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PROGRAM PLAN
FOR THE
BRAYTON ISOTOPE POWER SYSTEM
PHASE I
DESIGN, FABRICATION AND TEST
OF THE
BRAYTON ISOTOPE POWER SYSTEM

75-311376B

October 22, 1975

Prepared by Engineering Staff/ADM

Initial Issue

Approved by

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H.W. Longee

Closed Cycle Engines Project

MASTER

AIRESEARCH MANUFACTURING COMPANY

A DIVISION OF THE GARRETT CORPORATION
PHOENIX, ARIZONA

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REPORT NO. 75-311376B

TOTAL PAGES 48

ATTACHMENTS: Drawing 306960 Rev. A follows Page 3-2
Appendix A (11 pages)

REV	BY	APPROVED	DATE	PAGES AND/OR PARAGRAPHS AFFECTED
Orig			9-19-75	
A	ADM		10-14-75	Various
B	ADM		10-22-75	Various

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PROGRAM PLAN
FOR THE
BRAYTON ISOTOPE POWER SYSTEM

PHASE I
DESIGN, FABRICATION AND TEST
OF THE
BRAYTON ISOTOPE POWER SYSTEM

1.0 INTRODUCTION

This document defines the tasks to be accomplished by the AiResearch Manufacturing Company of Arizona, a Division of The Garrett Corporation, serving as the Prime Contractor for the implementation of ERDA Contract E(04-3)-1123. This program plan covers Phase I of an overall program for the development of a 500 to 2000 W_e (EOM), 7-year life, power system for space vehicles. The system uses a closed Brayton dynamic system to convert energy from an isotope heat source at a net efficiency greater than 25 percent. This first phase, a 35-months effort, is for the conceptual design of a 1300 W_e , 450 lb flight system and the design, fabrication, and test of a ground demonstration system. The flight system will use, for the baseline design, two of the multihundred-watt (MHW) heat sources being developed for the ERDA by the General Electric Company. The Ground Demonstration System will simulate, as closely as possible, the Brayton Isotope Power Flight System and will utilize components and technology being developed by the NASA under Contracts NAS3-18517, NAS3-18029, and NAS3-18541 for the Mini-Brayton rotating unit, recuperator and heat source assembly, respectively. The Ground Demonstration System includes a performance test and a 1000-hour endurance test.

Throughout Phase I, the contractor will be supported by the AiResearch Manufacturing Company of California, the Thermo-Electron Corporation and General Electric Company as major subcontractors for heat exchangers, insulation, and heat source and system support, respectively.

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Successful completion of the Phase I effort is expected to lead to the Phase II and Phase III follow-on contracts.

Phases II and III are presently estimated to be 36 month programs, during which the Brayton Isotope Power System (BIPS) will be developed and fully qualified for launch by April, 1981. Qualification will include testing with the Isotope Heat Source (IHS).

Phase III is the follow-on production phase which is being planned on the basis of providing for four Brayton Isotope Power System launches per year.

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2.0 SUMMARY

The objectives of the Phase I program are:

- (a) To conduct a conceptual design effort which will characterize the flight system requirements
- (b) To design, fabricate and assemble a GDS and to accomplish performance and endurance testing of the GDS to evaluate BIPS operational and performance characteristics
- (c) To conduct in parallel with GDS tasks, the long lead development activity required to assure the delivery of the first production flight system in April, 1981

The detailed Task Objectives are delineated on Table 2-1.

Using the knowledge gained from GDS testing and from the long lead development effort, a program plan for the BIPS Flight System Development and Qualification will be generated.

The GDS testing will be conducted using one GDS unit at an AiResearch, Phoenix test facility. GE will support AiResearch in the areas of component design, fabrication, and test support.

Phase I consists of ten tasks summarized on Table I and described in detail in this document.

The time phasing of these tasks is shown on the Phase I schedule, Figure 2-1. The schedule of Phases II and III is shown in Figure 2-2. The subsequent steps required to accomplish the development and production of flight application power units are shown in the preliminary schedules for Phases II and III, shown in Figure 2-2. Table 2-2 summarizes the required program reports; those that have been published have document numbers assigned and the dates shown are the first publication dates. Revision dates are not shown on Table 2-2. Published documents relating to the BIPS program with the latest revision dates are given on Table 6-1, Section 6.0.

TABLE 2-1

TASK OBJECTIVES SUMMARY

TASK 1 - PROGRAM MANAGEMENT

- o Define technical objectives
- o Control costs
- o Meet schedule
- o Manage resources to achieve all technical goals
- o Prepare advanced program plans
- o Timely reporting
- o Maintain CCD and IPP
- o Establish documentation procedures
- o Manage subcontracts

TASK 2 - IBFS PRELIMINARY DESIGN

- o Define system meeting ERDA objectives
- o Provide design flexibility
- o Show tradeoffs and compromise of:
 - o Checkout on launch pad
 - o Operate before or through launch
 - o Spin stabilized platform
- o Define long lead development (Task 9)
- o Design report
- o Design review meeting

TASK 3 - GDS PRELIMINARY DESIGN AND TEST PLAN

- o Prepare design, material and handling specifications
- o Prepare GDS test plan
- o Prepare P&I diagram
- o Prepare test facility specs
- o Prepare assembly, test and operating procedures
- o Prepare GDS layout drawings
- o Prepare test facility layout drawings
- o Prepare control circuit schematic diagrams
- o Conduct design review meeting
- o Prepare design report

TASK 4 - GDS DETAIL ANALYSIS AND DESIGN

- o Prepare manufacturing drawings for all GDS components
- o Prepare manufacturing drawings for all test facility components
- o Prepare Method of Test for all components
- o Prepare inspection procedure (IP)-components
- o Complete transient analysis
- o Prepare circuit diagrams and wiring diagrams
- o Build a mock-up (full scale)
- o Conduct detail design review
- o Submit detail design review report

TASK 5 - FABRICATION AND ASSEMBLY

- o Fabricate all GDS components
- o Fabricate all test facility components
- o Generate equipment logs
- o Assemble GDS
- o Install GDS in test facility

TABLE 2-1 (Contd)

TASK 6 - TEST AND EVALUATION

- o Operate at full design speed
- o Operate at full design power
- o Confirm component performance
- o Confirm system performance
- o Make fully automatic startup
- o Complete 1000-hr continuous run
- o Prepare test report

TASK 7 - QUALITY, RELIABILITY AND SAFETY

- o Implement QA plan and enforce compliance with procedures
- o Implement safety plan
- o Implement reliability plan
- o Complete PHA (Preliminary Hazard Analysis)
- o Complete FTA (Fault Tree Analysis)
- o Conduct PSSR (Preliminary System Safety Review)
- o Prepare GDS FMECA
- o Prepare IBFS FMECA

TASK 8 - REPORTS AND DATA

- o Prepare contractually required reports
 - o Monthly
 - o Annual
 - o Financial top summary
 - o QA, R&S
 - o Final
- o Prepare, issue and maintain program control documents
 - o Configuration control document (CCD)
 - o Integrated program plan (IPP)
 - o Subcontractor work statements
 - o Procurement control documents
- o Prepare test procedures
 - o Test flow plan
 - o Test, receiving, handling, cleaning, assembly instructions
 - o Test reports

TASK 9 - ADVANCED DEVELOPMENTS

- o Develop advanced controls
- o Develop Be radiator mfg. techniques

TASK 10 - FLIGHT DESIGN AND ENGINEERING PROGRAM PLAN

- o Prepare Phase II plan

E EXPECTED
R REQUIRED

FIGURE 2-1

[illegible]

FIGURE 2-2

TABLE 2-2

SUMMARY OF AIRPHX CONTRACTURAL REPORTS AND DOCUMENTATION

<u>Document No.</u>	<u>Title</u>	<u>Date Due</u>	<u>Initial Document Issued</u>
75-311376	Program Plan - Phase I	Rev as Req'd.	9-19-75
75-311457	Monthly Technical	8-12-75 (12th of each of 35 months)	8-28-75
75-311471	Top Summary	20th of each of 35 months	8-20-75
TBD	Annual Technical	8-30-76 & 8-30-77	TBD
TBD	Phase I Final	5-31-78	TBD
TBD	Task 2 Topical	1-31-77	TBD
TBD	Task 3 Design Review	6-30-76	TBD
TBD	Task 4 Topical	3-31-77	TBD
TBD	Task 6 Performance Test Report	2-28-78	TBD
75-311574	Integrated Program Plan	Rev as Req'd.	8-28-75
75-311274	Configuration Control Document	Rev as Req'd.	6-16-75
75-311360	GDS Reliability Program Plan	9-30-75	TBD
QC-048, Rev. 5	GDS Q.A. Plan	11-15-75	TBD
75-311221	System Safety Program Plan	7-25-75	TBD
TBD	Preliminary System Safety Review	10-31-77	TBD
TBD	BIPS Preliminary Hazard Analysis	10-31-75	TBD
TBD	GDS Preliminary Hazard Analysis	11-30-75	TBD
TBD	BIPS Preliminary Failure Mode Effects Criticality Analysis (FMECA)	12-31-76	TBD
TBD	GDS FMECA	1-31-76	TBD
TBD	Phase II Program Plan	12-31-76	TBD
75-311375	S.O.W. to GE	8-31-75	9-4-75
75-311472	S.O.W. to LA	8-31-75	9-1-75
75-311499	S.O.W. to TECO	8-31-75	9-12-75
TBD	GDS Test Plan	9-30-76	TBD

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3.0 TECHNICAL PROGRAM - PHASE I

The tasks required to accomplish the Phase I program objectives and prepare for Phases II and III are shown in their logical progression shown on the Phase I Program Approach Diagram, Figure 3-1. Each of these tasks is discussed in detail in the following paragraphs.

The basic GDS objectives are to:

- (a) Conduct a two-phase flight system conceptual design to establish typical flight system requirements as the basis for the GDS design. The first phase will summarize requirements known as of October 1, 1975. A finalized conceptual design will be prepared in the last quarter of 1976
- (b) Design, fabricate, and assemble the GDS and accomplish performance and endurance testing
- (c) Conduct long lead development required to effect delivery of the first production flight system in April, 1981

Testing will be conducted in an AIRPHX facility equipped to provide the clean room, assembly, and test support systems required to meet these basic objectives. The overall test system configuration is defined on Drawing 306960.

System testing is intended to provide the following design confirmation:

Component Performance Verification
Synergistic Effects
System Performance Verification
Control System Definition

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PHASE I PROGRAM APPROACH DIAGRAM
FIGURE 3-1

LEGEND

- 1. LOW-LEVEL INLET
- 2. LOW-LEVEL DISCHARGE
- 3. NOT USED
- 4. NOT USED
- 5. NOT USED
- 6. THERMAL INLET
- 7. THERMAL DISCHARGE
- 8. THERMAL DISCHARGE
- 9. THERMAL DISCHARGE
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- 99. THERMAL DISCHARGE
- 100. THERMAL DISCHARGE

NOMENCLATURE

LETTER	DESCRIPTION	LETTER
A	CONTROL	CONTROL
B	ELAPSED	ELAPSED
C	FLOW	FLOW
D	HAND	HAND
E	EVENING	EVENING
F	POWER	POWER
G	LEVEL	LEVEL
H	FIELD	FIELD
I	PRESSURE	PRESSURE
J	PASS	PASS
K	TOUCH	TOUCH
L	START	START
M	FEED	FEED
N	VOLUME	VOLUME
O	INSTRUMENT	INSTRUMENT

- STATE POINTS
- RELIEF VALVE
- CHECK VALVE
- SOLENOID OPERATED GATE VALVE
- MANUALLY OPERATED GATE VALVE

TITLE		3PS GCS - RING & INSTRUMENTATION DIAGRAM	
DRAWING NUMBER		06960	
DATE		10/1/60	
BY		J. H. H. H.	
CHECKED		J. H. H. H.	
APPROVED		J. H. H. H.

Startup and Shutdown
Electrical Power Quality
Component Contamination and Contamination Transport
Thermal Gradients
Reactive Torques and Component Loading
EMI
Insulation Effectivity and Structural Heat Loss
Configuration Flexibility
Maintainability Features
Ground Support Test Equipment
Endurance Test Cost
FMEA Substantiation
System Confidence

3.1 Task 1 - Program Management

The program manager is assigned the authority and responsibility for the complete program and has direct access to the division manager. A program team, see Figure 3-2, has been established with key individuals designated from all participating departments. Major subcontractors will be responsible to the program manager through the purchasing department.

The program manager is responsible for coordinating and directing all aspects of the program including:

- (a) Establishing a clear definition of the program requirements and objectives as stated in the contract and the capability to respond rapidly to these requirements.
- (b) The assignment, to key positions in the program organization, of carefully selected, senior personnel who are experienced in the analysis, design and development of systems substantially the same as those required in this program.

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FIGURE 3-2

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- (c) Communication with higher levels in the Garrett Corporation (e.g., the product line manager)--This assures rapid compliance with directives from the ERDA-SNS and that top management is closely involved in the successful conduct of the program.
- (d) Program control and financial reporting--This is done through the Master Work Order System, PERT or modified PERT networks for internal control, a cost and schedule control system (CSCS), progress schedules and data collection and display.

The Master Work Order System which establishes an Accounting Department charge number, describes the planned activity, the total dollars estimated to complete the activity, and the dollars allocated at the time of release of revision provides the basic authorization and control instrument. Release of the Master Work Order automatically authorizes work to proceed and places activity under the scrutiny of the Accounting Department.

- (e) Technical recommendations to the Purchasing Department on the selection of subcontractors--The technical and schedule performance of the subcontractors is monitored by the Project engineering team. The financial performance of the subcontractors and consultants is monitored by use of the Master Work Order described above.
- (f) Follow-up of implemented work by conducting technical, financial, schedule, manpower, and facility reviews of progress.

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- (g) Initiation of corrective action as required.
- (h) Planning and preparation of reports, meetings, and other communications with customers.
- (i) Review and approval of reports, major drawings, and other publications.

Program management personnel will utilize the supporting groups as necessary for the timely completion of program tasks. The key departments and supporting functions required in the program are summarized in Appendix A.

Subcontractor control includes:

- (a) Weekly reports to the program manager's office by subcontractor program managers.
- (b) Monthly technical and top summary (includes financial and schedular progress) reports to the project office by the subcontractors.
- (c) Monthly meetings (may include visits to subcontractors' facilities) between the prime contractor and the subcontractor.

3.1.1 Liaison Activities

AiResearch-Phoenix will maintain an effective system of communication with the NASA, GFE suppliers, and potential user organizations with ERDA participation. This task is greatly facilitated because AiResearch Phoenix, the contractor for BIPS and the associated NASA Mini-BRU, and AiResearch Los Angeles, the GFE recuperator supplier, have direct communication channels.

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Other liaison functions will be developed between the Program organization, the HSA subcontractors, and potential user organizations.

3.2 Task 2 - Conceptual Flight System Design

3.2.1 Requirements

The purpose of this task is to:

- (a) Identify the requirements which are expected to apply to the FS design
- (b) Identify the long lead items which require effort during Phase I
- (c) Perform a conceptual design study of the FS

GE will provide support in the areas of mission requirements definitions, spacecraft and launch vehicle design and integration and flight radiator conceptual design.

The objective of this task is to prepare a conceptual FS design which properly reflects the flight requirements. It is recognized that at this early date these requirements are not firm. Therefore, it is also an objective of Task 2 to maintain the greatest design flexibility possible so as to be able to quickly react to changing flight requirements. The task is divided into two efforts as shown on Figure 2-1 to allow an early review and later to incorporate flight system requirements as yet undefined. Basic design goals established by the ERDA are:

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- o 500 - 2000 W_e output
- o 1300 W_e design point
- o 7-year lifetime
- o 450 lb at 1300 W_e output
- o \$5000 per W_e
- o High reliability and safety design
- o Compatible spacecraft and launch vehicle integration

Reliability - Detailed Failure Modes, Effects and Criticality Analyses (FMECA), are an integral part of the conceptual flight system design. GE will provide contributions in the areas associated with the HSA and the MHW heat source. Derating criteria will be established to assure that all components are properly designed to attain the system objectives. Analysis of failure modes and their synergistic effect will be conducted with the primary objective being the identification and elimination of singular failures that would degrade system performance.

Envelope - The component arrangement for the FS will be that which represents the optimum packaging scheme while conforming to space limitations existing for potential launch vehicles. The FS envelope will be a base for the selected GDS configuration. The Space Shuttle is the reference Launch Vehicle.

Efficiency - The design objective will be to better the efficiency goal of 25 percent (BOM) specified for the 1300 W_e power level, consistent with the weight goals established by the ERDA.

Nuclear Safety - The Safety Program will place major emphasis on determining the impact of the BIPS System characteristics on the MHW IHS nuclear safety analysis.

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3.2.2 Preliminary Design

The preliminary design of the FS will define the cycle and component characteristics. The design approach will be to utilize technologies and, wherever possible, component design concepts available from previous programs.

During the creation of the FS preliminary design, evaluation of design alternatives will be emphasized. AiResearch and GE will address system operational and reliability requirements dictated by mission objectives. Particular attention will be given to material characterization for the proposed environment and life.

In the IHS area, GE will consider design configurations which optimize the packaging of the existing ERDA MHW IHS design. In-line packaging of two IHS's will be considered to minimize weight.

The major components included in the FS conceptual design are listed along with their prominent features in Table 3-1. Additional detail is provided in the CCD.

3.2.3 Identification of Long Lead Items

A review of the conceptual FS design conducted during the proposal preparation has led to the conclusion that there are several long lead items which could have an impact on assuring completion of the FS qualification program by April 1981. Those currently included in the program as discussed in Section 3.9 (Task 9) are:

- (a) High Temperature Material Evaluation and Characterization
- (b) Flight controls
- (c) Thermal Insulation Development

Additional items may be identified as the program progresses and will be submitted to ERDA for review and disposition at that time.

TABLE 3-1
CONCEPTUAL DESIGN COMPONENTS

Mini-BRU

- o 1600°F turbine inlet temperature (working fluid is Xe-He, M = 83.8)
- o Single shaft turbine, Rice alternator and compressor supported on foil bearings with compressor bleed cooling
- o Alternator cooled by compressor discharge
- o Refractory metal turbine plenum (Niobium)

Recuperator

- o Hastelloy X construction with gold type braze
- o Fin/plate counterflow design

Radiator

- o Material (Be, Al, stainless steel or combinations thereof)
- o Cylindrical or conical design, offset fin/tube geometry (heat pipes will be considered as an alternate)
- o Sink temperature, refer to Configuration Control Document 75-311274 latest revision.
- o Micrometeoroid survival, 0.99 (assumed)

Heat Source

- o ERDA Multi-Hundred Watt (MHW) heat source, (advanced ERDA HS concepts will also be investigated)
- o Electrically heated heat source simulator (EHS)

Heat Source Heat Exchanger (HSHX)

- o Niobium construction
- o Cylindrical geometry, annular, finned flow passages

Insulation

- o High temperature multifoil insulation
- o Eight percent heat loss from HSA (Goal)
- o Two percent heat loss from turbine and hot interconnecting ducting (Goal)

Auxiliary Cooling System

- o Helium Short Circuit

Emergency Cooling System

- o Melting insulation (alternates have been identified)

Controls

- o Motor start inverter
- o Parasitic load speed control
- o Voltage regulator exciter
- o Power supply
- o Rectifier/filter

Piping and Structure

- o Ducting
- o Support structure

3.3 Task 3 - Preliminary GDS Design and Analysis

A preliminary Ground Demonstration System (GDS) design and analysis will be conducted to identify, develop, and recommend the final design approach for the GDS to satisfy the requirements listed in the conceptual FS Design. Key program objectives of this task are to:

- o Simulate as closely as possible the Flight System configuration, operating characteristics, and performance.
- o Perform GDS Reliability Analysis
- o Define Test Facility
- o Prepare GDS Test Plan

3.3.1 Preliminary GDS Design

The GDS design will be generated using the conceptual design of the Flight System configuration as a model. The interacting of tasks for the fulfillment of Task 3 are shown in Figure 3-1, Phase I Program Approach.

The complete GDS design concept will resemble the FS as closely as practicable. The GDS will contain the following:

- o GFE Mini-BRU
- o GFE recuperator
- o GFE heat source assembly
- o GFE electrical heat source simulator and power supply
- o A simulated radiator heat sink
- o Ducting and insulation
- o Development controls

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The activities discussed below describe the effort included in C and D of the program approach shown in Figure 3-1.

Failure Mode, Effects and Criticality Analysis

The GDS failure modes, effects and criticality analysis (FMECA) conducted during this task will be a modification of that accomplished during Task 2 of the Phase I program. The FMECA will consider all failure modes and their related effects.

Reliability Objectives

The life requirement of the FS is a seven-year operation with a mean mission duration (MMD) of five years. GDS reliability objectives are those commensurate with achieving the performance of endurance testing on schedule in a cost effective manner. This demands that both the GDS and the testing facility possess a very high degree of reliability. Particular attention will be given to GDS assembly methods and operating procedures with special attention given to the refractory metal parts.

Packaging Layouts

The major components in the FS, and hence the GDS (i.e., BRU, recuperator, heat source assembly, cooler, ducting, controls, etc.) will be arranged to facilitate spacecraft integration with respect to the vehicle launch and operational limitations.

Interconnecting Ducting Optimization Studies

Techniques for minimizing pressure loss and thermal losses will be integrated using existing AiResearch computer programs. The results of these analyses will be used to optimize duct sizing and insulation schemes. The GDS design will be compared to the FS design study results.

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Piping and Instrumentation (P&I)

The P&I diagram (Drawing 306960, after Page 3-2) defines flow directions, control device input and output signals, energy flow, and the general location of all instrumentation. The P&I diagram represents the major components and control subassemblies as block diagrams and will be the primary document for maintaining a common system definition.

Control Schematics and Approach Definition

Control schematics will be constructed to assist in the design of control system concepts showing sufficient redundancy to ensure fulfillment of the reliability objectives over the desired lifetime.

Heat Rejection Heat Exchanger

A preliminary design for a reliable, low cost HRHE will be defined.

Test Facility

The test facility, test equipment and instrumentation for the GDS will be defined.

Design Review Meeting

Following completion of the preliminary design of the GDS, a document will be prepared summarizing the results of this design effort. Included in this document will be: all data necessary, including conceptual drawings, to clearly define the recommended GDS design approach and the rationale for its selection; a failure mode, effects and criticality analysis and definition of reliability objectives; and alternative GDS packaging layouts.

A draft of the Preliminary Design Summary Document will be submitted to the ERDA 15 days prior to the design review meeting (as scheduled on Figure 2-1). A final document will be submitted to the ERDA within 21 days after the meeting for approval within 30 days.

3.3.2 GDS Test Plan

AiResearch will prepare a GDS Test Plan defining detailed objectives, the functional requirements for the test facility, loop components, controls and instrumentation, special test equipment, and the data to be obtained. Performance and endurance tests of the GDS will be performed in a vacuum environment of $< 10^{-4}$ torr. The adequacy of this vacuum will be evaluated. The endurance test will be 1000 hours in duration.

3.4 Task 4 - Detailed GDS Design and Analysis

3.4.1 System Layouts

Detailed manufacturing layout and assembly drawings will be generated to support the fabrication and assembly activities of the GDS. The layout drawings will reflect the selected FS design features such as the ducting configurations (size, length, and routing), which will result in reduced FS pressure drop, insulation complexity, and weight while maximizing reliability. Structural interfaces will be defined with mounts designed to accommodate typical launch loads.

3.4.2 Transient Effects

The start-up and shutdown procedures to be used for the flight system will be determined from a combination of analytical studies and laboratory experimentation. A prime objective of determining recommended starting and shutdown procedures is to ensure that the system is not damaged from thermal stresses. This objective is best met by computerized transient studies which will determine problem areas and

viable solutions to these problems. An existing computer model of the FS will be used to perform this study. A common problem is the rate at which the recuperator can be heated. All anticipated starting and shutdown procedures will be analyzed by means of existing computer programs. The extent to which thermal stresses are imposed on the Heat Sink, HSHX, BRU, and recuperator will be determined. GE will provide a model of the HSA thermodynamic characteristics and will assist in performing this study.

The scheduling of speed and load in relation to the electrical output requirements will be established and scheduling of system pressure will be defined in this task by use of computer analyses and performance testing of the GDS with the two HSA configuration. Information gained in this task will be included in FMECA considerations and will assist in the design of the prototype FS.

3.4.3 Heat Sink

A GDS heat sink heat exchanger which will thermodynamically simulate the working fluid side of the FS space radiator will be designed. The design will take into consideration both the need to simulate thermal transient response of the flight radiator during GDS start up testing as well as the need for compressor inlet temperature control so that (T_1) sensitivity testing can be performed.

3.4.4 Control and Instrumentation Systems Detail Design

The detail design of the GDS control and instrumentation systems will be accomplished after the final preliminary design has been accepted by the ERDA. The controls detail design activities will evolve from the control concept selected for the FS and will include all safety features necessary for GDS testing. Output from this task includes:

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- o Circuit schematics
- o Circuit diagrams
- o Detailed parts lists
- o Assembly drawings
- o Wiring diagrams

The controls system will be the prototype of that designed for the BIPFS and will consist of the following functionally discrete components:

- o Motor Start Inverter
- o Power Supply
- o Parasitic Load Speed Control (PLSC)
- o Voltage Regulator Excitor (VRE)
- o Rectifier/Filter

The philosophy proposed for developing flight qualified hardware is shown on Figure 3-3. Prototype controls for the Mini-BRU developed at the Lewis Research Center and described in NASA TMX 3084 will be utilized as a point of departure for the design of the controls for initial GDS testing. Modifications will be made to the GFE NASA controls as necessary to permit study of the control functions defined by the system analysis. Once fabricated, the GDS controls will be checked as a system using a duplicate of the air turbine driven bearing test rig built for the Mini-BRU. Results from the test rig and system tests will be incorporated into the preliminary flight control definition. After the baseline flight circuits are functionally defined, detailed stress, FMECA, and reliability analyses will be performed. The circuits will be iterated until a satisfactory circuit is defined, at which time a prototype control will be fabricated and tested with the electrical system test rig and subsequently with the GDS. Results of these tests will be incorporated into the flight control design requirements and detailed procurement specifications for hybridized circuits will be prepared.

FIGURE 3-3

75-311376B
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A major concern during the design is the assurance that sound design techniques, such as power supply decoupling and grounding, are adhered to and that sufficient test points and testing procedures are defined to readily identify and isolate faults. Evaluation of these techniques during the GDS will assure rapid, rigorous performance evaluation during pre-flight system checkout.

The detail design will employ the following techniques to attain high reliability:

- o Component derating (voltage, current, temperature, stress)
- o Critical circuit redundancy with the establishment of preferred failure modes
- o Minimization of single point failures

All potential failure modes will be identified, and sufficient redundancy will be provided to assure that no single component failure will degrade system performance.

3.4.5 Structure; Ducting, Bellows, Valves, and Joints

The design of bimetallic joints, thermal insulation, ducting bellows, and valves will be accomplished in this task.

Ducting

Ducting length, routing, and insulation will be designed. All of the potential problems of using thermal insulations will be considered such as decompression damage, offgassing, oxidation, and application to complex geometries.

Bellows

Bellows will be used to accommodate ducting expansion and contraction. State-of-the-art bellows technology will be utilized where applicable.

Valves

The GDS will employ the following valves to facilitate development testing:

- (a) Turbine Bypass Valve - This is used in the GDS only for overspeed and fault protection should the parasitic load need development modification.
- (b) Pressure Relief Valve - This valve will prevent inadvertent overpressurization of the test system.
- (c) Check Valve - This valve assures one-way flow of the working fluid. This can be critical during the system start-up as the turbine will perform as a compressor until the working fluid is sufficiently heated.

3.4.6 Mock-Up

This task will include the construction of a wooden mock-up of the GDS to work out assembly structure and interface details.

3.4.7 Materials Compatibility

During the detail design and analysis task, special consideration of material compatibilities will be accomplished to ensure that all subsystems, once assembled, will operate for the lifetime requirement without experiencing the adverse effects associated with dissimilar metallic joints. Included in this task will be the fabrication of the bimetallic joints which will be used in the assembly of the GDS. Of particular importance is the usage of the refractory metal parts, such

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as the turbine plenum and HSHX, which require special consideration. The contractor will supply various test samples (e.g. bimetallic joints, bellows and ducting) to the ERDA for metallurgical evaluation.

Perhaps the most effective method available to the BIPS program to build a high level of confidence in the reliability and life potential of the BIPS is through materials testing during Phase I. During the three years that Phase I spans, materials evaluation work will be accomplished: (a) to suitably characterize the materials and bring the knowledge about them to the level where they can be seen to be legitimate engineering materials for BIPS (b) to identify and understand basic failure mechanisms that will exist due to interrelations of these materials and their operating environment and, with this knowledge in hand, (c) to modify and improve the design.

The Integrated Program Plan (IPP), AIRPHX document 75-311574, describes the interactive materials development program by AIRPHX and various government agencies. Recommendations and schedules are included.

3.4.8 Electric Heat Source (EHS)

Three EHS's that simulate the physical and thermal characteristics of the Multi-Hundred Watt (MHW) Isotope Heat Sources will be GFE. The EHS is the unit developed for the ERDA MHW program by GE and is assumed to be directly applicable to the GDS.

The following items are to be GFE with the EHS.

- o Heater power supply consoles (PSC) (2)
- o System control interfacing (cables, contactors, etc.)
- o Heater instrumentation and protection

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These are already designed and have been built for the MHW EHS; because the units may have been used, some refurbishing is anticipated:

- o Check for proper operation
- o Clean the Alumina Insulation
- o Replace the thermocouples

The required availability date shown on Figure 2-1 is the date which the items must be dedicated to the BIPS program. This reflects the required lead time to fabricate the EHS and PSC.

3.4.9 Test Facilities

The test facilities for the GDS will be designed in detail. The test facility's equipment includes the following:

- o A high quality vacuum chamber capable of holding vacuum levels of less than 10^{-4} torr for extended periods.
- o Vacuum pumping equipment consistent with the vacuum chamber capabilities.
- o The use of a heat sink to simulate the end-item space radiator.
- o Fast response tape recorders for transients and dynamic data acquisition.
- o Long-term response equipment for long-term trends, etc.
- o Electrically heated heat source simulators, two per test system ($2400 W_t$ each).
- o Gas management system for storing, purifying, and reclaiming the working fluid.
- o Assembly tools and fixtures

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- o Instrumentation harnesses and cables
- o Cleanroom handling equipment and facilities (including bake out and ultrasonic cleaning equipment).
- o HSA Auxillary Cooling System Gas Management System
- o Portable Gas Weld Fixture
- o Electric Heat Source Power Supply Consoles
- o Electric Heat Source Loading Fixtures
- o Leak Test Kit

3.4.10 Detail Design Review

Following completion of the detailed analysis and design of the GDS, a summary of this design will be presented to the ERDA for their approval in a series of design review meetings.

A draft of the Preliminary Design Summary Document will be submitted to the ERDA 15 days prior to the design review meeting (as scheduled on Figure 2-1). A final document will be submitted to the ERDA within 21 days after the meeting for approval within 30 days.

Included in the topical report will be: a complete system ducting layout; system transient behavior and FMECA studies; results of the heat sink design; detailed control system design; detailed structural design including materials selection and system mock-up; the results of the bimetallic joining program and materials compatibility studies; electric heat source design, including power supply and controls; and complete test facility and data management system design.

3.5 Task 5 - Fabrication and Assembly of GDS and Test Facilities

Fabrication and assembly of the GDS and the test facilities will be accomplished following the conclusion and ERDA approval of the

detail design task. Checkout of the test facility will be completed to prepare the test facility for the execution of the prescribed performance and endurance testing plans. Receipt of all GFE hardware is anticipated by January, 1977.

3.6 Task 6 - Test and Evaluation

3.6.1 GDS Performance Testing

During the first six months of the test and evaluation task, the performance testing of the GDS will be completed. Testing will be conducted for the following in accordance with approved test plans.

- o Startup and Shutdown - The startup and shutdown testing will consist of determining the most effective methods for achieving start and shutdown of the BIPS. Results from this activity will facilitate the determination of the effects of the following phenomena of interest:
 - o Working gas contamination
 - o Thermal stress effects on HSHX, BRU and recuperator
 - o HS operation during shutdown and its effects
 - o Reverse flow of working fluid
 - o Start method
 - o Recuperator and HSHX pre-heat
 - o Heat soak-back after shutdown
 - o HSA Auxiliary Cooling System Operation
- o Performance Mapping at 1300 W_e - The GDS will be tested with the design thermal input of 4800 W_t . The initial test conditions will be that of the predicted operating point. Provisions will be made for variable loop inventory (i.e., pressure level) to obtain the maximum performance and for fine tuning the system. Compressor inlet temperature will also be varied to obtain the

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empirical tradeoff between system performance and radiator size. Sufficient instrumentation will be provided to establish the efficiency level of the compressor, turbine, recuperator, cooler, and heater and the overall pressure loss, allowing possible performance deficiencies to be readily identified. The data will be recorded on Sanborn strip recorders and (DDAS) digital equipment. The operating point defined by this testing will be that which will be used in the endurance testing.

- o Off Design Performance Mapping - Since the BIPS addresses a $4800 W_t$ configuration, the proposed GDS includes two $2400 W_t$ HSAs. This will limit the electrical output of the GDS to about $1300 W_e$ depending upon the compressor inlet temperature (i.e., the cycle efficiency level). Off-design data will be obtained over a range of speeds, temperatures and pressures.

Performance Test Topical Report

A topical report will be prepared and submitted to the ERDA 30 days after completion of performance testing. The report will describe in detail the results of: a complete performance mapping at $1300 W_e$ output; system capability to provide power output over a range; and startup and shutdown testing. The report, further, will present data to permit a comprehensive cycle evaluation and loss analysis.

3.6.2 GDS Endurance Testing

AiResearch will conduct a 1000-hour endurance test program in accordance with the approved state points. AiResearch will provide a lifetime assessment of the potential flight system based on the combined results of component development tests, performance tests, and the endurance test.

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3.7 Task 7 - Quality, Reliability and Safety (QRS) (33 Months)

3.7.1 Quality Assurance and Reliability

During Phase I, the central objectives of the Quality and Reliability programs will be: (1) to assure high quality in the GDS and test facility, (2) to form a basis for a program of high reliability and quality in the FS development by identifying suitable materials, processes, and fabrication techniques, and (3) to provide periodic assessments of predicted reliability. The Safety Program will place its major emphasis on the system aspects of the BIPS with attention given to the integration of the MHW IHS with the BIPS.

The key tasks to be performed during Phase I are to:

- (a) Provide QA engineering necessary to collect, analyze, and report data relative to the quality of components manufactured or procured for the GDS. Additional QA engineering functions include the preparation of analytical studies and evaluation of processes, the implementation of corrective action on problems affecting product quality, and participation in design review activities
- (b) Provide QA inspection capability necessary to perform all required inspection activities as outlined in the AiResearch General Quality Program Plan QC-048 and/or as modified to meet special ERDA requirements that may be imposed
- (c) Define the test requirements needed to provide reasonable assurance that the minimum acceptable reliability can be demonstrated
- (d) Perform Failure Mode, Effects and Criticality Analyses on the GDS and the conceptual IBFS

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- (e) Develop system logic diagrams and probability equations to support reliability analyses of the GDS and IBFS
- (f) Provide periodic assessments of predicted system reliability
- (g) Conduct reliability program reviews in conjunction with scheduled preliminary and final design reviews of the GDS

3.7.2 Safety

The key safety tasks to be performed during Phase I are to:

- (a) Establish and maintain liaison with ERDA-SNS, the appropriate national laboratories (SLA, LASL, Mound Laboratory, etc.), and the subcontractors (GE, TECO, AIRLA)
- (b) Identify all applicable safety requirements, including those established by ERDA, NASA, DOD, and OSHA. Appropriate measures will be taken to eliminate or minimize all identified hazards in both the GDS and the FS.
- (c) Monitor and review all power system development and test activities for applicability to the safety evaluation. A continuous review will be required to assure that design changes do not adversely affect safety levels previously established.
- (d) Complete the analyses (PHA, FMECA, FTA) as outlined in the System Safety Program Plan.

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- (e) Review S/C mission characteristics as they become available and determine potential environments to which the FS can be exposed. Vehicle and mission information will be extracted from data of previously flown missions and from previous studies of planned missions of a similar nature.
- (f) Identify and define specific analyses and/or tests not already programmed or completed which will be required as part of the safety assessments.
- (g) Assure that all concerned are apprised of key, critical safety issues and are provided the assistance required to eliminate or minimize identified hazards/undesired events.
- (h) Conduct a Preliminary System Safety Review (PSSR). This safety review will in general fulfill the requirements of Section 4.2 of the ERDA-SNS document titled "Heat Source Safety Design Specification for Space Application." (dated July 8, 1974), but will be specifically tailored to reflect the tentative status of the FS preliminary design during Phase I. It is envisioned to be a somewhat abridged version of the typical PSAR but will serve as a basis for the safety work to be conducted during Phase II. Maximum utilization will be made of studies and data already available on systems which make use of the MHW heat source. The review will be prepared in two stages. The first draft will basically address the FS but will, in addition, address the safety aspects of the GDS.

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3.8 Task 8 - Reports and Data

Reports and data submissions will be made during the entire Phase I program. The types of reporting include:

- o Financial Top Summary Reports (monthly)
- o Technical Progress Reports (monthly)
- o Technical Progress Reports (annually)
- o Final Technical Reports (as required)
- o GDS Configuration Control Document (updated as required)
- o FS Configuration Control Document (updated as required)
- o Integrated Program Plan (updated as required)
- o Subcontractor Statements of Work, Work Plans and Technical Progress Reports
- o Topical Reports (Reference Table 2-2)

Published documents relating to the BIPS are listed in Section 6.0.

3.8.1 Monthly Reports

The Monthly Technical Progress Narrative and the Monthly Financial Top Summary Report will be submitted simultaneously to ERDA. These reports will be submitted by the 20th day of the following month. Six copies of each report will be submitted.

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Advance projected telecon financial and technical reporting to ERDA will also be provided in order to comply with the submission schedule. This telecon information will then be formally documented.

The program Manager or his assistant will sign the original copy of each Monthly Technical Progress Narrative and each Monthly Financial Top Summary Report.

3.8.2 Annual Reports

The Contractor shall, at the completion of 12th and 24th month after program initiation, prepare and submit for review an annual technical report covering all technical program activities for the 12 month report period.

The approved annual technical report must be of a quality suitable for publication and shall document in detail all of the technical activity performed under the program, including data, analysis and interpretations as well as recommendations and conclusions based upon results obtained.

3.8.3 Final Reports

The Contractor will prepare and submit for review a report covering all program activities. The final report submission date is shown on the schedule in Section 2 of this document.

The approved final report will document in detail all of the work performed under the program, including data, analyses, and interpretations, as well as recommendations and conclusions based upon results obtained.

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3.8.4 Configuration Control Document (CCD)

This document provides the baseline design definition to be used by all disciplines at AIRPHX and at the subcontractors for design, fabrication, and test of the GDS. The document will be continually updated to provide a current base and eventually an as-built and tested definition of the GDS. An appendix to the CCD provides reference Flight System (FS) information and will serve as the basis for an eventual FS CCD.

3.8.5 Integrated Program Plan (IPP)

The Integrated Program Plan provides a current definition of the program aspects which are being evaluated under the combined auspices of the contract personnel and government agencies and their consultants. A major area of interest is the performance of materials, in particular refractory metals, when operated in hard vacuum and/or a pure, inert gas.

3.8.6 Subcontractor Statement of Work and Work Plan

Statements of work have been issued to each of the major subcontractors:

- o General Electric - Heat source and mission definition
- o Thermo Electron - Insulation system
- o AiResearch Los Angeles -
 - o Conceptual design support
 - o Recuperator integration
 - o Bellows Design

Detailed work plans describing and scheduling the required activities are to be provided by the subcontractor.

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3.8.7 General

All reports will use the English Engineering System to express units of measurement. Prior approval will be obtained from ERDA for release of technical information relating to this contract.

3.9 Task 9 - Advanced Development

A development program for long lead development of flight system hardware will be initiated during Phase I. The effort, in support of the ERDA approved plans, will be conducted in any system or component area where such an effort is deemed necessary before the completion of Phase I. All Task 9 effort will be approved by the ERDA prior to initiation. The major advanced development efforts which have been identified to date are:

- (a) High Temperature Material - This task will include the determination of long term creep properties of candidate turbine and HSA materials and the investigation of environmental effects on these properties.
- (b) Controls - As discussed in Paragraph 3.4.4, sufficient advanced control development will be accomplished during Phase I to adequately define controls for qualification during Phase II. Control functions and redundancy necessary to meet the life requirements must be defined, implemented and tested prior to the start of Phase II to allow implementation with hybridized integrated circuitry.
- (c) Thermal Insulation Development - The primary objective of this effort is to determine the long term operational characteristics of candidate insulation configurations relative to insulation vaporization and compatibility with emergency cooling objectives.

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3.10 Task 10 - Flight Design and Engineering Program Plan

Recommended design and program plans for Phase II, Flight Development and Qualification, will be submitted. The program plan and cost estimates will be updated and improved. Appropriate consideration and recommendations regarding the following will be made:

- o Design to accommodate operation through launch
- o Advanced recuperator and radiator for flight design
- o Packaging and thermal insulation
- o Spare part requirements
- o Advanced alternator flight design (material upgrade)
- o Component environmental testing
- o Component upgrading (see Phase II Program Plan)
- o Safety and reliability assessment
- o Advanced HSA flight design
- o Advanced HS flight design

Phase II qualification testing will include the following test activities:

(a) FS Development Testing and Qualification

- o High vacuum performance with space radiator
- o Remote startup and shutdown
- o Launch and orbital inertia loads
- o Vibration
- o Shock
- o Control system function
- o Emergency shutdown
- o Orbital shutdown and restart
- o Performance verification
- o Off-design performance
- o Maintainability verification

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- o Endurance test
- o Other electrical tests
 - Short circuit
 - Sudden load
 - Frequency regulation
 - Harmonic distortion
- o Performance degradation with partial loss of gas
- o MIL-STD-810B tests
- o System safety

(b) IHS Development and Qualification Testing

- o Thermal Vacuum Testing
- o Verification of load and unload procedures
- o Testing to required performance criteria
- o Safety
- o Vibration and Shock
- o Post test evaluations by fueling agency

The BIPS-FS design will be reviewed and modified to reflect:

- (a) The information gathered from GDS testing
- (b) Data produced by the advanced development efforts
- (c) Updated flight requirements model

A preliminary Phase II Engineering Program Plan (EPP) will be prepared at the conclusion of Phase I activity. The EPP will include the design and analysis, testing, fabrication and assembly, quality assurance, reliability, and safety information from the GDS program. The EPP will serve as the outline for the initiation of the BIPS program, Phase II.

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4. DRAWINGS (PROCUREMENT OR MANUFACTURE)

The Contractor will prepare and furnish complete sets of engineering drawings as required conforming to the following with each item delivered:

- (a) The complete set of drawings, including parts lists, will be prepared in accordance with Form 3 (Industry Standards) of Military Specification MIL-D-1000 per latest revision in effect.
- (b) The drawing sizes will be limited to the following dimensions (in inches):
 - "A" - 8 1/2 x 11 (Parts Lists Only)
 - "B" - 11 x 17
 - "C" - 17 x 22
 - "D" - 22 x 34
 - "F" - 26 x 44
 - "R" - 36 (maximum roll width)
- (c) Each drawing submittal will include one full-size reproducible and one proof print.
- (d) The set of drawings and parts list supplied with each delivered item of hardware will describe the unit "as-delivered" including the respective drawing change letter or number.
- (e) The set of drawings will provide the necessary design, engineering, manufacturing, and quality support information directly or by reference to enable the procurement, without additional design effort or recourse to the original design activity, or an item that duplicates the physical and

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performance characteristics of the original design. These drawings will not provide manufacturing process information unless this information is essential to accomplish manufacture of an identical item by other than the original source.

- (f) Drawings will possess the following adequacy requirements, except as otherwise provided within this contract:

Details of unique processes essential to design and manufacture; details of performance ratings; dimensional and tolerance data; critical manufacturing assembly sequences; toleranced input and output parameters; schematics; mechanical and electrical connections; physical characteristics, including form and finishes; details of material identification, inspection test, and evaluation requirements and criteria; necessary calibration information; and quality control data

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5.0 INCORPORATION OF GOVERNMENT DOCUMENTS AND SPECIFICATIONS

The following government documents are hereby incorporated into this Program Plan:

MIL-D-1000	Drawings, Engineering and Associated Lists
MIL-G-21480A	Generators and Regulators, Air Cooled, A-C, Aircraft General Specification for
MIL-STD-100A	Engineering Drawing Practices
MIL-STD-810B	Environmental Test Methods
MIL-STD-202C	Test Methods for Electronic and Electrical Component Parts
MIL-STD-462	Electromagnetic Interference Characteristics, Measurement of
NASA SP-78	The Meteoroid Environment and Its Effect on Materials and Equipment
NASA TMX-53957	Space Environment Criteria Guide- lines for Use in Space Vehicle Development
NASA CR-1870	Design and Fabrication of the Brayton Rotating Unit

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6.0 PUBLISHED DOCUMENTS

Documentation requirements have been previously delineated in Section 3.8. Those documents that are known to have been published are listed on Table 6-1. As further documentation is published, they will be added to this list.

TABLE 6-1
DOCUMENTS RELATING TO THE BIPS

<u>Document No.</u>	<u>Issued By</u>	<u>Title</u>	<u>Date</u>
SC-6016	AIRPHX	Engineering Change Control Procedure for AiResearch Vendors	January 13, 1970 (Rev. A, April 14, 14, 1970)
APS-5440-R	AIRPHX	Preliminary Design of a Mini-Brayton Compressor Alternator-Turbine, Contract NAS3-16739	March 12, 1973
GEMS-417	GE-ESP	Mini-Brayton Economic RTG Study	January 1974
74-310831	AIRPHX	System Studies of Closed-Cycle Gas Turbine Engines Utilizing the Mini-Brayton Rotating Unit (Mini-BRU)	August 10, 1974
74-310631	AIRPHX	Progress Reports of Design and Fabrication of Compressor-Alternator-Turbine for the Mini-Brayton Rotating Unit (Mini-BRU), Contract NAS3-18517	May 1974 (first issue)
SNS-RFP-75-1-CAO	ERDA-SNS	Request for Proposal, Ground Demonstration Test of a 1.3 KW Isotope Power Conversion System Leading Toward Development of an Isotope Space Power System for the 0.5 to 2 KW Power Engine	November 4, 1974
74-311015-1,-2	AIRPHX	Isotope Brayton Ground Demonstration Testing and Flight Qualification	December 9, 1974
QC-048, Rev. 4	AIRPHX	AiResearch Manufacturing Company of Arizona General Quality Program Plan	October 1, 1974
75-311267	AIRPHX	Mini-BRU Design Final Report	May 1975
75-311279	AIRPHX	Transient Analysis	May 19, 1975
75-311274	AIRPHX	Configuration Control Document (CCD)	June 16, 1975 (Rev A, September 25, 1975)
75-311211	AIRPHX	Alternator Design Final Report	May 31, 1975
75-311217C	AIRPHX	SOW, Refractory Metal Turbine	June 20, 1975
Plenum/Nozzle Assemblies			
75-311472	AIRPHX	SOW to AIRLA	September 1, 1975
75-311375	AIRPHX	SOW to GE	September 4, 1975
75-311499	AIRPHX	SOW, Multi-Foil Insulation System	September 12, 1975
75-311574	AIRPHX	Integrated Program Plan	August 28, 1975 (first issue)
74-10188	AIRLA	Recuperator Progress Reports	September 1975 (first issue)
TBD	AIRLA	Recuperator Final Design Report	TBD
TBD	GE	HSA Final Design Report	TBD
- -	GE	HSA Progress Reports	September 15, 1975 (first issue)
75-311376	AIRPHX	Program Plan	September 19, 1975 (Rev B, October 22, 1975)
75-311360	AIRPHX	Reliability Program Plan	September 30, 1975 (Rev A, October 24, 1975)

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APPENDIX A

AiResearch-Phoenix (AIRPHX)
Organizational
Description

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APPENDIX A

AIRPHX ORGANIZATIONAL DESCRIPTION

1. PROJECT ENGINEERING

Project engineers are responsible for the soundness and performance of equipment to be designed, built, and tested for the customer. This responsibility includes:

- (a) Technical approval of vendors
- (b) Preparation and/or approval of procurement and test plans and instructions
- (c) Preparation and approval of technical reports including documentation control through the engineering files system--Data distribution within AiResearch and its divisions is performed by engineering; data distribution outside the Garrett corporate structure is effected by contract administration
- (d) Providing for adequate inspection and quality control support
- (e) Technical approval of drawings and development reports

The project team engineers are responsible for supplying designs, technical information, test results, hardware deliveries, report material, and consultation. This includes:

- (a) Scheduling the internal design and development work load to meet commitments

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- (b) Implementation and follow-up of fabrication and testing as required to meet schedules
- (c) Technical contributions to and support of meetings

2. MANUFACTURING ENGINEERING

Manufacturing engineers will provide support to assure the manufacture of the engineering design including:

- (a) Initial design input regarding producibility, cost, impact, and material selection
- (b) Issue and maintenance of the detail manufacturing operations and tooling requirements for each part, subassembly and/or assembly
- (c) Participation in make-buy decisions

3. DESIGN OFFICE

The design office provides design support to the program and is responsible for all preliminary design, detail design, and manufacturing drawings. The design office provides the following services:

- (a) Supervise the designers, detailers, and checkers assigned to this program
- (b) Control drawing format and preparation to the appropriate MIL STDs
- (c) Provide document control, change records, and filing and distribution service
- (d) Participate in design reviews and serve as a major checkpoint in the configuration control system.

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- (e) Providing material for incorporation in reports, schedules, and planning documents.

4. CONTRACT ADMINISTRATION

The contract administrator supports the program manager in all contractual requirements. He is responsible for monitoring AiResearch compliance with all ERDA requirements. His specific duties include:

- (a) Monitoring of program tasks to ensure completion within program schedule
- (b) Monitor cost and schedule of major subcontracts
- (c) Updating and submittal of network and program schedules
- (d) Contract negotiations, documentation, and close-out of contract requirements
- (e) The interpretation and resolution of all contractual requirements
- (f) The formal communicating liaison focal point

5. ENGINEERING SCIENCES

This department includes specialists that provide electrical, materials, aerodynamic, stress, mechanical, thermal and cycle analyses necessary for the successful conduct of this program. The department also provides the preparation and technical editing of the required engineering reports.

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6. MATERIEL

This group controls fabrication and procurement of all parts and items as implemented by the project engineers. This includes:

- (a) Initiation of purchase orders or shop hardware orders
- (b) Initial recommendations regarding vendors and suppliers
- (c) Scheduling and following parts through the fabrication, inspection, and quality-control areas as required
- (d) Providing fabrication status reports on a weekly basis, cost estimates, and parts cost reports

7. LABORATORY

The laboratory group will provide engineers and technicians to supervise and coordinate all activities as required to support the program. This support includes:

- (a) Readiness of facilities, including all test and recording equipment
- (b) Buildup and instrumentation of test rigs
- (c) Instrumenting components and units to be tested
- (d) Implementing tests in accordance with schedule
- (e) Maintaining logs of all test activities
- (f) Readyng all development and research units for shipment.

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8. PURCHASING DEPARTMENT

The objective of the AiResearch subcontracting policy is to initiate make-or-buy studies for all equipment manufactured in order to control fabrication and procurement expenditures to the degree that maximum economy will be afforded to the customer consistent with program delivery and quality requirements.

To assure quality and reliability, AiResearch utilizes a comprehensive system for surveying and selecting prospective suppliers. The purchasing and quality control organizations approve prospective suppliers on the basis of ability to supply products meeting the required standards in accordance with the concepts stated in the AiResearch quality control manual. Specific areas of supplier activity monitored by the quality control member of the survey team included the suppliers' quality control organizational structure, receiving inspection, shop control (with emphasis on the control of parts in process), nonconforming material control, functional testing, supplier subcontract control (for special processing facilities), shipping, and general housekeeping.

Control of subcontractors is accomplished by the following methods:

- (a) Review of procurement documents to ensure that quality provisions meet contractual requirements
- (b) Maintenance of supplier performance ratings
- (c) Performance inspection of supplied items, both at source and upon receipt at AiResearch
- (d) Inspection of test methods and equipment to ensure full compatibility between suppliers and AiResearch

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- (e) Coordination with subcontractor contract administrators to ensure compliance with prime contract requirements, funding arrangements, and any special considerations peculiar to the program
- (f) Subcontractor submittal of fiscal status, manpower status, program progress, percentage of completion, and final reports as well as other required special reports.

Control of subcontractor processing methods is a part of the quality control procedures.

9. ACCOUNTING

The Accounting Department is the gathering point for all charges against the Master Work Order. Manpower (Engineering, Laboratory, and Shop) charges are reported on IBM cards against each individual Master Work Order. Purchased parts and those fabricated in outside shops are reported by invoice. All charges are tallied and issued weekly with a breakdown by Master Work Order, each Work Order tally showing a breakdown by department, facility charges, energies, purchased parts, etc. In addition, a weekly summary sheet of all Master Work Orders is issued. This up-to-date reporting allows the Program Director to compare actual charges against each task with the projected expenditure for the amount of the task completed.

10. COST AND SCHEDULE CONTROL

AiResearch uses a cost and schedule control system (CSCS) to provide a single integrated cost, schedule, and technical performance measurement system. Cost, schedule, and performance control are applied by using the computerized WBS, (Work Breakdown Structure) which defines the divisions of work. The cost and schedule controls utilized by the program office provide:

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- (a) Cost and schedule supporting data in the detail required for cost, schedule, and technical performance status reporting and analysis
- (b) Development plan alternatives and supporting data to resolve technical, cost, and schedule problems
- (c) Required monthly schedule and status reports for management use in fulfilling contract reporting requirements
- (d) Effective schedule control and technical evaluation information
- (e) Technical performance monitoring with the use of written progress reports at set intervals by cognizant personnel

Through schedule and reporting methods, the system provides continuous visibility of the program to all levels of management. This results in early problem identification and the availability of supporting data for analysis of alternative corrective action.

11. RELIABILITY AND QUALITY ASSURANCE

11.1 Reliability

The AiResearch, Phoenix (AIRPHX) reliability organization, with its access to the Division Manager for ultimate authority, provides the talent and direction for performing those specific tasks necessary to provide assurance that the required quantitative reliability is achieved in service. Responsibility for overall guidance, policy, and coordination of the reliability program for the AIRPHX Division is assigned to the Director of Engineering and administered by the Supervisor of Reliability Engineering. Since reliability is inherent in design, prime responsibility for establishing reliability design

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objectives is assigned to the cognizant project design team. This includes the continuous monitoring and control of those activities necessary to ensure and demonstrate full achievement of the reliability objectives. For the BIPS, this responsibility has been assigned to the GDS/WBFS Project Director and will be administered by the Reliability and Quality Assurance Manager.

A Reliability Program Plan (Report 75-311360) has been drafted and submitted to ERDA for review and approval. Once approved, the plan will be published, distributed, and implemented. Additional information relative to reliability is included under Task 7 (see Section 3.7).

11.2 Quality Assurance

The Manager of Quality Control of AIRPHX reports to the Division Manager. The Quality Control organization is equivalent in stature to other major departments of the Division. The Manager of Quality Control has full responsibility and jurisdiction in all matters involving standards of workmanship, quality of materials, conformance to Engineering standards, and the relationship with customer Quality Control personnel. Commensurate with these responsibilities and authority, the Manager of Quality Control implements the necessary Quality Control policies by means of control procedures designed to assure that the Division produces and delivers quality products. The Quality Control organization, operating in accordance with the established system, is responsible for assuring that the quality standards established for any given product are met and maintained. For the BIPS, a Reliability and QA Manager has been established within the Project Group and will be responsible for coordinating QA activities for the program.

The AiResearch General Quality Program Plan QC-048 (Rev. 4), dated October 1, 1974 was provided in the original Garrett Technical Program submitted on 9 December 1974 for review. As was then stated,

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the plan details the standard practices employed to assure the quality of AIRPHX products and systems. Informal comments have been received from ERDA/DANES, and modifications to the plan have been made in the form of a draft QC GI to satisfy the requirements of SNS-1, "Quality Assurance Program Requirements for Space Nuclear Systems" deemed to be applicable to the development and test of the Ground Demonstration System (GDS). When approved by ERDA, the plan will be implemented.

Additional information relative to QA is included under Task 7 (see Section 3.7).

12. SAFETY

AiResearch Operational Procedures 2.57 and 10.35 specify the organizational responsibilities for Safety at AiResearch.

The Engineering Project is responsible for safety in the product design and has primary responsibility for defining and conducting the System Safety Program as it affects product design. A System Safety Manager has been designated for managing the safety program for the IBS Project.

The Safety Manager assigned to the program is charged with implementing, maintaining, and controlling the system safety portions of the program described in this document. He reports to the IBS Project Director.

Other departments are required to appoint system safety monitors for this program with responsibility to work within the scope of the System Safety Program Plan. These monitors will provide information and support upon request from the Project Safety Manager.

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The Director of Product Integrity is responsible for monitoring and coordinating all divisional policies and procedures related to System Safety. He is also responsible for the overall effectiveness of the methods for complying with applicable portions of MIL-STD-882.

The Product Integrity Committee is responsible, among other things, for final resolution of major areas of disagreement which may arise within the program concerning safety.

Subcontractors will provide safety data, analyses, and support as determined to be required and as covered by contractual agreement.

A System Safety Program Plan (Report 75-311221) has been drafted and submitted to ERDA for review and approval. Once approved, the Plan will be published, distributed, and implemented. Additional information relative to safety is included under Task 7 (see Section 3.7).