ORNL/M-1137

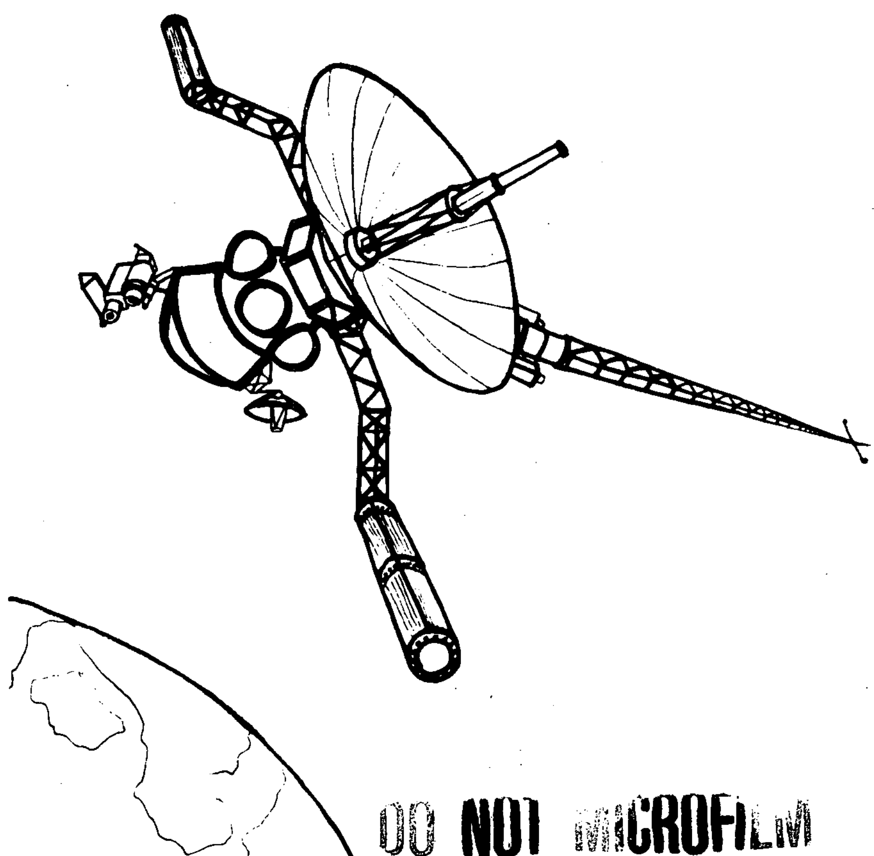
oak ridge

ornl & Y-12

OPERATIONAL READINESS REVIEW PLAN FOR THE RADIOISOTOPE THERMOELECTRIC GENERATOR MATERIALS PRODUCTION TASKS

Prepared by the Operational Readiness Team:

R. H. Cooper
M. M. Martin
C. R. Riggs
R. L. Beatty
E. K. Ohriner
R. N. Escher



DISCLAIMER

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

ORNL/M--1137

DE90 012026

OPERATIONAL READINESS REVIEW PLAN

FOR THE

RADIOISOTOPE THERMOELECTRIC GENERATOR MATERIALS PRODUCTION TASKS

Prepared: April 19, 1990

Prepared by the
Operational Readiness Team:

R. H. Cooper
M. M. Martin
C. R. Riggs
R. L. Beatty
E. K. Ohriner
R. N. Escher

Prepared by
Oak Ridge National Laboratory
Oak Ridge, Tennessee
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract DE-AC05-84OR21400

OPERATIONAL READINESS REVIEW PLAN
FOR
RADIOISOTOPE THERMOELECTRIC GENERATOR MATERIALS
PRODUCTION TASKS

Effective Date of Plan: April 19, 1990

Prepared by:

R. H. Cooper	Chairman, Operational Readiness Review Team
M. M. Martin	Manager, Special Applications Program
R. L. Beatty	Task Manager, CBCF Thermal Insulator Piece Part Production
for C. R. Riggs	Task Manager, Iridium Alloy Clad-Vent-Set Production
E. K. Ohriner	Task Manager, Iridium Alloy Blank and Foil Production

Approved by:

R. H. Cooper	Manager, Space and Defense Programs
J. R. Weir	Chairman, Operational Readiness Review Board

CONTENTS

OPERATIONAL READINESS REVIEW PLAN
FOR
RADIOISOTOPE THERMOELECTRIC GENERATOR MATERIALS
PRODUCTION TASKS

1. INTRODUCTION

1.1 PLAN OVERVIEW

In October 1989, a U.S. shuttle lifted off from Cape Kennedy carrying the spacecraft Galileo on its mission to Jupiter. In November 1990, a second spacecraft, Ulysses, will be launched from Cape Kennedy with a mission to study the polar regions of the sun. The prime source of power for both spacecraft is a series of radioisotope thermoelectric generators (RTGs), which use plutonium oxide (plutonia) as a heat source. Several of the key components in this power system are required to ensure the safety of both the public and the environment and were manufactured at Oak Ridge National Laboratory (ORNL) in the 1980 to 1983 period.

Currently, the U.S. Department of Energy (DOE) is in the process of accepting a commitment from U.S. National Aeronautical and Space Administration (NASA) to provide a number of similar RTG power systems needed to deliver the prime power for two new missions – the Comet Rendezvous and Asteroid Flyby (CRAF) and Cassini. These missions are scheduled to be launched in 1995 and 1996, respectively. Because of a unique alignment of the earth with specific comets and asteroids and with Jupiter, there is only a 1.5-month window open for the launch of these respective spacecrafts without delaying subsequent launches by more than a year. The timely manufacture of reliable components and delivery of the integrated power system for these two missions will be a highly visible interagency commitment of DOE.

For these two missions, Martin Marietta Energy Systems, Inc. (Energy Systems), will provide an iridium-alloy component used to contain the plutonia heat source and a carbon-composite material that serves as a thermal insulator. Since manufacturing hardware for the Galileo and Ulysses missions began, the capabilities of ORNL and the Oak Ridge Y-12 Plant have been integrated to fabricate the iridium-alloy components, whereas ORNL alone will continue to fabricate the carbon-composite material. Because of the importance to DOE that Energy Systems deliver these high-quality components on time, performance of an Operational Readiness Review (ORR) of these manufacturing activities is necessary.

Energy Systems Policy GP-24 entitled "Operational Readiness Process" describes the formal and comprehensive process by which appropriate Energy Systems activities are to be reviewed to ensure their readiness. This Energy System policy is aimed at reducing the risks associated with mission success and requires a management-approved "readiness plan" to be issued that (1) describes the activity under review, (2) defines the scope of the process, (3) identifies the readiness review participants, (4) establishes organizational responsibilities of all participants, (5) defines the methodology and criteria to be used for determining readiness, and (6) defines the events that must take place to complete the process. This document is the readiness plan for the RTG materials production tasks.

1.2 PLAN SCOPE

The RTG Materials Production and Technology Tasks at Energy Systems can be grouped into three major areas. The first, technology development tasks, is associated with the development of advanced materials technologies for application in future RTG power systems. The second is management of the iridium inventory. In this area, Energy Systems has responsibility for the financial management of the $3.7M inventory of iridium used by all RTG program participants to support this national program. The third area, materials production, is associated with the manufacture of materials and components for RTG power systems to be used in specific space missions. The scope of this ORR will be limited to the third component, specifically, production of iridium-alloy blanks and foil, iridium-alloy clad-vent sets (CVS), and carbon-bonded carbon-fiber (CBCF) thermal insulator piece parts.

This plan describes the process that will be followed in performing this ORR. The plan has been prepared in compliance with Energy Systems Policy Procedure GP-24 and DOE-Oak Ridge Operations Office (DOE-ORO) Order 548X.1. The plan also reflects the unique requirements imposed by DOE's Office of Special Applications (DOE-OSA). These requirements include quality requirements described in OSNP-2 (ref. 1) and interface responsibilities among the national program participants summarized in the Interface Working Agreement for Encapsulated Plutonium-238 Fuel Form Production.[2,3,4]

DOE-OSA proposes to convert the quality requirements of the program from OSNP-2 to NQA-1 standard plus program specific supplements. Because these supplements are currently in draft status, this conversion has not been considered in the scope of this review.

Specifically, the purpose of this ORR is to assess the three RTG materials production tasks to ensure that none of the three has the potential to embarrass Energy Systems, DOE-ORO, or DOE-OSA through:

1. failure to deliver flight-quality hardware on the schedule required by DOE-OSA to support the on-time delivery of the integrated RTG power system to NASA,
2. failure to maintain the control of the quality of the hardware produced such that the hardware is found unsuitable for flight applications, and
3. operating in a way that endangers the health and safety of Energy Systems employees or the public or endangers the environment.

In performing this review, the scope will be limited to those work areas, specific pieces of equipment, operational areas, personnel, and documents directly associated with these three production tasks.

2. RTG MATERIALS PRODUCTION TASKS DESCRIPTION

2.1 GENERAL DESCRIPTION

The objective of DOE-OSA's RTG program is to provide safe, reliable, and cost-effective compact power systems to meet the needs of, and in some cases, enable selected civil and military missions. These missions have required compact power systems for both terrestrial and space-based applications. For more than 25 years, ORNL has provided materials technology and system design support to the national program. In the more recent past, this support has been oriented toward the invention, development, characterization, and manufacture of innovative materials required to facilitate achievement of national program objectives. In FY 1988, an additional objective of our RTG materials production tasks has been the consolidation of the manufacture of selected RTG hardware (iridium-alloy hardware) in the Oak Ridge area through use of the manufacturing expertise of the Oak Ridge Y-12 Plant. Near-term objectives included the qualification and subsequent manufacture of RTG hardware (specifically, iridium-alloy CVS and CBCF thermal-insulator piece parts) needed for systems to power spacecraft for NASA's CRAF and Cassini missions.

2.2 PROGRAMMATIC INTERFACES

Before describing the components manufactured by Energy Systems, a brief description of an RTG power system and the interfaces among program participants is required. The current design of the RTG power system is the General Purpose Heat Source (GPHS). As indicated in Figs. 1 and 2, the RTG is contained in an aluminum radiator, below which are thermoelectric converters followed by 18 rectangular carbon aeroshells that contain the radioisotope materials. Each rectangular aeroshell contains four plutonia pellets encapsulated in iridium-alloy cladding. These encapsulated pellets are further contained in a CBCF thermal insulator shell (Fig. 3). General Electric Company (GE)—Valley Forge was responsible for the design and the reliability of the GPHS system.

For the RTG systems to be flown on the CRAF and Cassini missions, Energy Systems, specifically ORNL, will process iridium powder into 2-in.-diam by 0.035-in.-thick blanks and 0.005-in.-thick foil. The Y-12 Plant will use these blanks and foil to manufacture CVS. CVS will be sent to Westinghouse Savannah River Company, which will encapsulate the plutonia pellets by performing a closure weld on the CVS and subsequently shipping the encapsulated pellets to the EG&G Mound Applied Technologies (EG&G-MAT) plant. EG&G-MAT will also receive the aluminum radiator and thermoelectric materials from GE, high-density carbon components from industrial vendors, and the CBCF thermal insulators manufactured by ORNL. These components will be assembled into the RTG power system and certified for its end use by EG&G-MAT (Fig. 4).

2.3 ENERGY SYSTEMS PRODUCTION TASKS

As indicated previously (Sect. 1), Energy Systems has responsibility for manufacturing and ensuring the quality of the CVS and CBCF components. To ensure the quality requirements of the program are met, a hierarchy of quality assurance (QA) and configuration control documents have been prepared by Energy Systems. These documents have been prepared to ensure the flowdown of quality actions to the appropriate subtier documents. The top-level document has been approved by DOE-ORO, and the Interface Working Agreement document identifies the organizations having approval and concurrence responsibilities for other important quality-related documents related to Energy Systems activities. With regard to the timely delivery of these Energy Systems—fabricated components, DOE-OSA has facilitated the preparation of an integrated delivery schedule for all components and subassemblies. This integrated schedule provides the current basis for determining Energy Systems component delivery requirements (Fig. 5).

2.3.1 Iridium Alloy Blank and Foil Production Task

The processing of iridium powder into blanks and foil is required before subsequent processing of these blanks and foil into CVS. The initial processing is performed at ORNL using the metal-working equipment located in the Metals and Ceramics (M&C) Division. Activities associated with the fabrication of iridium-alloy blanks have been in continuous operation since before 1980 (Fig. 6). The process in use now requires blending and consolidation of iridium powder and alloying iridium with 0.3% tungsten and 60 and 50 ppm thorium and aluminum, respectively, for blanks. For the foil application, a similar alloy containing only 30 ppm thorium is used. This material is electron-beam and consumable-arc melted, extruded to sheet bar, and rolled to 0.035-in.-thick sheet or 0.005-in.-thick foil. Iridium-alloy blanks are machined from this sheet, and both blanks and foil are dimensionally and nondestructively inspected and certified as meeting specifications requirements before shipment to the Y-12 Plant (Fig. 7). The systems in place at ORNL to ensure the quality of the iridium-alloy blanks and foil remains unchanged from those used to ensure the quality of hardware manufactured by ORNL for the Galileo and Ulysses spacecraft. Assurances that these systems currently are being followed has been determined through recent audits performed by the M&C Division, ORNL, and Energy Systems personnel. To further ensure these quality requirements are met, a quality review of this task is planned for June 1990. The quality review team will include participants independent of Energy Systems.

Since the time of the Galileo and Ulysses production activities, some changes have been made in the processing methods to improve the yield and metallurgical quality of blanks and foil. Specifically, the size of the initial ingot was increased from ~0.7 kg per ingot to ~4 kg per ingot. The small noncomsumable arc-melted and drop-cast ingots were rolled directly to final sheet thickness for blanks, whereas the larger consumable arc-melt ingots are now hot-extruded to a sheet bar and rolled to final thickness.

As indicated, DOE-OSA has generated an integrated production schedule for the activities of all program participants. On the basis of this schedule, activities associated with the fabrication of iridium-alloy blanks and foil that will be ultimately used for the CRAF and Cassini missions was initiated at ORNL in April 1989. Deliveries of blanks and foil for flight applications began in the second quarter of FY 1990 and will continue through FY 1993 and will provide the Y-12 Plant with 1103 blanks and 0.9 m^2 of foil (Fig. 6). The suitability of these production procedures and controls shall be reaffirmed by an independent Quality Readiness Review (QRR).

2.3.2 Iridium Alloy Clad-Vent-Set Production Task

This task is performed at the Y-12 Plant. For this operation, the Y-12 Plant uses iridium powder and iridium-alloy foil provided by ORNL to fabricate a number of small components. Iridium-alloy blanks supplied by ORNL are formed into a pair of small flat-nosed cups (formed cups, see Fig. 7). Assembly of selected components results in a CVS assembly composed of a shield cup and a vent cup. The Y-12 Plant has the responsibility for preparing the certification package required to ensure that the CVS meets the required specification and is fit for its end use.

Fabrication of the CVS used for the Galileo and Ulysses missions occurred between FY 1980 and FY 1984 and was performed by EG&G-MAT using blanks and foil fabricated by ORNL. In FY 1987, DOE-OSA requested that the CVS manufacturing technology be transferred to the Y-12 Plant to integrate all iridium-alloy fabrication at one site. The transfer to the Y-12 Plant was initiated in November 1987. Demonstration of effective transfer of this technology is expected to be complete in April 1990 with the successful fabrication of 15 CVS. With fabrication of the 15 CVS and successful completion of a QRR performed by an independent review team, the Y-12 Plant will initiate a pilot production run of 20 CVS using ORNL-provided products of iridium-alloy blanks, iridium-alloy foil, and iridium powder. Successful completion of this ORR will allow the initiation of routine production that will provide an additional 400 CVS through FY 1994.

2.3.3 CBCF Thermal Insulator Piece Part Production Task

This task is performed at ORNL. Thermal insulator piece parts are manufactured to make highly porous carbon-composite material having a density of ~10 to 15% that of graphite. These parts consist of a hollow cylinder called a sleeve (~3 in. long by 1.5 in. diam with a 0.070 in. wall) and two thin discs (~1.3 in. diam by 0.070 in. thick). These parts are manufactured by vacuum-molding a slurry of chopped carbon fibers and phenolic resin in the shape of a hollow billet and a plate. The billet and plate are made rigid by curing the resin and are subsequently carbonized at 1600°C. The carbonized parts are then machined to final design configuration, inspected, certified as meeting specification requirements, and shipped to EG&G-MAT. Approximately 324 CBCF sets were manufactured in this manner for use in Galileo and Ulysses spacecraft.

The equipment and staff utilized for this task have been involved continuously in the fabrication of CBCF since before 1980. Further, the methods for ensuring the quality and certifying this material have not changed since the fabrication of hardware for the Galileo and Ulysses missions. Since 1984, activities have been under way to evaluate new CBCF raw materials and minor modifications to the manufacturing process intended to improve the process controls. Characterization of hardware prepared from new raw material and utilizing the minor process changes has been completed and is being performed to demonstrate that this hardware meets all customer specified requirements for the material. Specifically, this includes dimensions, thermal diffusivity, mechanical properties, density, and radiographic quality relative to the current specification. A document review is being performed by Energy Systems and a quality review performed by a team including independent members will be completed by June 1990. Completion of the document review will allow production of flight-quality hardware for CRAF and Cassini to begin and continue into FY 1992 with the delivery of 190 thermal insulator sets.

3. PROJECT MANAGEMENT

3.1 RTG MATERIALS PRODUCTION AND TECHNOLOGY TASKS

A definitive management structure for the RTG materials program has been developed by Energy Systems in a management plan approved by DOE-ORO.[5]

This document describes the flow of guidance and funding from DOE-OSA to DOE-ORO to Energy Systems (Fig. 8). The plan indicates that programmatic responsibility for this program flows from and through the Associate Director of Nuclear Technologies at ORNL to the Director of Reactor Programs to the Program Manager for Space and Defense Programs to the Manager of Special Applications Program to individual RTG materials task managers (Fig. 9).

3.1.1 Program Manager, Space and Defense Programs

The manager has responsibility for all space nuclear power programs performed at Energy Systems. Specifically, the manager is responsible for developing and expanding the program and ensuring that current program commitments are met safely with high-quality products in a timely manner and within the constraints of existing funding.

3.1.2 Manager, Special Applications Program

The manager has responsibility for all Special Applications Program tasks performed at Energy Systems. Specifically, the manager is responsible for developing and expanding the RTG materials tasks and ensuring that current program commitments are met safely with high-quality products in a timely manner and within the constraints of existing funding.

3.1.3 RTG Materials Task Managers

Each RTG Materials task manager is responsible for developing and expanding the program and ensuring that current program commitments are met safely with high-quality products in a timely manner and within the constraints of existing funding.

3.2 OPERATIONAL READINESS REVIEW BOARD

The ORR Board has been established by senior Energy Systems management[6] to provide an independent assessment of the readiness of the RTG materials production tasks. As a result of this review, the Board will provide recommendations regarding the readiness of the three RTG materials production tasks.

Members of the ORR Board are:

D. E. Beck, Y-12 Quality Department;

A. F. Kiriluk, Energy Systems Quality Division;

M. W. Kohring, Office of Operational Safety;

M. K. Morrow, Y-12 Product Engineering; and

J. R. Weir, Chairman, ORNL Metals and Ceramics Division.

Specific responsibilities of the ORR Board include:

- approving the readiness review plan and the readiness criteria identified in the plan,
- verifying the implementation of the readiness review plan,
- assessing risk of continuing or initiating RTG production tasks based on the criteria provided in the plan,
- recommending actions regarding the initiation and/or continuation of the RTG materials production tasks, and
- documenting all ORR Board actions and assessing that such documents are included as part of the permanent record of the ORR process.

3.3 OPERATIONAL READINESS TEAM

The Operational Readiness Team (ORT) is a management-appointed multi-disciplined group that has been established to (1) evaluate the state of readiness of the three RTG materials production tasks, (2) identify and validate supportive objective evidence of readiness for these three tasks, and (3) assist the program manager in presenting the evidence of readiness to the ORR Board. Specific responsibilities include:

- preparation of this readiness review plan,
- use of appropriate analytical techniques to ensure full assessment of all three tasks,
- preparation of the readiness criteria,
- identification and verification of the objective evidence justifying readiness,
- monitoring and determining the state of readiness and reporting this information to the program manager, and
- presentations to the ORR Board on the state of readiness.

Because the team is assessing the state of readiness of three different production tasks, a hierarchial organization of the team has been implemented. The chairman of the team is Roy Cooper, Program Manager for Space and Defense Programs. The chairman is assisted by Mel Martin, Manager of the Special Applications Program, and Steve Ivey, who supports the quality planning and control for the Space and Defense Programs. Also reporting to the ORT Chairman are three subteams with responsibility for assessing the readiness of the Iridium Alloy Blank and Foil Production task, the Iridium Alloy CVS Production task, and the CBCF Thermal Insulator Piece Part Production task. The chairmen of these subtasks are Evan Ohriner, Ray Riggs, and Ron Beatty, respectively (Fig. 10). Each subteam has assembled a number of experienced individuals to assist in several key areas. A summary of those individuals supporting these subteams and their area of specialization is given in Table 1.

3.4 TEAM AND BOARD INTERFACE

The ORT has the responsibility for providing the ORR Board with the appropriate data necessary to assess the readiness of initiating or continuing any of the three production tasks. The ORT will make this information available in the form of this plan, reports, and/or presentations to the ORR Board.

On the basis of this data, the ORR Board will be responsible for assessing the readiness of the Iridium Alloy Blank and Foil Production task and the CBCF Thermal Insulator Piece Part Production task to continue with production activities.

To ensure this interface operates smoothly, the ORR Team Chairman will have responsibility for developing an up-to-date schedule of activities associated with this ORR. This schedule will be provided to the Board at all Board and Team meetings.

4. REVIEW METHODOLOGY

4.1 OPERATIONAL READINESS PROCESS

The Operational Readiness Process (ORP) is a management tool that establishes and verifies the readiness of a task or tasks. A flow chart of the ORP consistent with Energy Systems General Policy Procedure GP-24 is presented in Fig. 11. The process has already begun with the creation of this plan and the identification of initial readiness criteria for each of the three production tasks. More-detailed criteria will be formulated, if necessary, by the teams and will be reviewed by the Board at their discretion. Relative to these criteria the ORT will:

1. develop verifiable objective evidence that all criteria have been met,
2. identify the steps that have been initiated to satisfy any criteria that have not been fully met, or
3. provide evidence that any criteria that is not fully met does not represent a significant risk of yielding an unacceptable outcome.

The process will conclude with documentation of the recommendations of the ORR Board regarding the readiness of each of the three RTG material production tasks. The recommendations will be transmitted to DOE for review and approval by DOE-ORO and concurrence by DOE-OSA before the Iridium Alloy CVS task is initiated.

4.2 OPERATIONAL READINESS REVIEW TREE

Readiness criteria are the standards by which the three RTG material production tasks have been assessed and identified through the use of an operational readiness tree (a positive logic tree) developed by Energy Systems. This Energy Systems tree was prepared using the EG&G-Idaho tree developed for DOE. The Energy Systems tree has been continuously upgraded using lessons learned from previous application of the readiness process.

Starting with the comprehensive Energy Systems tree, the ORT developed an abbreviated tree. This abbreviated tree serves as a tool in developing operational readiness criteria and aids in guarding against omission of an item that could affect system performance. The events at the top of the logic tree are major elements of readiness and below them are more-detailed elements of readiness that have been evaluated for each of the three production tasks. A copy of this abbreviated tree is available for inspection by the Board and will be maintained as a permanent record of the ORR.

4.3 OPERATIONAL READINESS REVIEW CRITERIA

Through a review of the abbreviated operational readiness tree, the team has identified a number of top-level criteria that should be assessed relative to each of the three RTG material production tasks. The criteria discussed below have been organized under one of the three major elements of the abbreviated tree and, where necessary, further organized by a specific production task.

4.3.1 Facility Equipment Hardware and Process Materials Ready

This major element of the tree is intended to cover the following areas of each of the three RTG material production tasks: all process equipment, tooling, and materials; all utilities and support services, which include maintenance, engineering, equipment test and inspection, analytical laboratories, emergency response, medical, environmental, and safety; and primary and secondary materials. The operational readiness criteria that represent the greatest potential risk to any of the three RTG material production activities have been identified by the ORT. In some cases criteria were identified that are equally applicable to all three production tasks. These are:

Criterion 1

All equipment is adequate to make quality components to specification and is sufficiently available during the duration of the production activities.

Criterion 2

All primary and secondary materials are adequate to make specification-grade components to specification and are sufficiently available or reorderable to ensure uninterrupted production.

Criterion 3

The risk of an unacceptable health, safety, or environmental event directly associated with any of these three RTG materials production tasks has been found to be acceptably low or is being dealt with as part of an Energy Systems–wide initiative.

Relative to the Iridium Alloy CVS Production task, the following criterion has been identified:

Criterion 4

Demonstrate that the technology for the manufacture of CVS has been effectively transferred from EG&G-MAT to the Y-12 Plant.

4.3.2 Personnel

The second major element of the abbreviated operational readiness tree deals with manpower availability and training requirements. Relative to the three RTG materials production tasks, the following broad criterion has been identified.

Criterion 5

Provide assurance that appropriate staff will be available and qualified to support on-time delivery of flight-quality component through the duration of each respective task.

4.3.3 Managerial Control Systems and Procedures

The third major element of the abbreviated operational readiness tree is managerial control systems and procedures. The emphasis of this element is to ensure that all necessary documents are accurate, approved, and in place for QA and configuration control. Further, management systems are adequate for control and coordination of these production tasks.

Criterion 6

Provide assurance that quality requirements called out in DOE-OSA requirements document OSNP-2 and the Interface Working Agreement have been and will continue to be satisfied.

Criterion 7

Demonstrate that management systems are adequate to coordinate the activities of all Energy Systems participants.

5. REFERENCES

1. U.S. Department of Energy, Office of Special Applications, "Quality Assurance Program Requirements for Space and Terrestrial Nuclear Power Systems," OSNP-2, Rev. 0, October 1982.

2. Attachment to memorandum, B. J. Rock to Distribution, "Interface Working Agreement for Encapsulated Plutonium-238 Fuel Form Production," February 5, 1981.

3. Attachment to memorandum, G. L. Bennett to Distribution, "Interface Working Agreement for Encapsulated Plutonium-238 Fuel Form Production, fated August 1980," June 10, 1982.

4. Attachment to memorandum, J. A. Turi to Distribution, "Interface Working Agreement for Plutonium-238 Fuel Form Production, Rev. 1," draft dated April 1990, April 5, 1990.

5. Letter, A. Zucker to J. A. Reafsnyder, "Revised Management Plan for Radioisotope Thermoelectric Generator (RTG) Materials Production and Technology Tasks," April 1990.

6. Letter, A. W. Trivelpiece to H. D. Bewley et al., "Operational Readiness Review of the Production Tasks Associated with the Radioisotope Thermoelectric Generator Materials Program at Martin Marietta Energy Systems," April 1990.

Table 1. Summary of members of the RTG Materials Task Operational Readiness Review Team

Name	Specialty
	RTG Materials Tasks
R. H. Cooper	Manager, Space and Defense Programs
M. M. Martin	Manager, Special Applications Programs
J. S. Ivey	Analyst, Quality Planning and Control, Space and Defense Programs
M. C. Vance	Quality Assurance Specialist, M&C Division
	Iridium Alloy CVS Production Task
C. R. Riggs	Task Manager
H. W. Berry	Task Quality Engineering
G. B. Ulrich	Task Engineer
M C Wiest	Task Engineer, Environmental, Safety, and Health
	Iridium Blank and Foil Production Task
E. K. Ohriner	Task Manager
W. H. Miller, Jr.	Group Leader, M&C Division Environmental, Safety, and Health
J. L. Johnson	Compliance Specialist, M&C Division
	Carbon-Bonded Carbon-Fiber Thermal Insulator Piece Part Production
R. L. Beatty	Task Manager
J M Robbins	Task Engineer
W. H. Miller, Jr.	Group Leader, M&C Division Environmental, Safety, and Health
J. L. Johnson	Compliance Specialist, M&C Division

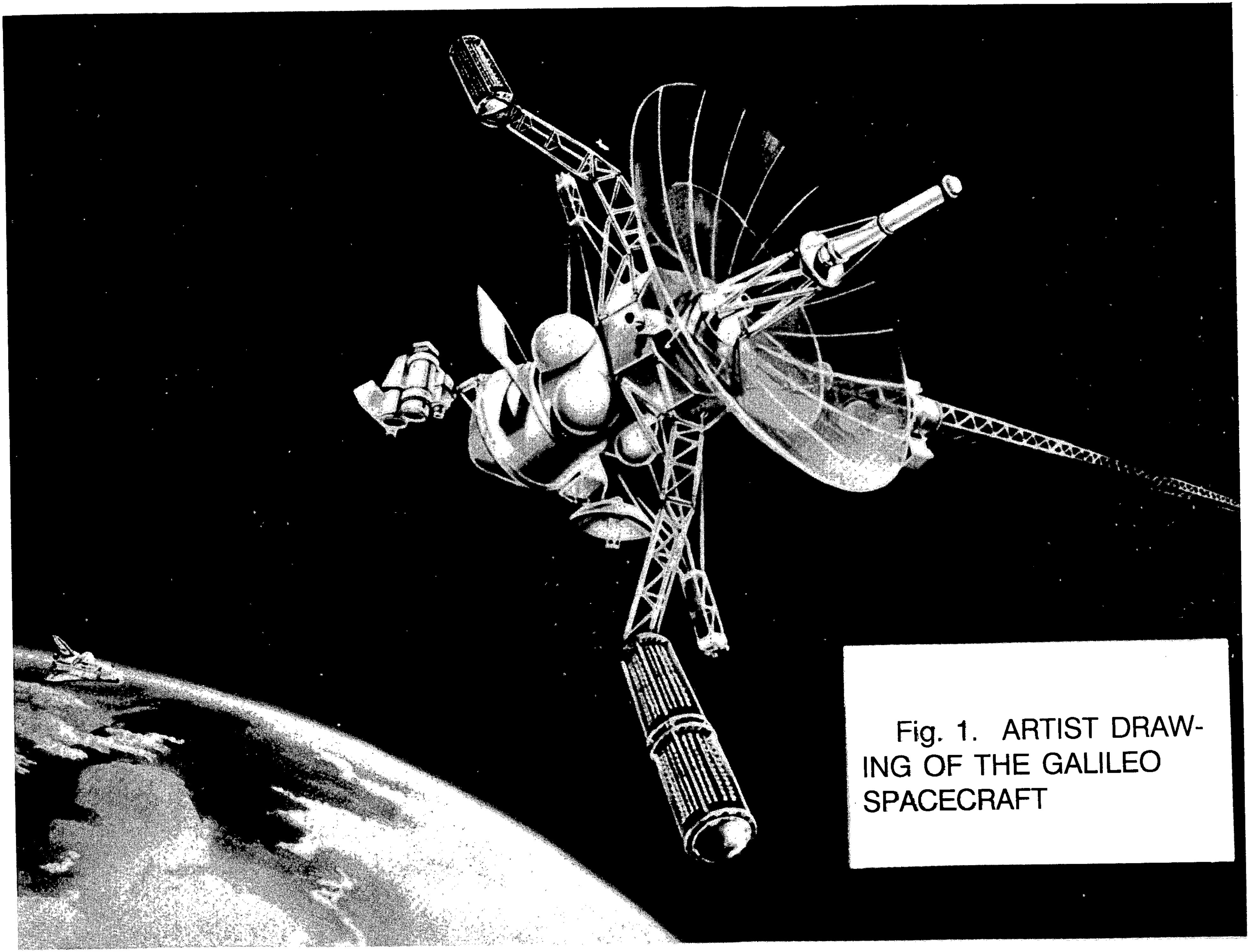


Fig. 1. ARTIST DRAWING OF THE GALILEO SPACECRAFT

Fig. 2. ARTIST DRAWING OF ISOTOPE POWER SYSTEMS USED FOR VOYAGER SPACECRAFT (MHW) AND GALILEO AND ULYSSES (ISPM) SPACECRAFT

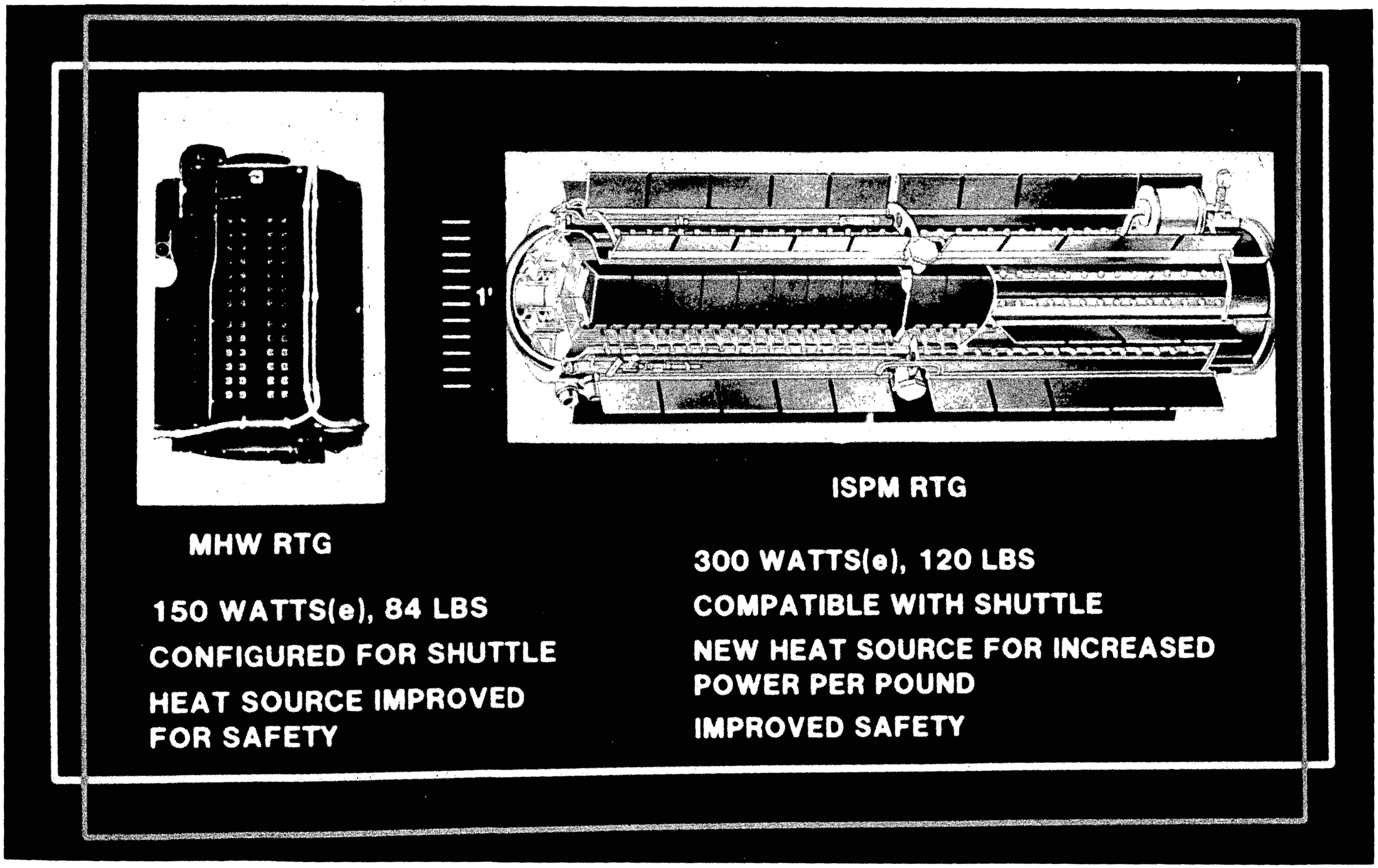
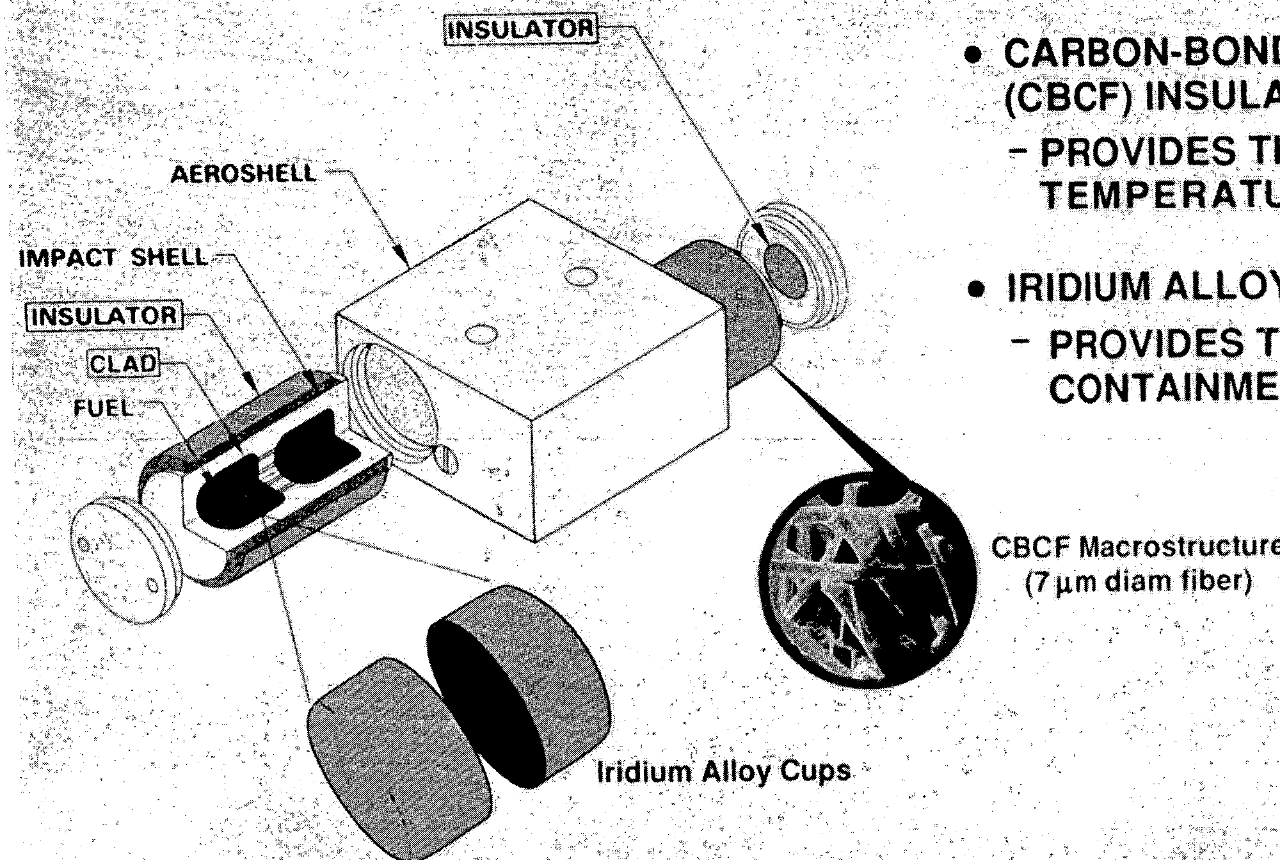


Fig. 3

ORNL-DWG 89-5908

OAK RIDGE'S COMPONENTS SERVE A CRITICAL PURPOSE IN THE GENERAL PURPOSE HEAT SOURCE



- CARBON-BONDED CARBON-FIBER (CBCF) INSULATOR
  - PROVIDES THE NEEDED HIGH-TEMPERATURE THERMAL PROPERTIES
- IRIDIUM ALLOY CLAD
  - PROVIDES THE NEEDED FUEL CONTAINMENT

MARTIN MARIETTA

MARTIN MARIETTA ENERGY SYSTEMS, INC.

VG040290-1

Fig. 4. ORIGIN OF COMPONENTS USED TO ASSEMBLE RTG POWER SYSTEMS

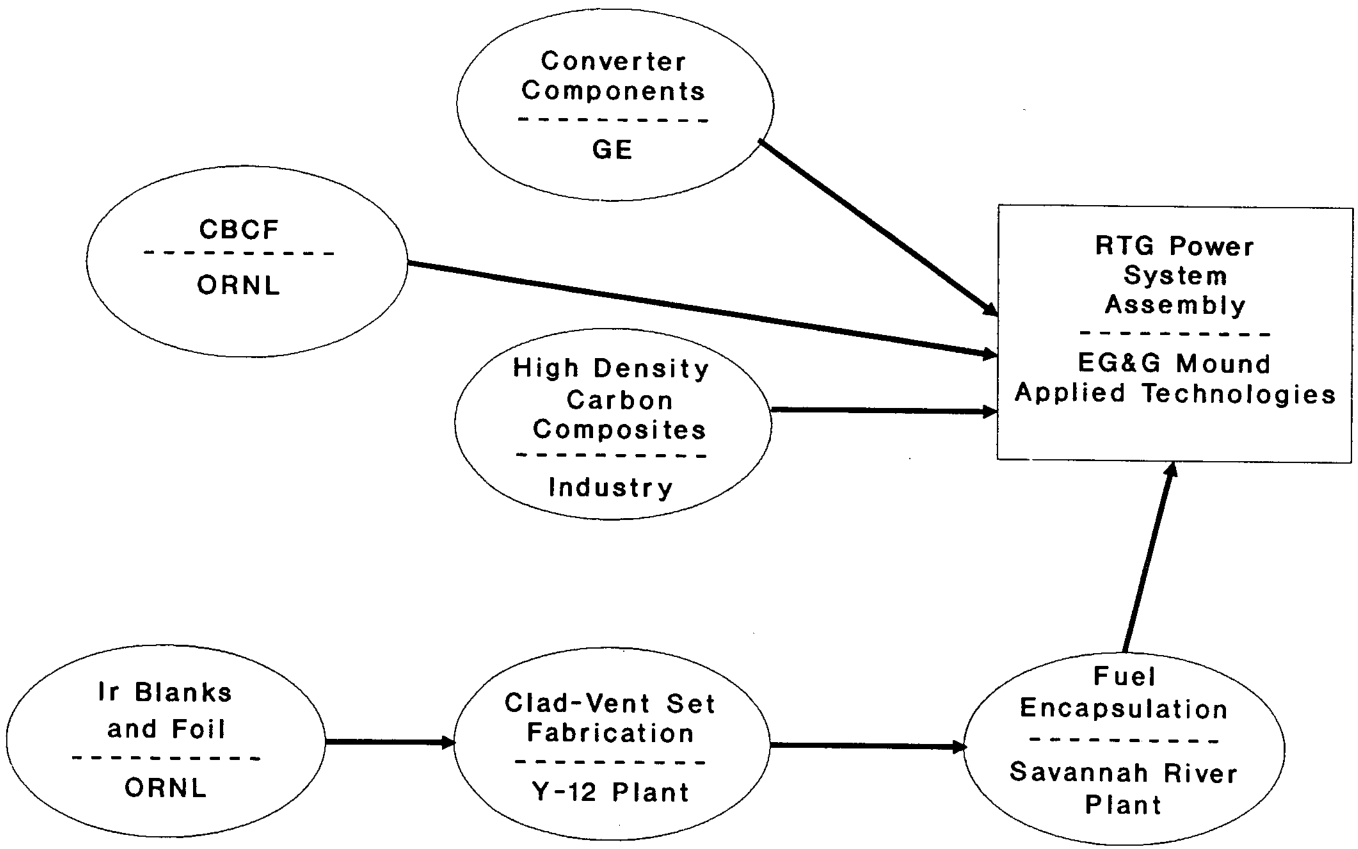


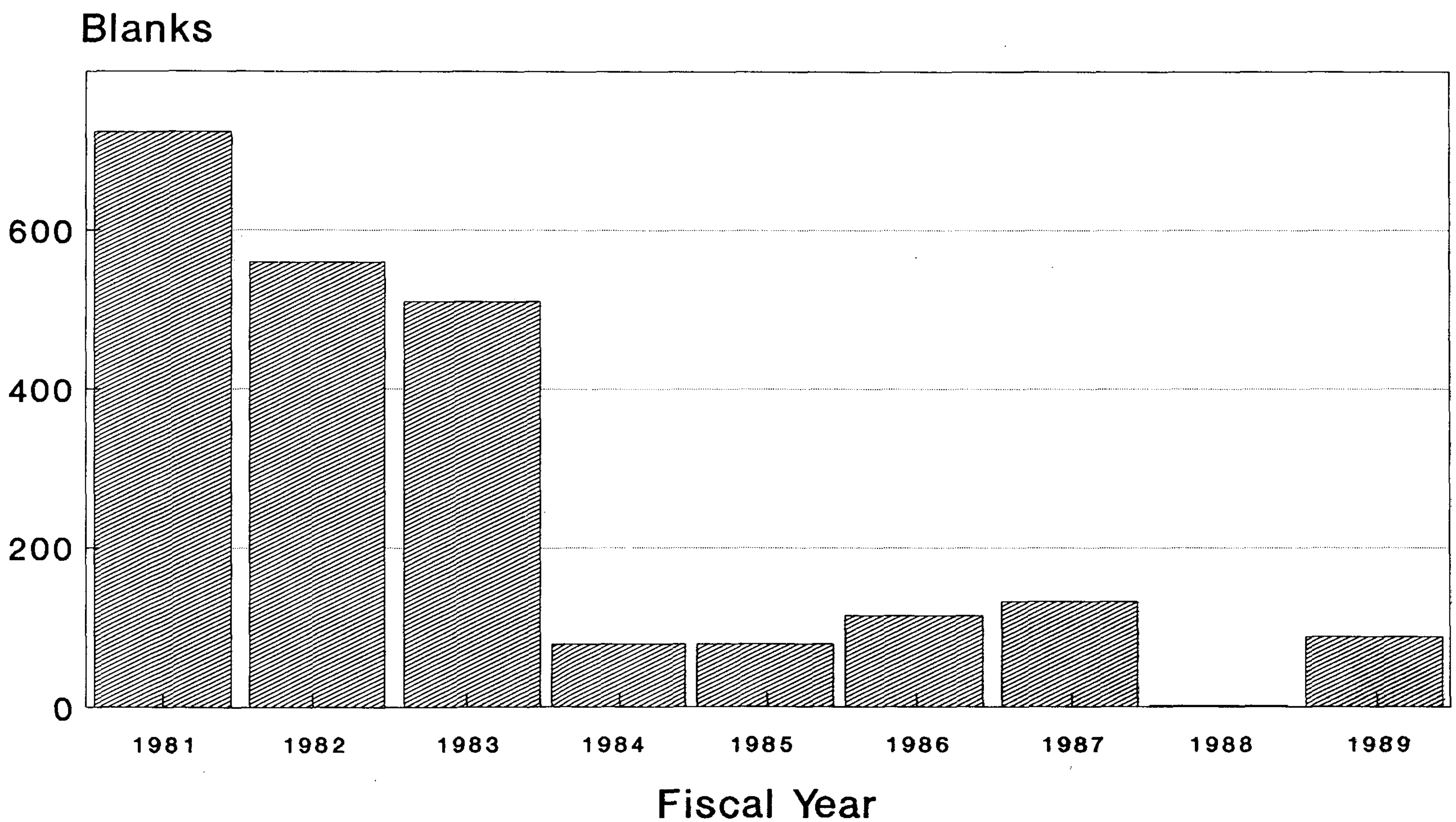
Fig. 5. CRAF AND CASSINI MISSIONS REQUIRE TIMELY DELIVERIES OF BLANKS, FOIL, CLAD-VENT SETS, AND CBCF PIECE PARTS

PRODUCTS	DELIVERIES					
	89	90	91	92	93	94
Iridium-alloy foil (m^2)		0.2	0.4	0.3		
Iridium-alloy blanks	60	225	315	400	163	
Iridium-alloy clad-vent sets			115	160	145	
CBCF piece parts		30	130	30		

FISCAL YEAR

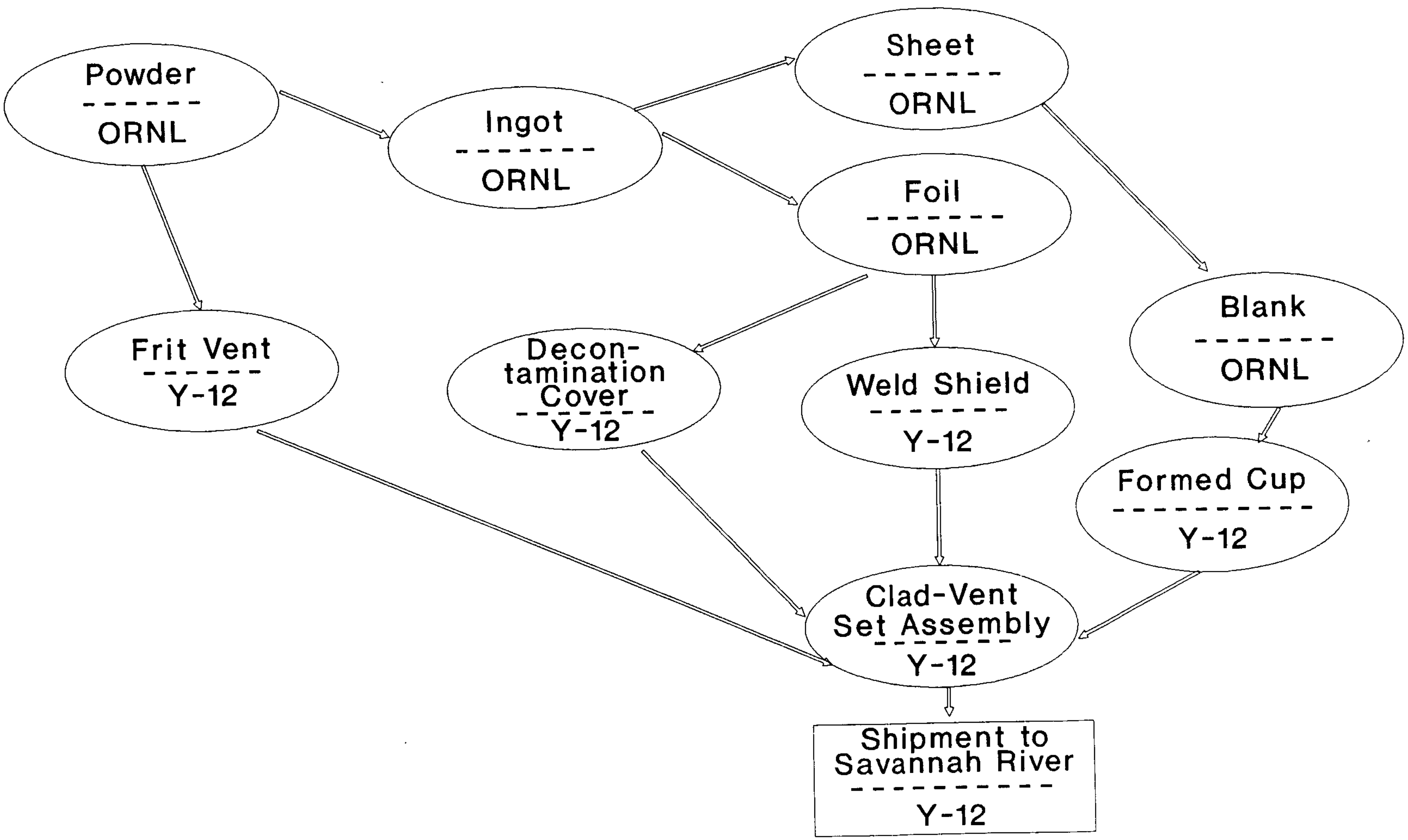
VG030790-18

Fig. 6. IRIDIUM ALLOY BLANK PRODUCTION HAS BEEN CONTINUOUS SINCE 1981



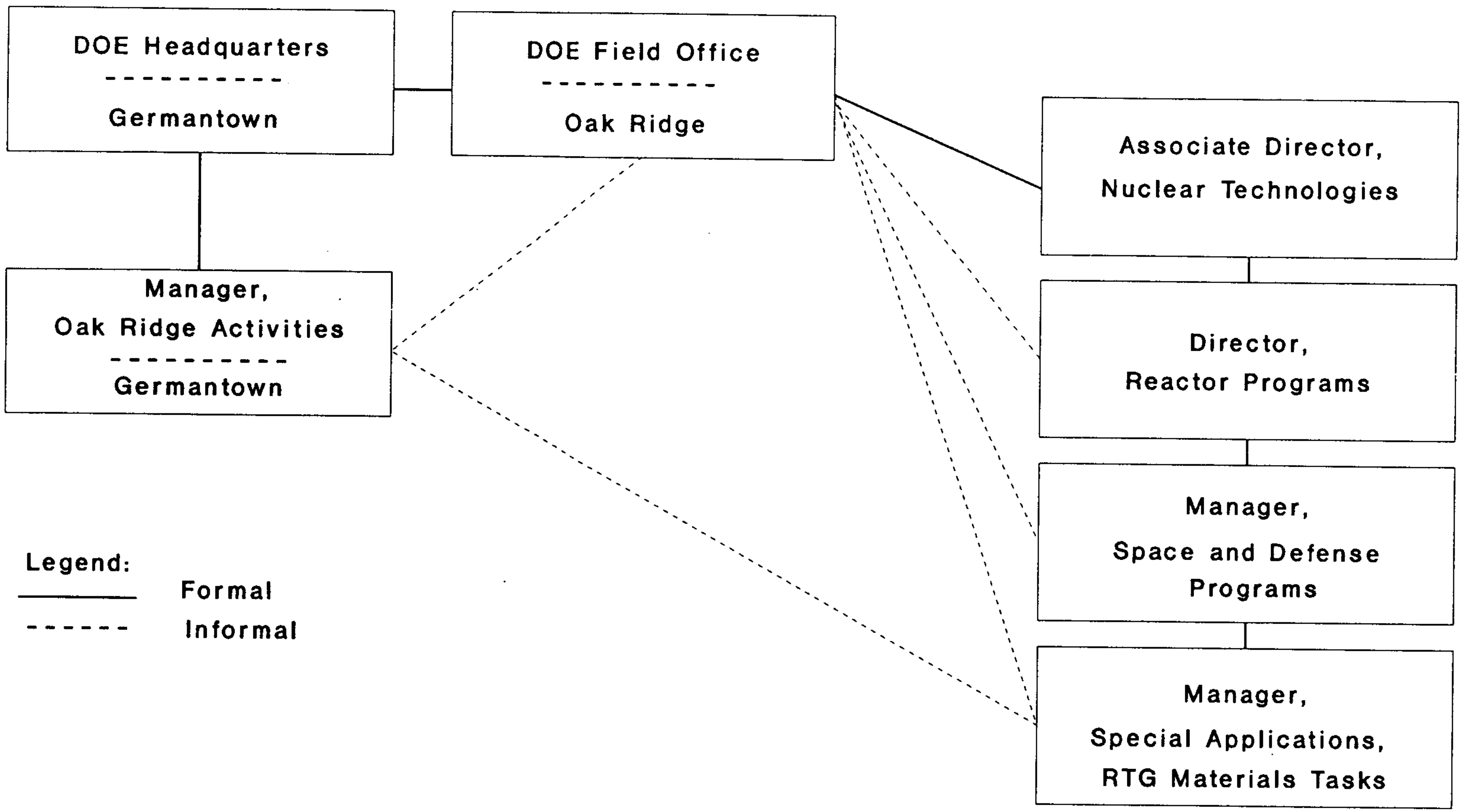
VG030790-21

Fig. 7. NUMEROUS COMPLEX STEPS ARE REQUIRED IN THE MANUFACTURE OF IRIDIUM ALLOY HARDWARE



VG040290-3

Fig. 8. FLOW OF GUIDANCE AND FUNDING



VG040290-2

Fig. 9. MANAGEMENT STRUCTURE FOR THE INTEGRATED RTG MATERIALS TASKS

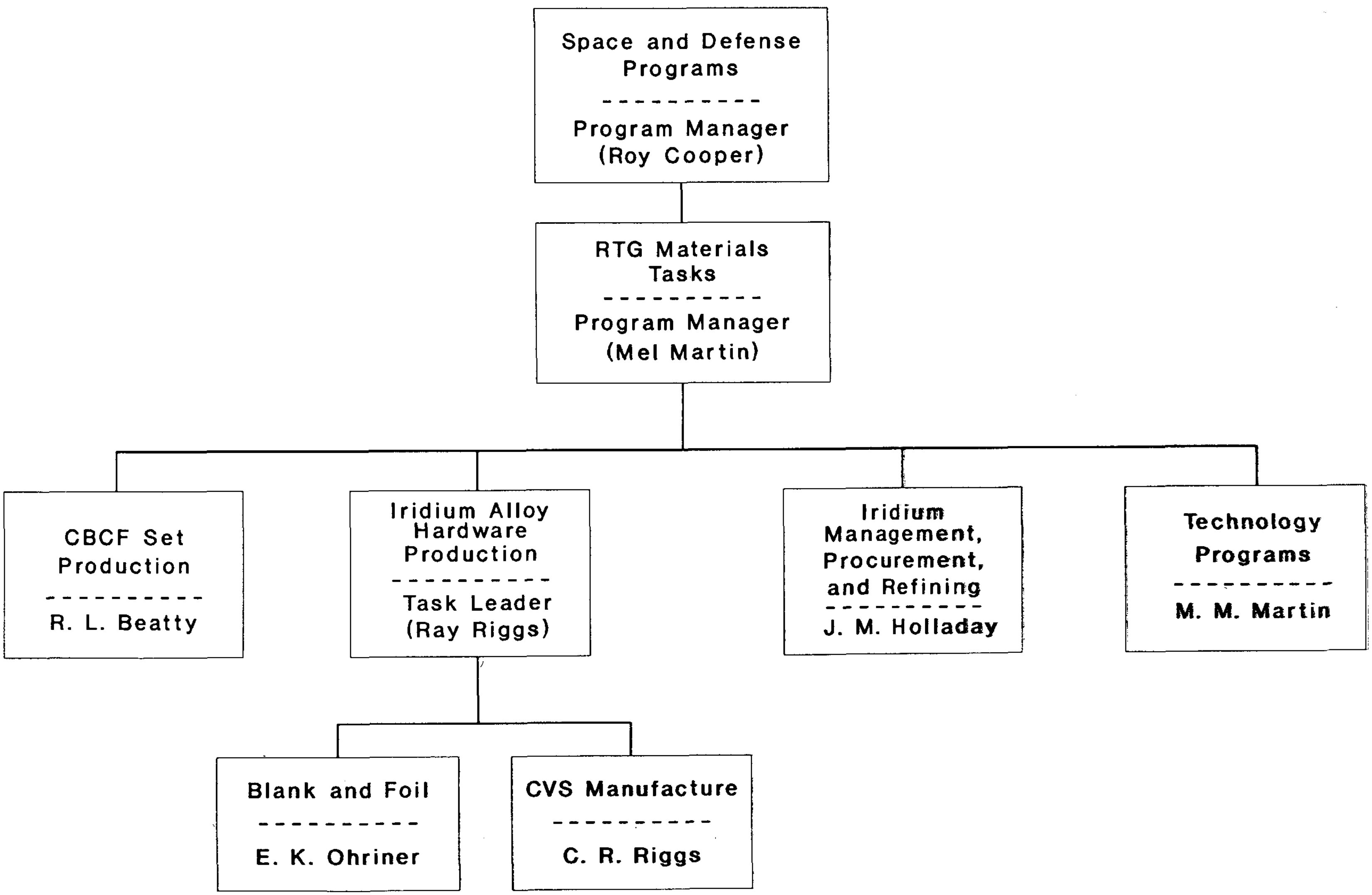
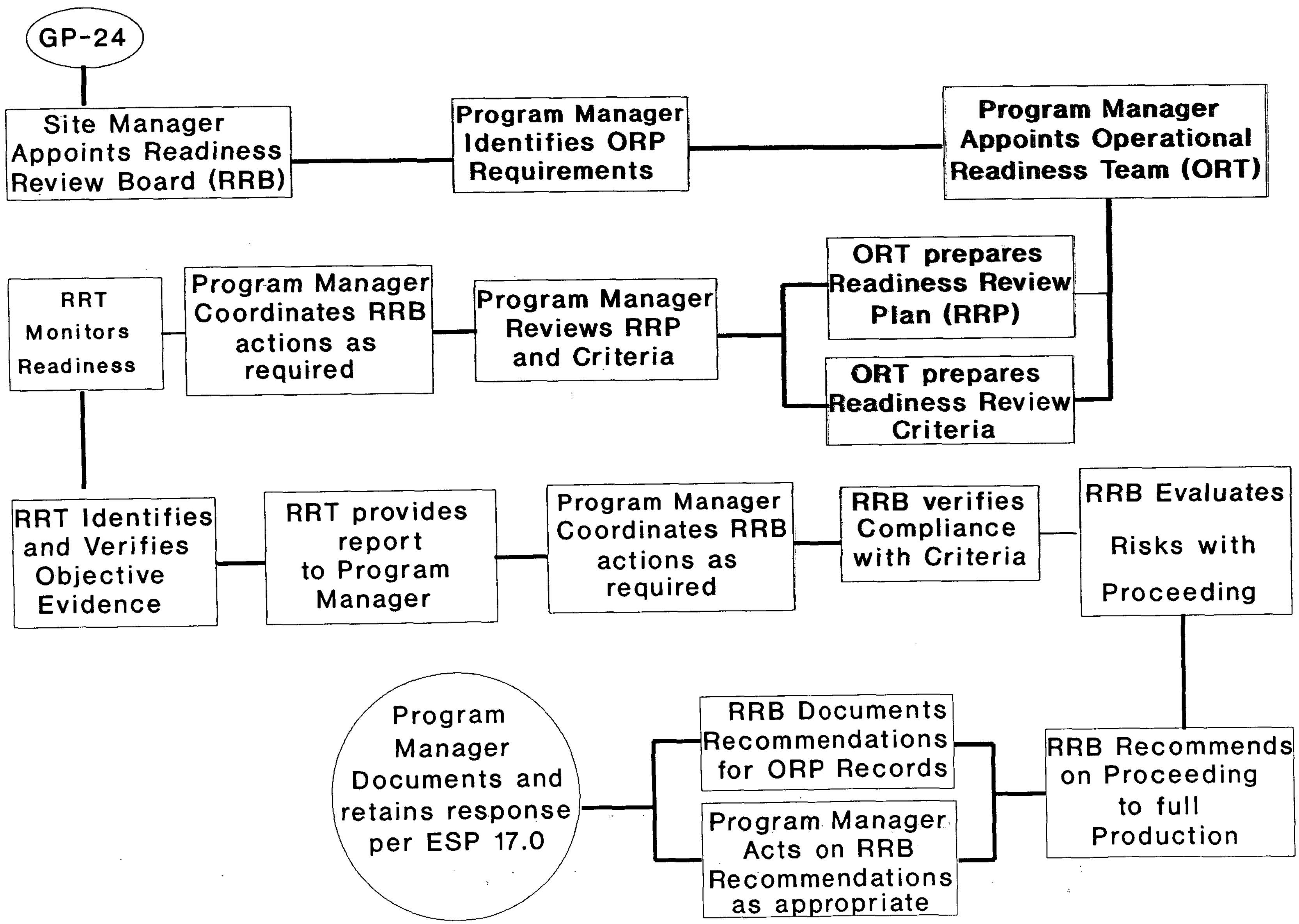


Fig. 10. AN OPERATIONAL READINESS TEAM WITH SUBTEAMS WILL BE UTILIZED FOR ENERGY SYSTEMS REVIEW

Operational Readiness Team Chairman

Technical Expertise	Iridium blank & foil subteam	CVS Subteam	CBCF Subteam
Fabrication	X	X	X
Inspection	X	X	X
Certification	X	X	X
Quality Assurance	X	X	X
Health & Safety	X	X	X

Fig. 11. OPERATIONAL READINESS PROCESS (ORP)



ORNL/M-1137
Distribution Category
UC-528

INTERNAL DISTRIBUTION

1-2.	Central Research Laboratory	31.	A. F. Kiriluk
3.	Document Reference Section	32.	M. W. Kohring
4-5.	Laboratory Records Department	33-37.	M. M. Martin
6.	Laboratory Records, ORNL RC	38.	W. H. Miller, Jr.
7.	ORNL Patent Section	39.	M. K. Morrow
8-10.	M&C Records Office	40-44.	E. K. Ohriner
11-15.	R. L. Beatty	45-49.	C. R. Riggs
16.	D. E. Beck	50.	V. K. Sikka
17-21.	R. H. Cooper, Jr.	51.	J. O. Stiegler
22.	W. S. Dritt	52.	M. C. Vance
23-27.	R. N. Escher	53.	J. R. Weir, Jr.
28.	F. J. Homan	54.	M. C. Wiest, Jr.
29.	J. S. Ivey	55.	S. R. Wilson
30.	J. L. Johnson		

EXTERNAL DISTRIBUTION

56. PAI CORPORATION, 116 Milan Way, Oak Ridge, TN 37830

    J. G. Morgan

57. U.S. DEPARTMENT OF ENERGY, Office of Special Applications, NE-53, GTN, Washington, D.C. 20585

    W. J. Barnett

58. U.S. DEPARTMENT OF ENERGY, Oak Ridge Operations Office, P.O. Box 2001, Oak Ridge, TN 37831-8600

    G. A. Mills

59. U.S. DEPARTMENT OF ENERGY, Oak Ridge Operations Office, P.O. Box 2008, Oak Ridge, TN 37831-6269

    E. E. Hoffman

60-178. U.S. DEPARTMENT OF SCIENTIFIC AND TECHNICAL INFORMATION, P.O. Box 61, Oak Ridge, TN 37831

    For distribution as shown in DOE/OSTI-4500, Distribution Category UC-528 (Space and Defense Reactor Power Systems)

U.S. GOVERNMENT PRINTING OFFICE: 1990--748-114/20029