to aid project work statement preparation and cost estimation.

6. MODEL SHARING PLANS

Suggested sharing plans should allow for different levels of participation by ESRO, extent of responsibilities, technical participation, and possible cost savings.

ESRO has not prepared a schedule for conducting the orbiter program. Therefore schedule considerations must be based on a logical presumed ESRO schedule. Examination of a schedule of program milestones, Figure 6-1, is useful in arriving at any appropriate presumptive ESRO schedule. It shows that design of the orbiter common elements is mostly completed near the end of 1975 and components for the prototype are delivered. Experiment hardware is delivered by the end of the third quarter 1976. The launch opportunity for the orbiter occurs in the third quarter of 1978. Another launch opportunity does not occur until the third quarter of 1980, 2 years later.

This situation suggests that delay of orbiter launching until 1980 would result in a stretchout of the U.S. effort (which might be intolerable), and in the launching of possible obsolete components of 1974 design vintage. Undoubtedly the stretchout would add to U.S. cost, and would significantly reduce the savings from sharing the program.

Different task mixes for ESRO will require different degrees of schedule discipline by the ESRO community. If an approach is used where the ESRO community contributes only subsystems, then the schedule established for the program must be maintained in order to prevent stretchout of assembly, integration, and test (at substantially greater cost of the program and perhaps other increased costs to ARC due to any schedule slippage).

In an approach where a much greater proportion of the work is done by the ESRO community, the financial impact on ARC of a schedule slippage is less. The cost to ARC of a stretchout would depend somewhat on the changes, if any, which might be required in the common subsystems due to unforeseen program situations (since these items are under ARC procurement in that plan).

An approach in which the ESRO community purchases the subsystems directly from the Ames prime contractor offers the greatest schedule flexibility for the ESRO community. It is possible through that approach to

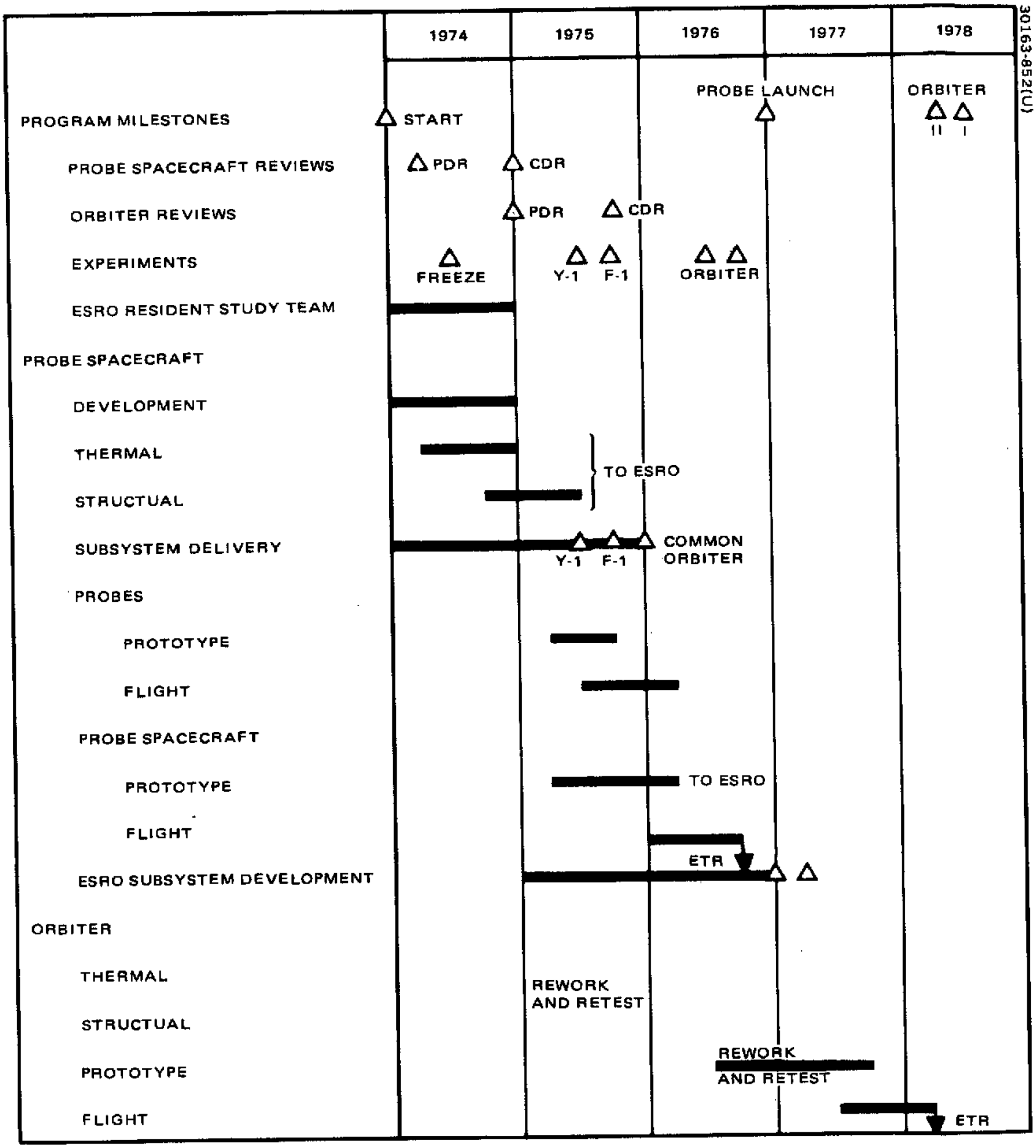


FIGURE 6-1. PIONEER VENUS INTERNATIONAL COOPERATION BASELINE SCHEDULE

consider an orbiter schedule adjusted to a 1980 launch with the bulk of the stretchout costs borne by ESRO; however, there would be some cost increase to ARC. The obsolescence factor and the general hazards and frustrations of a dragged out schedule would be present.

Consideration could be given to a policy which requires ESRO to agree to complete any program which it undertakes in time to meet the 1978 orbiter launch window, as scheduled in the proposed Pioneer Venus program.

A schedule for ESRO, shown in Figure 5-1, is constructed to meet this objective. It is attained by accelerating the initial elements of the ESRO program, i.e., the study phases, contractor selection, and go-ahead. These steps could be completed by the time drawings are completed at the end of 1974.

Since ESRO is closely monitoring U.S. efforts, it has some prior knowledge of the design directions on which to build its own program. About mid 1973, a choice of U.S. contractor and of U.S. design could be made to provide specificity to the ESRO program. Early in the second quarter of 1974 a preliminary design review could further aid the ESRO contractor selection process by pointing with greater certainty to the U.S. technical directions. During the second half of 1973, and by the end of the fourth quarter of 1974, when released drawings are available, the contractor selection process should be completed and ESRO should be able to let contracts.

The schedule of Figure 5-1, prepared on the previously described basis, shows that ESRO could have over 2 years of procurement phase time if it moves with determination and decisiveness in the contractor selection phase. A key element to successful use of the schedule is the ESRO resident study team. This activity essentially provides ESRO with a running start on the orbiter program.

This last plan is the most difficult plan from the schedule point of view. This is so because ESRO groups must take a more fundamental responsibility with respect to orbiter design. Also they must coordinate any modification of common units through a long chain of organizations. Direct procurement of the common subsystems by the ESRO prime contractor would help to expedite the ESRO delivery schedule by reducing some of the time consuming formal steps required for supplying them through NASA.

In the following paragraphs five sharing plans are described. All plans apply to orbiter sharing only. These plans are illustrative, and are intended to show nominal configurations of plans of five different scopes. Specific sharing plans that might be adopted probably would be variants of those shown and would require extensive detailed joint ESRO/ARC/contractor consideration beyond the intent of this study.

Plan 2 conveys significant responsibility to ESRO beyond that of Plan 1. Plan 3 conveys more than Plan 2, and so forth through the list. Between Plan 3 and Plan 4 the control of orbiter design passes from ARC

TABLE 6-1. SHARING PLAN 1 - SUMMARY

CONCEPT

Ames prime contractor designs all hardware in detail.

Ames prime contractor prepares construction kits which selected ESRO community contractors will assemble, under contract to the APC.

Ames prime contractor prepares specifications for some support equipment that can be contracted to selected ESRO community contractors for design and manufacture. The Ames prime contractor provides technical assistance as required for successful accomplishment of the contract.

Ames prime contractor assembles and integrates spacecraft, tests, supports launch.

Advantages	Disadvantages
• High confidence in product	• Not attractive/substantative participation (to ESRO)
• Minimum program risk in event of ESRO community failure	• Kit method increases program cost
• No reliable parts problem for ESRO	• Dollar contribution by ESRO is reduced
• Extensive experience on Intelsat, etc., with this method	• Prolongation of program duration due to procedure, and uncontrolled shipping and customs delays
	• Customs costs are significant
	• Excessive manipulation of hardware
	• Extensive international subcontracting by Ames prime contractor
	• Presents contractual and responsibility chain problems related to ESRO involvement

to ESRO due to assignment of design responsibilities. This condition necessitates that mission analysis and schedule responsibility also be given to ESRO. This exchange in technical prerogatives between ARC and ESRO should bring increased financial savings to ARC and increased cost and involvement to ESRO.

A word of caution regarding the cost estimates is necessary. First, the costs are approximate, but should be sufficiently accurate to show the relative economic scopes of the plans. Second, the incremental and support costs are estimated at a comfortable level, being neither generous nor tight. Third, in estimating the basic costs, the Delta booster configuration current in February 1973 was used. Fourth, the plans are representative only. Any exact plan negotiated would likely have its own financial conditions which would depart some from the plans described.

The format of cost comparisons in the plan is as follows. The Rough Order of Magnitude (ROM) cost of the Delta booster version of the orbiter was estimated in February 1973 and was reported to ARC in Hughes document SCG 36036 V (Hughes Ref. No. 73(44)-00636/C6529). To obtain the savings for each plan, the allocated work in the plan is identified and priced. Then the added cost to ARC of conducting the sharing plan is estimated. This added cost arises from the factors described in the previous paragraph outlining contractor Support and Technical Assistance (S&TA) tasks. The difference between the transferred costs and the S&TA costs is the saving due to sharing the program. This saving does not reflect ARC or government in-house cost differences, which cannot be evaluated here.

6.1 SHARING PLAN 1

This sharing plan, summarized in Table 6-1 and diagrammed in Figure 6-2, is suggested by its successful use in the Intelsat IV program and the extensive experience gained in its use. It does not meet the ESRO requirement for substantive participation as defined by ESRO, and for that reason is not a viable plan. It is presented here for the record because of initial interest by ARC in its possible use due to its successful application in Intelsat IV and ANIK programs.

The way this plan works is that the Ames prime contractor designs all of the satellite and support equipment, in detail, and procures parts and materials to specifications. These parts and materials are collected into kits for various hardware and a set of instructions is prepared for assembly of each kit. The kit is then exported to the appropriate non-U.S. contractor for assembly and test according to these instructions. After this step, the assembled unit is imported for assembly into the spacecraft. Support is given to the assembly contractor in accordance with his need.

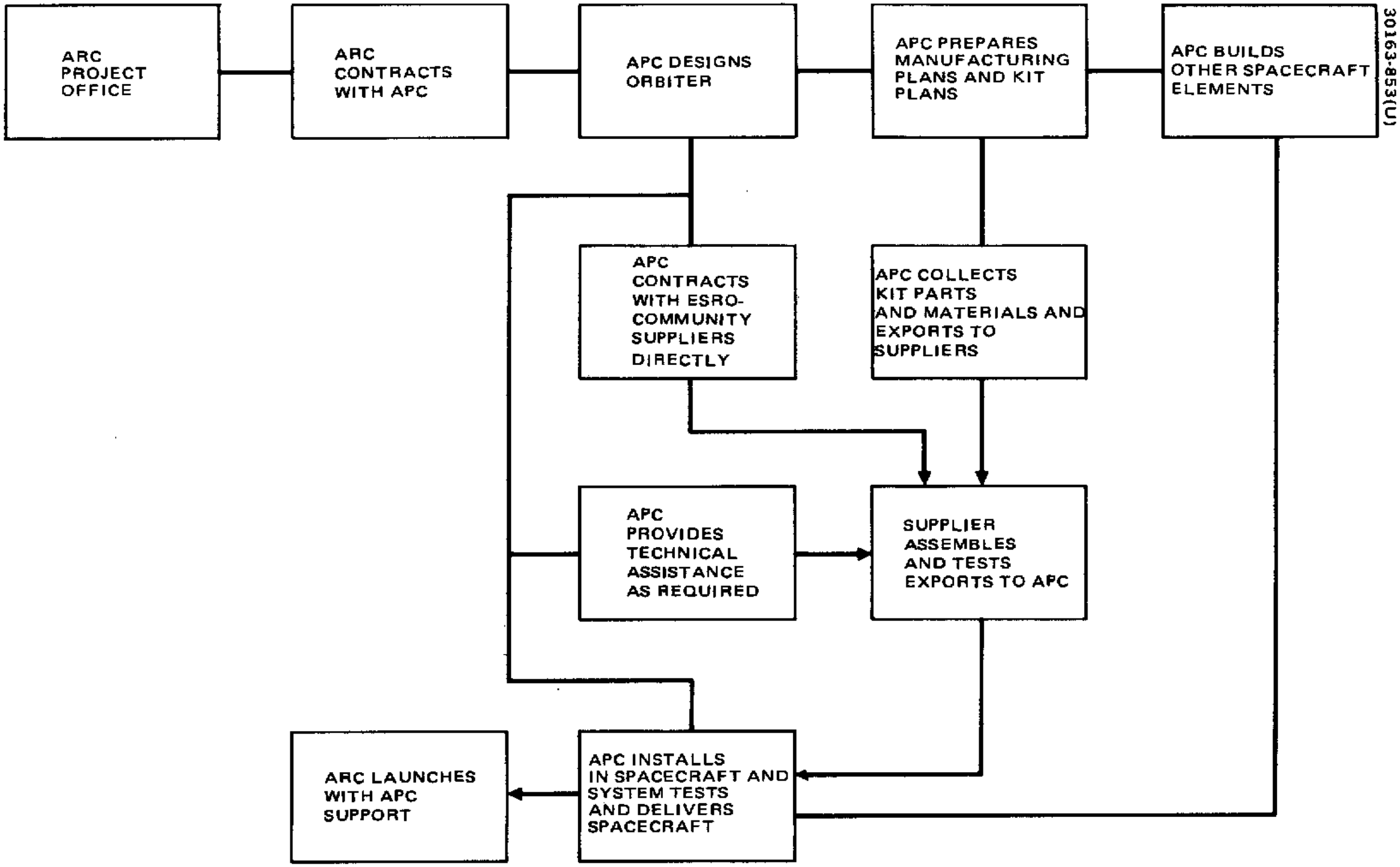


FIGURE 6-2. SHARING PLAN 1 ACTIVITY FLOW CHART

The fact that all design is performed in-house and control is kept of all parts, materials, and assembly methods, is very effective in maintaining design integrity, and the responsibility trail is clear and clean.

However, this procedure reserves all the "noble work", a point of considerable objection by foreign suppliers now that they feel capable of independently designing satellites and satellite subsystems.

Generally this approach is more expensive than a non-sharing program because the added cost of preparing kits and instructions, providing support, and paying import duties, offsets any labor-cost saving at the non-U.S. contractor. It also raises the risk of program slippage through default of a contractor. This risk was reduced on Comsat Intelsat IV because several spacecraft were ordered and the quantity on most items trusted to foreign suppliers was divided among several. Hughes built the prototype and first flight models and retained this capability during the program as insurance against subcontractor failure. This protective procedure is too expensive for a single spacecraft program such as the Pioneer Venus orbiter.

For effective structure of the responsibility trail, it may be necessary to omit ESRO from the responsibility chain. This approach to sharing of the ESRO orbiter work is judged not suitable for the program.

6.2 SHARING PLAN 2

This plan, summarized in Table 6-2 and flow diagrammed in Figure 6-3, offers a style of participation for the ESRO community in which it can supply subsystems for the orbiter by a procedure somewhat similar to that used for science instruments. It permits participation at a low budget level.

It provides design integrity through the responsibility of the Ames prime contractor for the overall orbiter design with specification of the interfaces and the performance characteristics required of all ESRO supplied items.

The responsibility trail is relatively direct and clean, except for the fact that the ESRO subsystem supplier and the Ames prime contractor designer have no contractual mutual obligations. This situation places the burdens of design rectification, should a design conflict arise, on either ESTEC or ARC, or both, a situation similar to that of the science packages.

Some degree of protection from default or from possible failure of the ESRO supplier is provided by the fact that the Ames prime contractor (APC) supplies technical monitoring of the ESRO contractor (on behalf of ARC and by contract with ARC). In view of these obligations, and the fact that the APC previously will have specified the performance characteristics, it is to be expected that the APC would be able to help correct a deficiency or

TABLE 6-2. SHARING PLAN 2 - SUMMARY

CONCEPT

Ames prime contractor designs systems and hardware functionally, does detail design of, and builds and tests common hardware and certain noncommon hardware.

Ames prime contractor provides detailed interface design and interface specifications, and provides a design requirements specification for selected noncommon hardware. These documents are provided to ESRO through ARC for use in procurement actions.

ESRO selects hardware contractors from the ESRO community and funds their work, accepting responsibility for effective performance by the contractors. Contractors deliver to ESRO hardware fully ready for assembly into the satellite. ESRO exports the hardware to ARC which would provide it GFE to Ames prime contractor. ESRO also supplies appropriate support for its hardware.

Ames prime contractor provides, through contract with ARC, technical monitoring of ESRO contractors to aid in achieving interface compatibility and performance adequacy of ESRO equipment.

Ames prime contractor assembles and integrates the ESRO hardware into the orbiter spacecraft and performs the test program.

Ames prime contractor delivers the spacecraft to ARC at the launch site and assists in the launch with other participants who may be required.

Advantages	Disadvantages
• Provides some substantive work for ESRO, where its contractors qualify	• Some launch schedule risk if ESRO unable to hold subsystem schedules, with consequent effect on cost
• Provides a unified system design	• Technical risk on ESRO hardware
• Has simplified lines of responsibility	• Has possible reliable parts problem

TABLE 6-2 (Continued)

Advantages	Disadvantages
• Has some risk reduction through Ames prime contractor technical monitoring • Contracting is simple • AIT is simplified by conducting it where the majority of components originate (at Ames prime contractor) • No funding exchanges between ESRO and ARC are required	• Provides relatively low cost saving to ARC, part of which is offset by added ARC support costs

This approach is similar to the approach used for handling science instruments. It could be used if ESRO participation consisted of supplying only certain subsystems.

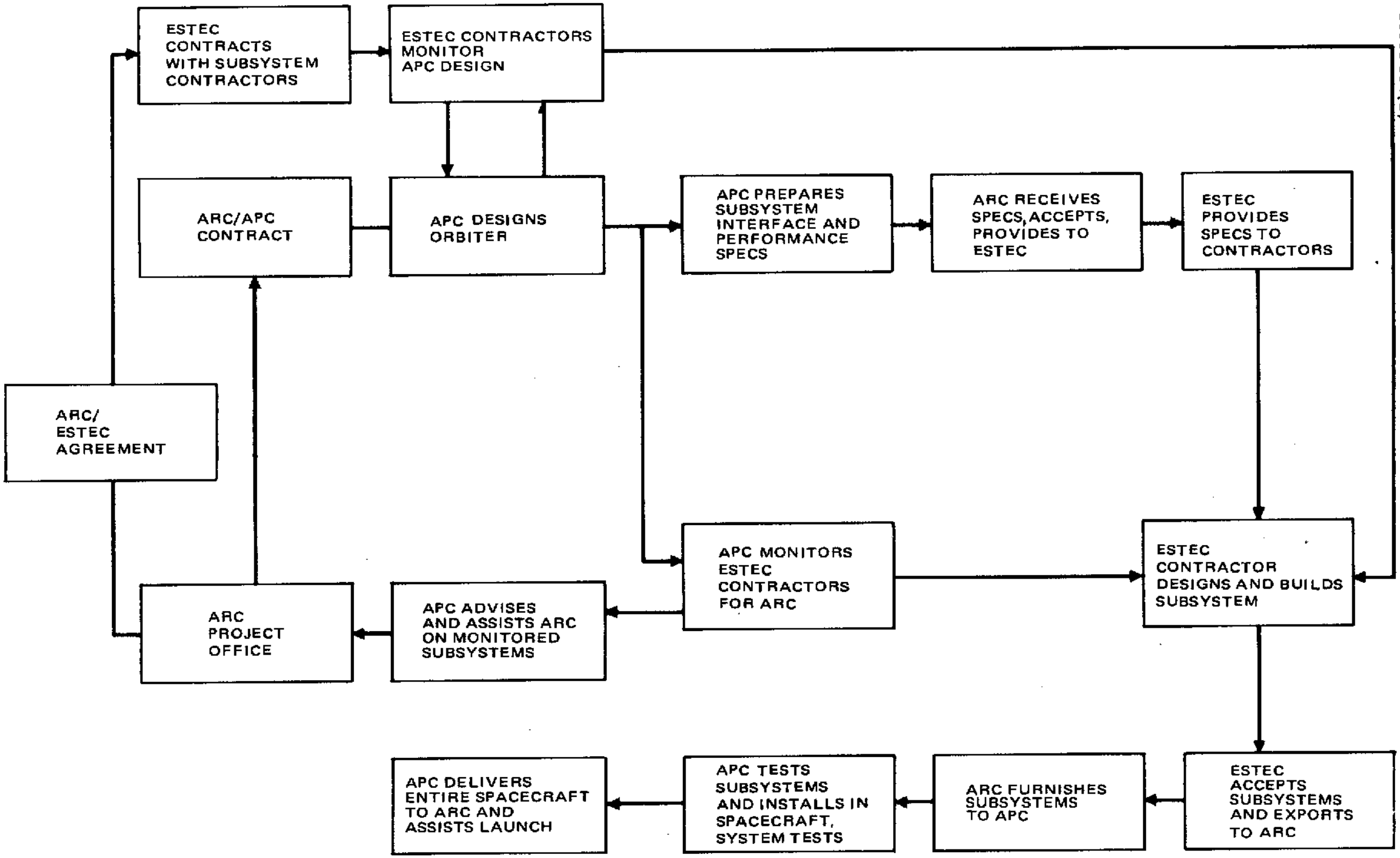


FIGURE 6-3. SHARING PLAN 2 ACTIVITY FLOW CHART

provide a backup article, albeit on a delayed schedule (possibly), and at increased program cost (certainly).

An important aspect of this sharing plan is that ARC and ESTEC would require a procedure for adjusting interface and performance specifications to assure compatibility of subsystems with orbiter design goals and to ease any conflicts between specifications and practical design problems. Adjustments of this kind would be made through the configuration management and change control function of the ARC project office. Table 6-3 summarizes the incremental cost and support cost attributable to this plan and savings are summarized in Table 6-4.

In this sharing plan, the ESRO community subsystems would be imported into the U.S. for installation into the spacecraft and testing. Unless NASA/ARC are able to obtain forgiveness of the import duty, this importation will add about five percent of these subsystem values plus certain administrative costs to the ARC cost of the orbiter program.

6.3 SHARING PLAN 3

This sharing plan, summarized by Table 6-5 and flow diagrammed in Figure 6-4, provides a plan of participation for ESRO of much greater scope than Plan 2. It includes both hardware and functional work.

In addition to the tasks of designing, and building noncommon hardware, it assigns to the ESRO community the functional work of assembly, integration, and test for qualification and flight models. Some test and support equipment is assigned also, as is certain mission analysis.

A key aspect of this support method is that the Ames prime contractor contracts only with ARC and does not undertake any separate obligations to the ESRO community. Therefore, the Ames prime contractor supplied hardware is built to ARC specifications, schedule, and acceptance conditions. Any changes, technical or program, are carried out under ARC directive, according to the mutually agreed procedures. Technical assistance is delivered to ARC in accordance with ARC directives.

This approach provides a very clean responsibility trail. Relative to the shared work, it places considerable administrative burden on ARC, some of which can be delegated effectively to the Ames prime contractor. Areas in which the administrative burden is significantly increased include information exchange with the ESRO community participants, design changes to common hardware for benefit of the orbiter, support of orbiter design aspects that affect the common hardware fielding in the ESRO community of an ARC and contractor support team of significant size (at ARC expense), handling trouble and failure reports from assembly, integration, and test, which impinge on ARC-responsible activities, and other areas. Description of a project office structure for handling these activities has already been given.

TABLE 6-3. INCREMENTAL COST AND SUPPORT COST - PLAN 2

Host ESTEC/contractor engineers		$ 187, 200
Six ESTEC engineers for 24 months during 1974 to 1976 (6 x 24 = 144 mm)		
Average Ames prime contractor person fully occupied with visitors:		
Two for 24 months: 48 mm at $3000/mm	$144, 000	
Providing space and service to visitors:		
144 mm at 300/mm	$ 43, 200	
Engineering software (added tasks due to shared program)		$ 121, 000
Orbiter-unique subsystems		
Subsystem performance specifications	$ 9, 000	
Subsystems interface specifications	$ 42, 000	
Orbiter data		
Baseline design data (existing)	$ 10, 000	
Data management (attributed to sharing)	$ 60, 000	
Change engineering	(as incurred)	
Support		$ 705, 000
Orbiter unique subsystems		
At Ames prime contractor		
Interfaces and changes	$ 72, 000	
Import duties and administration	$200, 000	
Special handling and testing	$ 24, 000	

TABLE 6-3 (Continued)

At ESTEC		
Interface and changes	$384,000	
Travel	$ 25,000	
Total of incremental cost and support cost		$1,013,000

TABLE 6-4. SUMMARY OF SAVINGS - PLAN 2

Subsystems value transferred to ESRO responsibility	
	$ (Thousands)
Despun antenna	1,035
Data handling	1,119
Orbit insertion	429
Power	1,116
Total	3,762
Additional support costs	1,013
Net savings	2,749

TABLE 6-5. SHARING PLAN 3 - SUMMARY

CONCEPT

Ames prime contractor designs spacecraft and subsystems functionally, does detail design of, and builds and tests common hardware and certain noncommon hardware, performs structural and thermal tests on Ames prime contractor-modified probe structural and thermal models and makes baseline design for orbiter qualification model.

Ames prime contractor designs the interface detail for the selected noncommon hardware and prepares the performance specification for the noncommon hardware. These documents are given to ESRO by ARC for selecting ESRO suppliers. Ames prime contractor coordinates science instrument interfaces.

ESRO funds and procures noncommon hardware and functional work, including AIT, and takes the attendant management and technical responsibility for it. ESRO modifies probe qualification model to orbiter qualification model configuration.

Ames prime contractor supplies technical monitoring, via ARC contract, of ESRO contractors to coordinate interface and functional requirement matters related to ESRO work packages, and to assist ARC in its monitoring tasks.

Ames prime contractor delivers their hardware to ARC, which exports it to the ESRO assembly, integration, and test contractor. The assembly, integration, and test contractor performs the assembly, integration and test task with technical monitoring from the Ames prime contractor, via ARC contract.

ARC imports the finished spacecraft and launches it with support of Ames prime contractor and other participants as required.

Advantages	Disadvantages
• Provides extensive ESRO participation	• Requires high technical competence from ESRO community
• Provides a cohesive baseline design	• Requires large investment by ESRO community
• Manageable contractual arrangements	• No backup or workaround plan if ESRO fails to deliver

TABLE 6-5 (Continued)

Advantages	Disadvantages
• Provides some program risk reduction through Ames prime contractor technical monitoring	• AIT may be difficult for ESRO community
• Substantial saving for U.S. seems possible	• Has possible reliable parts problem

This approach is applicable to the situation in which ESRO contributes extensively, including performance of the AIT program. It retains a strong influence of ARC through the ARC provision of hardware and Ames prime contractor monitoring service.

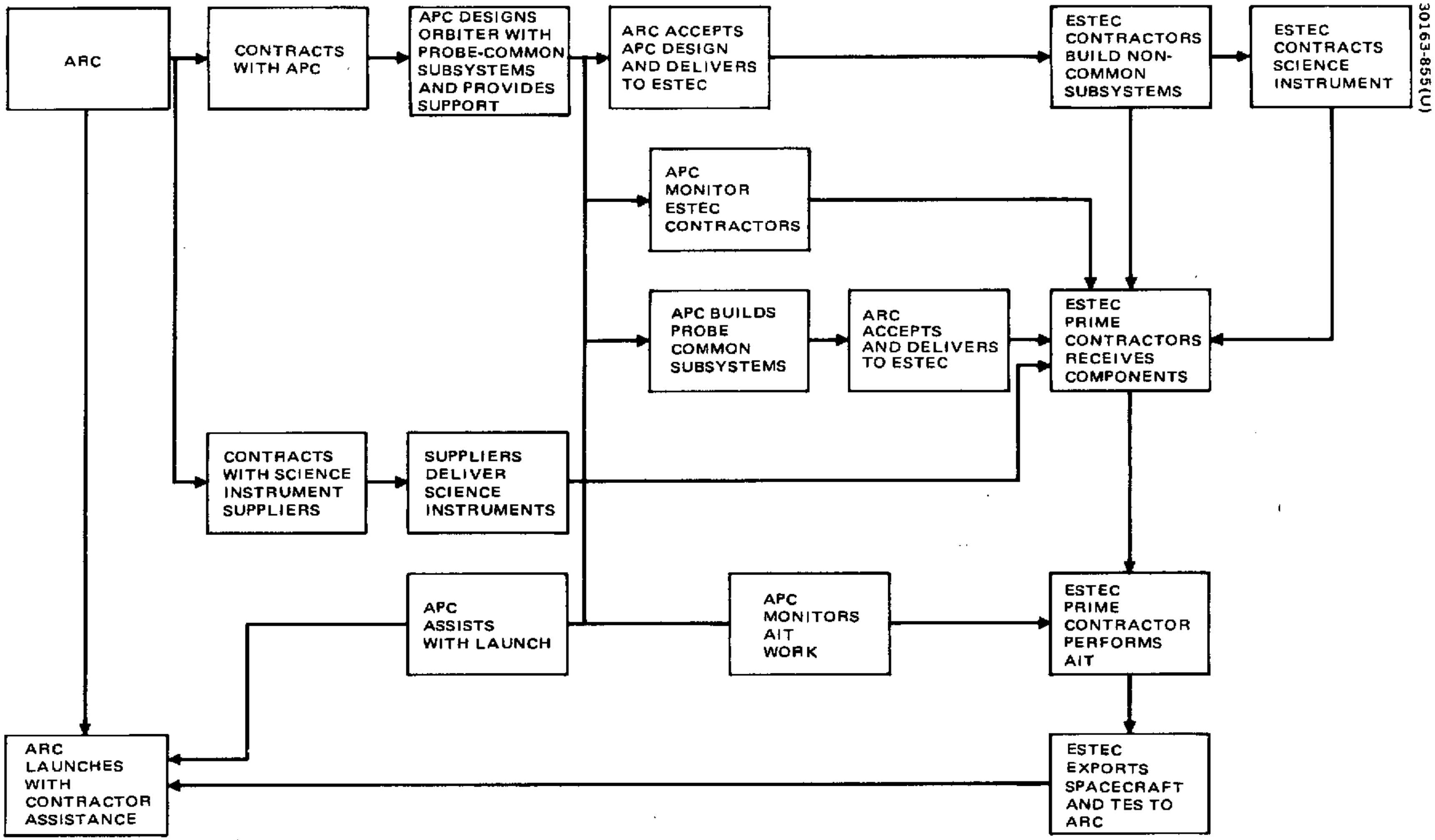


FIGURE 6-4. SHARING PLAN 3 ACTIVITY FLOW CHART

The cost of the Pioneer Venus program under this sharing plan will be increased by any delays in the program caused by ESRO-community problems; however, it is not so sensitive to delays as Plan 2, because the bulk of activity related to sharing is financed by ESRO and occurs at a time of relatively low project activity for ARC and its prime contractor. The incremental cost and support costs are estimated in Table 6-6. The cost saving analysis projected for this plan is shown in Table 6-7.

6.4 SHARING PLAN 4

This plan, diagrammed in Figure 6-5 and summarized in Table 6-8, is devised to place the main responsibility on ESTEC for carrying out the orbiter program, based on the conceptual (baseline) design provided by Ames prime contractor to ARC. Through this plan substantial savings are realized by ARC.

The key to transfer of authority and responsibility is in the treatment of thermal and structural model design and test, and in the treatment of the prototype model for qualification test. Ames prime contractor will have prepared, in conjunction with its probe spacecraft program, a baseline design of the orbiter, which achieves orbiter mission requirements and permits an effective design of common subsystems to be made. Structure and thermal models of the probe bus will be prepared and tested and the lessons learned will be reflected into the probe bus design. Then these models will be sent via ARC to ESTEC.

ESTEC will design suitable modifications for the structure and thermal models reflecting orbiter mission requirements, modify the models and conduct tests, and reflect the lessons learned into orbiter design.

ESTEC will procure the orbiter unique hardware reflecting the Ames prime contractor baseline design, but will procure from its own specifications and procedures. Under this Plan 4, the requirements dictated by its own mission analysis, structure and thermal activities, and its coordinate of science missions will be reflected in the procurement.

With this control over basic orbiter spacecraft design, and by specifying modifications of probe bus/orbiter common subsystems (by arrangements through ARC), ESTEC is in control of and responsible for the orbiter.

ESTEC will receive the probe prototype model and convert it to an orbiter prototype, performing the qualification tests at ESTEC under its own plan. ARC will provide probe-orbiter common subsystems purchased from the Ames prime contractor.

Ames prime contractor technical support, in most areas, will be substantially reduced under this plan, placing greater emphasis on ESTEC selfreliance.

TABLE 6-6. INCREMENTAL COST AND SUPPORT COST - PLAN 3

Host ESTEC/contractor engineers		$ 360,000
10 for 18 months, 5 for 12 months (240 mm)		
Average manpower burden on Ames prime contractor is four persons for 18 months, 2 for 12 months		
Total 72 + 24 = 96 mm; 96 at $3000	$288,000	
Space & service for 240 mm at $300/mm	$ 72,000	
Engineering Software (new tasks due to sharing)		$ 405,000
Orbiter unique subsystems		
Subsystem performance specifications	$ 12,000	
Subsystem interface specification (4)	$ 60,000	
Orbiter preliminary test plan	$ 18,000	
Orbiter data		
Baseline design data (copies of existing)	$ 10,000	
Probe/orbiter common subsystems		
Installation data (new task)	$100,000	
Performance data (new task)	$ 25,000	
Data mgt (attributable to sharing)	$180,000	
Change engineering	(as incurred)	
Test models and tooling		$ 75,000
Orbiter mockup (general arrangement)	$ 75,000	
Booster/spacecraft matched interfact tooling	(ESRO cost)	
Booster/spacecraft interface test simulator	(ESRO cost)	
Support		
Orbiter unique subsystems		$ 648,000
At Ames prime contractor (interface and changes	$ 72,000	
At ESTEC (interface and changes)	$576,000	
Travel	$150,000	$ 150,000
Assembly, integration, and test		$ 609,000
Test program development	$100,000	
Assembly and integration development	$100,000	
Assembly and integration support		
System engineering	$ 45,000	
Product assurance engineering	$ 45,000	
Special subsystem engineering	$ 75,000	
Qualification and acceptance test	$244,000	
Support of test preparation		
System engineering		
Product assurance engineering		
Test engineering		
Trouble and failure report assistance		

TABLE 6-6. (Continued)

Project office support at ARC	$760, 000	$ 760, 000
Resident at ESTEC		
Ames prime contractor manager		
System engineer		
Project assurance engineer		
Test engineer		
Total incremental cost and support cost		$3, 007, 000

TABLE 6-7. SUMMARY OF SAVINGS - PLAN 3

	$ (thousands)
Subsystem value transferred to ESRO responsibility	
Despun antenna	1, 035
Data handling	1, 119
Orbit insertion	492
Power	1, 116
Support equipment	300
Total hardware transferred	4, 062
Functional tasks transferred to ESRO	
Assembly, integration	2, 000
System test	2, 800
Product effectiveness	2, 500
Total of functional tasks	7, 300
Total transferred to ESRO	11, 362
Additional support costs	3, 007
Net Savings	8, 355

TABLE 6-8. SHARING PLAN 4 - SUMMARY

CONCEPT

Ames prime contractor prepares baseline orbiter design to include common subsystems, prepares preliminary orbiter design requirements, preliminary orbiter-unique subsystem specifications, preliminary interface specifications for science instruments, delivers these documents to ARC, delivers the probe structure test model, the probe thermal test model, and the probe qualification model to ARC.

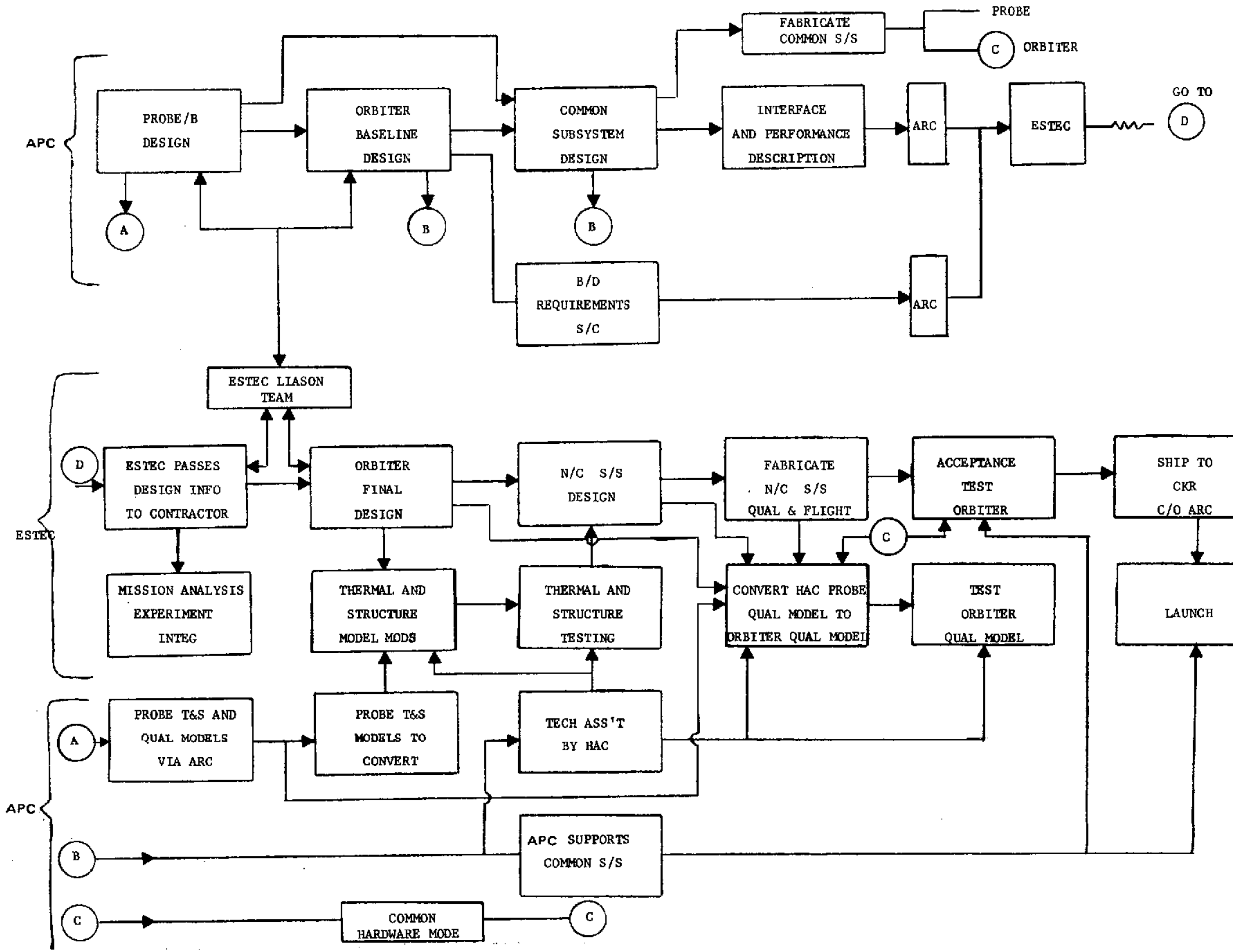
ARC exports the Ames prime contractor prepared items to ESTEC. ARC also orders the probe-orbiter common subsystems from the Ames prime contractor and provides them to ESTEC.

ESTEC engages contractors to make final orbiter design, to reconfigure test models from probe to orbiter configuration and perform tests, to build orbiter-unique hardware, to perform assembly, integration, and test of orbiter spacecraft (including the converted qualification model). ESTEC conducts mission analysis, science instrument coordination, and other software functions. ESTEC takes full responsibility for orbiter.

Ames prime contractor provides technical assistance to ESTEC and its contractors according to contract with ARC and under ARC auspices.

ESTEC accepts orbiter spacecraft and exports it to ARC for launch from Cape Kennedy Range with support of ESTEC and its contractors and the Ames prime contractor.

Advantages	Disadvantages
• Large cost saving to U.S.	• ARC relinquishes control of orbiter design
• Appealing substantive work for ESRO	• ARC has no direct schedule control
• Improved ARC protection from cost of any ESRO schedule delays	


APC
PROBE/B DESIGN
ORBITER BASELINE DESIGN
COMMON SUBSYSTEM DESIGN
FABRICATE COMMON S/S
PROBE
ORBITER
INTERFACE AND PERFORMANCE DESCRIPTION
ARC
ESTEC
GO TO
D
A
B
B
B/D REQUIREMENTS S/C
ARC
ESTEC LIASON TEAM
ESTEC
D
ESTEC PASSES DESIGN INFO TO CONTRACTOR
ORBITER FINAL DESIGN
N/C S/S DESIGN
FABRICATE N/C S/S QUAL & FLIGHT
ACCEPTANCE TEST ORBITER
SHIP TO CKR C/O ARC
MISSION ANALYSIS EXPERIMENT INTEG
THERMAL AND STRUCTURE MODEL MODS
THERMAL AND STRUCTURE TESTING
C
CONVERT HAC PROBE QUAL MODEL TO ORBITER QUAL MODEL
TEST ORBITER QUAL MODEL
LAUNCH
APC
A
PROBE T&S AND QUAL MODELS VIA ARC
PROBE T&S MODELS TO CONVERT
TECH ASS'T BY HAC
B
APC SUPPORTS COMMON S/S
C
COMMON HARDWARE MODE
C

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Incremental costs and support costs are estimated in Table 6-9. Projected savings are shown in Table 6-10.

Plan 4 could be adjusted to show an improved saving if less support is given to ESRO. Elimination of certain support items and reduction of others has been considered. One such study eliminates the support of the ARC program office at ESTEC and makes other economies which further improve the savings. Without a specific program to negotiate with ESRO it is difficult to determine whether more or less support would be in ARC's best interest. However, the range of possible savings may lie between these two plans.

6.5 SHARING PLAN 5

This plan is actually a variant of Sharing Plan 4. Two basic differences distinguish Plan 5 from Plan 4. First, Plan 5 is an effective method for transferring additional responsibility and costs to ESRO/ESTEC. In this plan, summarized in Table 6-11 and flow diagrammed in Figure 6-6, the common subsystems are procured from the APC by the ESTEC prime contractor instead of being given to ESTEC by ARC. Any necessary modifications, technical support for the common subsystems, and delivery schedule, are determined by negotiation between the Ames prime contractor and the European prime in a company to company negotiated contract. In this procedure is seen the second important distinction of Plan 5: Ames prime contractor contracts to the ESTEC prime contractor, establishing for the "common" subsystem a responsibility sub-trail independent of NASA/ARC.

This plan transfers greater responsibility and design authority to ESTEC by giving it a route independent of ARC for controlling the detailed design and interface characteristics of the common subsystems.

This plan has an effective responsibility trail and can be economically advantageous to ARC through savings of the recurring costs of common hardware and costs of support activities related to ESTEC use of it. Compared to the cost of making its own independent design of these subsystems, in order to independently control them, this method offers ESTEC a significant cost saving. For all parties, this arrangement simplifies the change and technical support procedure, which is reflected as program cost savings, though its benefit is unevenly distributed.

This plan can also reduce substantially the additional ARC costs that would be incurred in the event that ESTEC cannot meet the 1978 orbiter launch window, and thus forces a stretchout of the program to 1980.

A disadvantage of this approach from the ARC point of view is that it reduces the ARC influence on the basic design of the orbiter.

TABLE 6-9. INCREMENTAL COST AND SUPPORT COST - PLAN 4

Host ESTEC/contractor engineers		$450, 700
14 ESTEC engineers for 18 months, 6 engineers for 12 months (252 + 72 = 329 ESTEC mm)		
Average extra burden on Ames prime contractor: 5 Ames prime contractor engineers for 18 months, 2 Ames prime contractor engineers for 12 months (90 + 24 = 114 Ames prime contractor mm)		
114 mm at $3000/mm	$352, 000	
Space and service for 329 ESTEC mm at $300/mm	$ 98, 700	
Engineering software (new tasks)		$375, 000
Orbiter data		
Baseline design data (existing)	$ 10, 000	
Orbiter-probe common subsystems		
Installation data	$100, 000	
Performance data	$ 25, 000	
Data management (portion due to sharing)	$240, 000	
Change engineering	(as incurred)	
Test models and tooling		
Shipping thermal, structure and qualification models	$ 35, 000	$ 35, 000
Booster/satellite matched interface tooline	(ESRO furnish)	
Booster/satellite compatibility simulators	(ESRO furnish)	
Support		
Orbiter-unique subsystems		$290, 000
Interfaces and changes at Ames prime contractor	$ 40, 000	
Interfaces and changes at ESTEC	$250, 000	
Travel	$100, 000	$100, 000
Special test models support		$140, 000
Structure model and test	$ 50, 000	
Thermal model and test	$ 50, 000	
Qualification model modification	$ 40, 000	
Assembly integration and test		$463, 000
Test program development	$ 50, 000	
Assembly and integration development	$ 50, 000	

TABLE 6-9 (Continued)

Assembly and integration support		
Engineering	$ 38, 000	
Product assurance	$ 38, 000	
Special subsystem engineering	$ 25, 000	
Qualification and acceptance test	$122, 000	
Support of test preparation		
System engineering		
Product assurance engineering		
Test engineering		
Trouble and failure investigation		
Sustaining support of common subsystem	$180, 000	$ 180, 000
Project office support of ARC at ESTEC		$ 904, 000
Resident at ESTEC	$760, 000	
Ames prime contractor manager		
System engineer		
Product assurance engineer		
Test engineer		
Nonresident	$144, 000	
Coordinator and support at Ames prime contractor		
Total incremental cost and support cost		$2, 937, 700

TABLE 6-10. SUMMARY OF SAVINGS – PLAN 4

Subsystem value transferred to ESRO responsibility	$ (thousands)
Subsystem engineering	1,800
Despun antenna	1,035
Data handling	1,119
Orbit insertion	492
Power	1,116
Support equipment	300
Structure	419
Cabline	317
Thermal control	160
Miscellaneous parts and components	600
Total hardware transferred	7,358
Functional tasks transferred	
Experiment integration	1,310
Program management	400
System engineering	2,000
Product effectiveness	2,900
Assembly, integration	2,000
System test and launch operations	3,100
Total functional tasks transferred	11,710
Grand total of tasks transferred	19,068
Additional support costs	2,937
Net Savings	17,131

TABLE 6-11. SHARING PLAN 5 – SUMMARY

CONCEPT

Ames prime contractor prepares baseline orbiter design to include common subsystems, preliminary orbiter design requirements, preliminary orbiter-unique subsystem specifications, and preliminary interface specifications for science instruments. Ames prime contractor delivers these documents, delivers the probe structure test model, the probe thermal test model, and the probe qualification model to ARC.

ARC exports the Ames prime contractor prepared items to ESTEC.

ESTEC engages contractors to make final orbiter design, to reconfigure test models from probe to orbiter configuration and perform tests, to build orbiter-unique hardware, to perform assembly, integration, and test of orbiter spacecraft (including the converted qualification model).

The ESTEC prime contractor purchases common subsystems from Ames prime contractor according to ARC specifications previously used for the probe program. Any modifications required for the orbiter are negotiated between Ames prime contractor and the ESTEC prime. Ames prime contractor provides technical assistance to the ESTEC prime for application problems of the common subsystems under contract to the ESTEC prime.

ESTEC conducts all mission analysis and performs all other software and functional tasks. ESTEC takes full responsibility for the orbiter. It accepts the ready spacecraft from the prime contractor and exports it to ARC for launch at Cape Kennedy Range, supporting the launch as required.

Ames prime contractor contracts separately with ARC to support ARC with technical assistance at ESTEC as required by ARC.

Advantages	Disadvantages
• Maximum cost saving to ARC	• ARC loses control of orbiter program
• Maximum protection for ARC against ESRO schedule delay	• Purchase of Ames prime contractor subsystems conflicts with ESRO financial policies
• Minimized duplication of ARC/ESRO effort through use of common subsystems	
• Attractive program to ESRO	

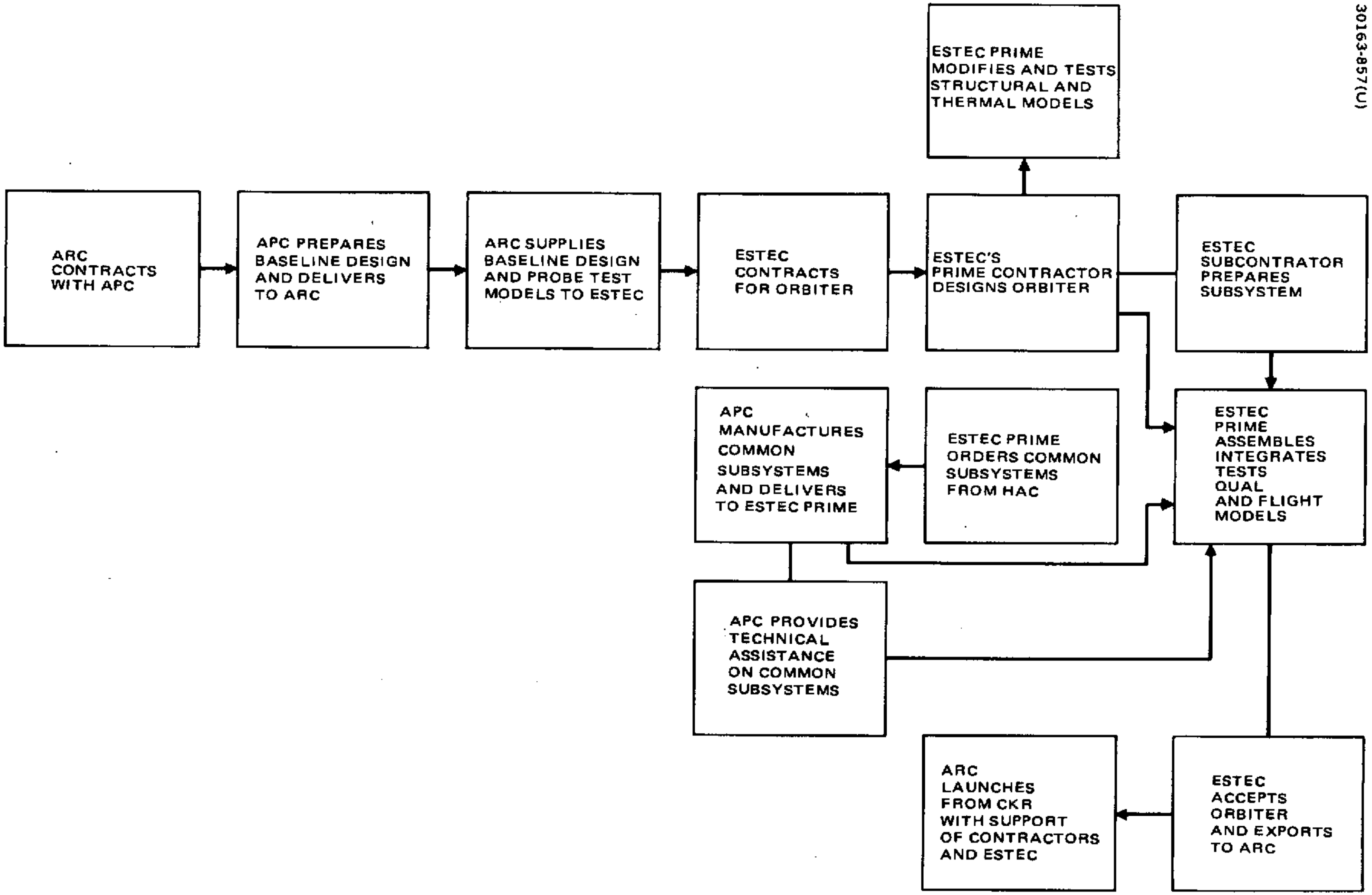

FIGURE 6-6. SHARING PLAN 5 ACTIVITY FLOW CHART

A disadvantage from the ESRO point of view is that a substantial amount of its funds would be paid to the Ames prime contractor for the common systems, modifications, if any, and common-system technical support. This requirement may come into basic conflict with the financial precepts of the ESRO organization.

Clarification regarding technical assistance provided by the Ames prime contractor under this plan is in order. Two different segments of technical assistance would be contracted. With ARC, the Ames prime contractor would contract "program office" (i.e., overall) support. The amount of this support would be reduced because of the transferrence of common subsystem support to common subsystem contracts at ESTEC's cost. With the common subsystem contracts, Hughes would supply that technical assistance which is necessary for understanding, proper performance, and effective application of the common subsystems.

Incremental costs and support costs are shown in Table 6-12 and projected cost savings are shown in Table 6-13.

TABLE 6-12. INCREMENTAL COST AND SUPPORT COST - PLAN 5

Host ESTEC/contractor engineers (same as Plan 4)		$ 450,700
Engineering software		$ 10,000
Baseline design data (existing)	$ 10,000	
Test models and tooling		$ 45,000
Shipping test models, structure and qualification models	$ 45,000	
Travel	$ 50,000	$ 50,000
Project office support of ARC at ESTEC		$ 644,000
Resident	$500,000	
Nonresident	$144,000	
Total of incremental cost and support cost, Plan 5		$1,199,700

TABLE 6-13. SUMMARY OF SAVINGS - PLAN 5

Subsystem value transferred to ESRO responsibility	$ (thousands)
Hardware orbiter unique (from Plan 4)	7, 358
Hardware common (purchased directly from Ames prime contractor)	4, 142
Total hardware	11, 550
Functional tasks transferred to ESRO responsibility (from Plan 4)	11, 710
Additional product effectiveness	500
Additional system engineering	500
Total functional tasks transferred	12, 710
Grand total of cost transferred to ESRO	25, 260
Additional support cost to ARC	1, 200
Net cost transferred (saving)	23, 060