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DOE/SF/18852--T13

Semi Annual Technical Report

Contract No: DE-AC03-91SF18852

GPHS-RTGs In Support
of the
CRAF/Cassini Missions

30 September 1991
through
29 March 1992

Document No. RR16

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Semi-Annual Technical Report
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Semi Annual
Technical Report

1. INTRODUCTION

The technical progress achieved during the period 30 September 1991 through 29 March 1992 on Contract DE-AC03-91SF18852.000 Radioisotope Thermoelectric Generators and Ancillary Activities is described herein.

This report is organized by the program task structure as follows:

- 1.X Spacecraft Integration and Liaison
- 2.X Engineering Support
- 3.X Safety
- 4.X Qualified Unicouple Production
- 5.X ETG Fabrication, Assembly, and Test
- 6.X Ground Support Equipment (GSE)
- 7.X RTG Shipping and Launch Support
- 8.X Designs, Reviews, and Mission Applications
- 9.X Project Management, Quality Assurance, Reliability, Contract Changes, and Non-Capital CAGO
- H.X CAGO Acquisition (Capital Funds)

Note: Program Task H.X scope is included in SOW ¶ Task 9.5. Task H. was created to manage capital funding.

Also included as significant activities in the Qualified Unicouple Production Task (4.X) are the inter-related efforts of the EMQ Campaigns and Process Readiness.

2. PROGRESS BY MAJOR TASK

2.1 Spacecraft Integration and Liaison

During this six month period, activity continued with JPL to support the establishment of spacecraft and launch vehicle derived RTG requirements and test environment specifications and the preparation of an Interface Control Drawing (ICD) for the attachment of the RTGs to the spacecraft. These requirements and specifications are to be issued by JPL with DOE concurrence in three documents: (1) the RTG Environments and Testing specification; (2) the RTG Requirements specification; and (3) the Interface Control Drawing. These documents include requirements for the operation and characteristics of RTGs, ground handling and shipping equipment, RTG testing definition of the environments for ground, launch and flight operations; and the hardware configurations. Note that the design of the RTG is fixed so the approaches to resolve any problems which are discovered will not involve design changes.

Because JPL's definition of flight environments has been significantly delayed and the RTGs for CRAF/Cassini mission are the same as for the Galileo and Ulysses (GLL, ULS) missions, with the exception of the pressure relief device, JPL agreed to the use of GLL/ULS launch dynamic requirements for the CRAF/Cassini Design Review. At the same time, GE and JPL have continued to work to mutually develop the RTG Requirements specification and ICD. Work on the RTG Environments and Testing specification has been deferred pending the availability of definitive dynamics data from the JPL Vibration Verification Program and confirmation of the applicability of the GLL/ULS dynamic loads. Work on the RTG Requirements specification has resulted in wording and language generally acceptable to both JPL and GE for nearly all of the specification. At the close of this report period, GE and JPL were in disagreement over the imposition of increased test load requirements for existing ground handling equipment. Having been unable to reach agreement on this remaining point, the GE-JPL discussions have been widened to include DOE which likely will take up consideration of the matter.

GE-JPL discussions concerning the ICD have been concluded and the drawing is now ready for DOE review.

2.2 Engineering Support

2.2.1 Specifications/Drawings

The major activities this reporting period were completion of the barometrically activated Pressure Relief Device (PRD) design and the Design Review (CDRL B.2) held 21 November 1991. The PRD Product Specification which defines requirements for design, qualification and acceptance testing was completed. The PRD structural analysis, tradeoffs, activation layouts and design were presented at the Design Review. One action item concerning the PRD was generated during the Design

Review. This action item required GE to evaluate several techniques to assure that the bellows have not expanded in addition to the visual inspection now in place. Several techniques were evaluated and a system utilizing fibre optics was recommended. The PRD drawings were issued including the adaptor plate for mounting the PRD to the ETG shell and the cover plate for when the PRD is not mounted on the ETG. The detail drawing of the bracket, for use if the JPL vibration requirements exceed that of Galileo, was also issued. In total, nine detail and two assembly drawings were issued.

The Design Review held at Valley Forge on 21 November 1991 included representatives from DOE, JPL, Fairchild, NASA, Mound, LANL, ORNL, WAES, and GE. The principal objective was to review changes in requirements for the CRAF/Cassini missions. The RTG Reliability Assessment (CDRL B.15) was updated as part of the Design Review Presentation Package (CDRL B.2). The update included only structural assessment and changes resulting from the new PRD. The Design Review resulted in five action items which have been answered and two comments. The Design Review Report (CDRL A.2) was submitted to DOE on 9 December 1991. As a result of the successful Design Review, DOE approval to proceed with flight unit fabrication was obtained.

2.2.2 Government Laboratory Interface

During this report period, extensive DOE comments were received on the draft Interface Working Agreement (IWA) prepared by GE for GPHS-RTG assembly, RTG fueling and assembly and RTG acceptance test activities at Mound. The IWA establishes a basis for the joint efforts of GE, Mound and DOE in accomplishing the above activities for the CRAF/Cassini missions. At the close of this report period, the draft IWA was in the process of revision at GE.

Under this task, support has been provided for heat source related activities at various DOE installations. Draft isotope fuel specifications have been reviewed to support activities at both LANL and Savannah River site related to the development of powder, pellet and fueled clad specifications. Heat source fabrication procedures have also been reviewed in support of clad vent set production at ORNL and fueled clad process development at LANL.

Also under this task, FWPF drawing changes proposed by Mound were evaluated and subsequently approved.

2.3 Safety

2.3.1 RTG Safety Assessment

During the first part of this reporting period, NASA continued to make revisions to the EIS Databook. These revisions pertained to the contributions from the explosion of the Titan Core vehicle propellants to the fragment environments in the SRMU fail-to-fire and near-pad command destruct scenarios. Also, the blast and fragment environments arising from the Centaur in the SRMU fail-to-fire scenario were defined in more detail. The effect of these changes in the environments on the response of the RTGs was assessed, and a revised draft of the RTG Safety Assessment Report was prepared and sent to DOE for review.

In November 1991, a draft of Section 10.0, System Failure Probability Analysis, of the EIS Databook was received from NASA for review. Shortly thereafter, preliminary failure probabilities were received, but these numbers had not been reviewed and approved by NASA.

The draft of the RTG Safety Assessment was revised in the February 1992 timeframe based on comments and direction received from DOE, and the revised draft was then sent to DOE for review. As of the end of this reporting period, official approval of the EIS Titan Databook by NASA had not been received by DOE. Finalization and publication of the preliminary RTG Safety Assessment Report is still contingent on receipt of the official Databook.

2.3.2 Safety Test Program Plan

Comments and suggested changes to the Draft Safety Test Program Plan (CDRL A.10), submitted August 1992, were received from DOE in the February 1992 time frame. The DOE transmittal also included changes suggested by LANL, Applied Physics Laboratory, and Fairchild. Where possible, updates to the plan incorporated comments received. Resolution of some comments had to be deferred because of their dependency on the quantity of GPHS-RTG hardware available. Also to be considered were informal recommendations received by DOE from INSRP for additional testing.

A meeting was held at Fairchild by DOE to discuss the Safety Test Program Plan and comments received. Other topics discussed included the requests submitted by the Power System Subpanel (PSSP) of INSRP, the Applied Physics Laboratory (APL) reentry testing and analysis program, and the draft RTG Safety Assessment Report. Considerable discussion occurred pertaining to the three proposed test series (i.e., RTG end-on impact, edge-on (thin) fragment impact on the RTG, and aged module impact). Of especial interest was the configuration and makeup of the heat source stack for the RTG end-on impact and the edge-on fragment impact tests. The decision was made that hydrocode analyses were necessary to help make final recommendations for these test configurations.

Because of the limited amount of test hardware available, it may be necessary to alter or eliminate parts of the proposed tests. Another major factor to be considered in the final test plan definition, as discussed by DOE, is the projected overall test program cost. DOE requested that detailed costs be developed for each test plan option to include inputs from all affected groups/organizations. The decision was made to defer issuing the Safety Test Program Plan until preliminary groundwork and more detailed test plans are complete.

The recommendations related to the safety test program received by DOE from the PSSP/INSRP were discussed. DOE has requested that INSRP submit recommendations and suggestions from all other subpanels as applicable. DOE will evaluate all suggestions and comments and prepare a response on their position and/or course of action.

APL summarized the work they have been doing in their aerospace nuclear safety program. A number of tests have been recommended to obtain additional data on heating distributions and aerodynamic characteristics and as influenced by motion of the GPHS-RTG module. It is not known whether NASA will provide the support and facilities needed to conduct these tests. APL still has not been able to obtain the needed support from NASA to get their computational fluid dynamics codes (obtained by APL from NASA) operational.

2.3.3 Risk Analysis Codes Development

A meeting was held at GE to brief DOE on the risk analysis computer codes being developed by GE for use in the Cassini safety analysis. Emphasis was placed on the necessity for a detailed validation plan and schedule in preparation for briefings to INSRP. Also, the need to develop the approach to performing variability/sensitivity analyses for the SARs was emphasized. The urgent need for formal definition of the Cassini launch data and window by NASA was reiterated in order to plan the detailed schedule for the safety analyses and reports.

2.3.3.1 Dose Analysis Modeling

The model that has been formulated for inhalation dose is based on ICRP 30 in its particle-size dependent form and modified to accept a fraction inhaled, also particle sized dependent, as input. The dose conversion factors input to this model have been modified according to DOE/EH-0071, a recent revision to ICRP-30.

The decision was made to simplify the seafood ingestion model to provide a single ingestion dose value for all persons within a given affected local area. This area will be defined by the code user based on food distribution geography. This decision was based on a review of other models such as those used in the Galileo and Ulysses

FSARs as well as that reported by INSRP for those missions. Also, the lack of data was deemed likely to preclude the use of more sophisticated models such as that developed in Japan and tested against NUREG 1.109.

2.3.3.2 Data Acquisition

The following data was acquired during this reporting period:

- Florida Agricultural Production Data by County (Florida Department of Agriculture)
- One day of 3-D sea breeze wind field data for KSC (Lawrence Livermore Laboratory)
- KSC Area Population and Surface Type - 1995 (Halliburton NUS)

Data transfer and processing tasks were also completed during this period. A set of 720 global equal-cell data was input using the average values of population and surface type from the DOE Overall Safety Manual. This data will have to be updated to the 1997 launch date.

The 3-D sea breeze data from Livermore was for 15 minute time intervals, but it required 16 megabytes of data storage. This emphasizes the importance of efficient processing in using such data. A program to read, process, and reformat the KSC area meteorology data was written, tested, and successfully applied to one day's worth of data from the single tower data used in the Ulysses FSAR.

2.3.3.3 SATRAP Code Development

SATRAP = Site Specific Analysis for Transport and Dispersion of Radioactive Particulates

Turbulent Dispersion Coefficients

Several code modules have been generated to evaluate the horizontal and vertical dispersion coefficients for released puffs at any position in space and time of travel.

1) The vertical dispersion coefficient sz, a module based on similarity theory, to compute the energy dissipation rate at any altitude in the surface and mixed layers was completed. This will accommodate sparse data collection, where

the bulk profile of meteorology parameters such as heat flux and momentum flux are determined with empirical relationships. With the use of typical surface characteristics such as the Obukhov stability length, the friction velocity and the scaling temperature, the code was tested and provided satisfactory results.

2) Another module to compute the vertical dispersion coefficient sz, using grid-scale data of wind velocity and potential temperature was generated. This will apply to availability of a wind field prediction model, such as SABLE from LLNL, to be used concurrently with the dispersion analysis. In this code, the energy dissipation rate has to be derived from either eddy diffusivities calculated by the O'Brien polynomial or the local Richardson number dependent exchange coefficients. The code was designed to be flexible in accommodating any size of input data array. As an illustration, Figure 2.3-1 shows the test results for a typical convective condition: the normalized dissipation rate displays a near constant value throughout the mixed layer. Z_i is the mixing layer height.

3) Based on the Lagrangian-Dynamical theory, a module for the lateral dispersion coefficient sy, was coded and tested. This will allow the evaluation of sy, at any travel time between 1 and 1E+5 sec, given the characteristics of the applicable wind field such as the Lagrangian time scale, the large-scale diffusivity. The effect of initial puff size was implemented using the ratio of the initial sigma to the Eulerian length scale.

4) Since the puff trajectory in the atmosphere may last several hours, a module was required to compute the effect of turbulence variations in space. A change in stability regime was incorporated through the evaluation of a virtual time spent over the new area. At each time step of advection, the virtual time will be updated by scanning the wind cell data; then the growth rate of puffs in the actual condition will be evaluated. This will provide a realistic representation of the change in atmospheric stability.

Wind Component Interpolation

The analysis of particle advection in a 3-D wind field requires the knowledge of wind components (u, v, w) at any given time or set of coordinates. The interpolation of these components within a rectangular grid cell was coded using a tri-linear formulation for spatial variations. Temporal variations of meteorological data inputs were assumed to vary linearly between Input values.

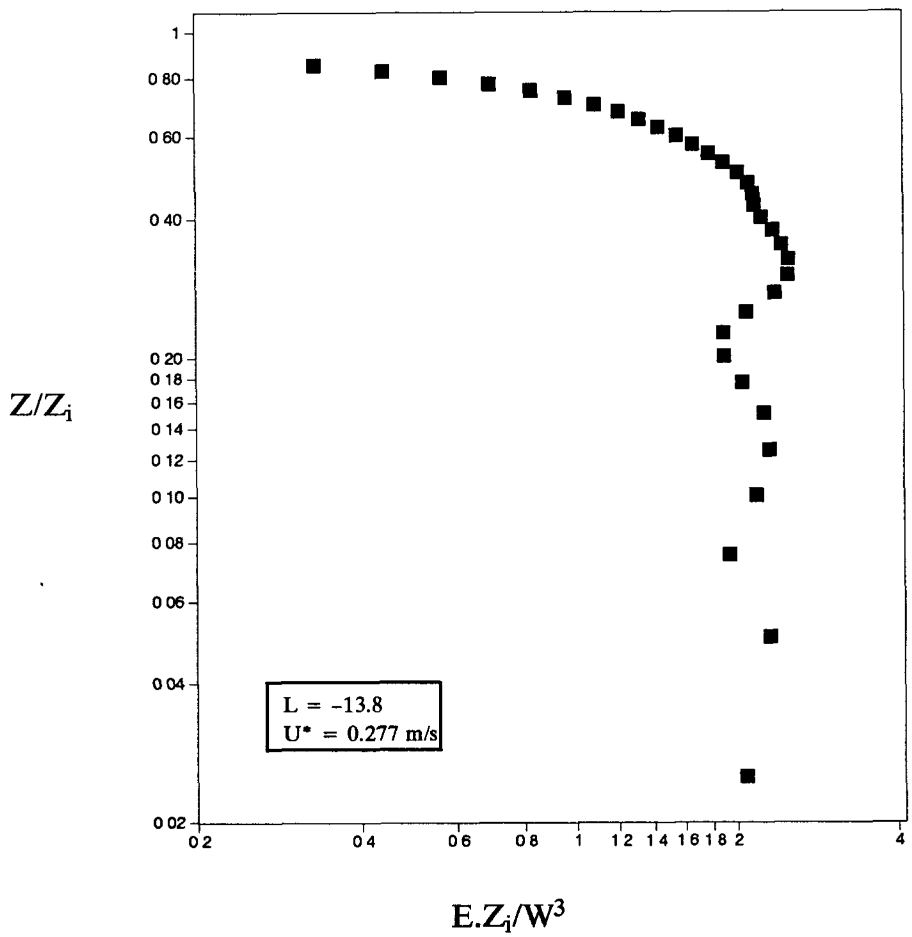


Figure 2.3-1. Normalized Energy Dissipation Rate for Unstable Condition, Using Grid-Scale Data

For other parameters such as wind shear or potential temperature, a cubic spline procedure was implemented with a user defined length of data array. This procedure has been demonstrated to provide accurately both interpolated values and first derivatives of the parameter of interest.

A code is currently being tested to interpolate wind components to a defined grid reference, using weighted functions and sparse data collected from a given number of wind stations. The code will be used to prepare a wind field database in case of unavailability of a wind prediction model for the launch site.

Meteorological Data

A preprocessor for preparation of meteorological parameters was coded and tested. These parameters are characteristic to each advection grid cell. Using the wind speeds and temperatures measured at 2 levels, and the surface roughness length, the code evaluates the following parameters: the Monin-Obukhov stability length, the friction velocity, and the scaling temperature. Stability regimes derived from these parameters are expected to provide a better description of the turbulence diffusion than the conventional Pasquill-Gifford categorization.

Receptor Grid Design

Combining the concentrations of heavy and light particles deposited during the dispersion process requires a complex multi-size reference grid. While the heavy particulates have the tendency to cluster around a central point due to gravity settling, the light or small particulates will be dispersed to large areas, depending on actual travel time and turbulent conditions. Thus, the receptor grid for each category has to be designed separately. This task was initiated with the coding of a module to determine sub-areas of interest when there is interference between the 2 receptor grids. Given a receptor cell and a random number of inside sampling points, the code will define the sub-areas created by intersections of all available coordinates. Once the sub-areas are defined, different levels of concentrations within a receptor cell can be evaluated for the dose calculation.

Since most of the primary tasks in the concentration calculation include searching of sampling data points which belong to the same receptor cell, a fast sorting module for data structures was coded. Using the mergesort approach, the algorithm is best suited for the existing linked-list architecture in data management of SATRAP.

2.4 Qualified Unicouple Fabrication

The objectives of this task, which includes most of the manufacturing activity this period, are to reestablish the silicon germanium unicouple fabrication and production capability and verify that this has been accomplished by long term testing of three 18 couple modules assembled from hardware produced in this program. The intent is to reestablish the processes which have been developed and used successfully in the fabrication and assembly of product for the GPHS-RTG program and earlier programs. The starting point included several participants from previous RTG programs; an inventory of DOE-owned material and equipment used on the previous program, and a body of existing design, process, and program documentation.

The changes required to reestablish the unicouple production have been more extensive than originally estimated. Reasons include vendors that no longer can or will provide parts or materials to unicouple specifications; changes in Environment, Health, and Safety standards; and changes in the equipment available for this work. In addition, more than anticipated effort has been required to establish process and setup parameters. This is partly a consequence of specific instances where there is insufficient documentation to completely describe a production setup or cleaning process, or where available personnel can not determine how a task was done in the past. At this point in time, much progress has been made. Note that a readiness review is conducted for each critical process to ensure that the quality of the product will be equal to the output from previous programs. Details on the accomplishments of this reporting period and current status are provided in the following paragraphs.

Manufacturing staffing was completed and stabilized during this six month period for the current planned level of activity considering fiscal year funding constraint guidelines provided by DOE.

Operator training, certification and process readiness status, as of the end of this reporting period, is reflected in Table 2.4-1.

Table 2.4-1. Status of Unicouple Processes

Process	Training	Certification	Process Readiness
Vacuum Casting	Complete	Complete	Complete WE 9/8/91
Powder Blending	Complete	Complete	Complete WE 9/8/91
Hot Pressing (N-Type)	Complete	Complete	Complete WE 11/1/91
Hot Pressing (P-Type)	Complete	Complete	Complete WE 10/20/91
Hot Pressing SiMo	Complete	Complete	Complete WE 1/26/92
Hot Pressing N-P Bond	Complete	Complete	Complete WE 1/26/92
Machining TE Parts			
Pellets & Segments	Complete	Complete	Complete WE 2/2/92
Hot Shoe Fabrication	Complete	Complete	Complete WE 2/16/92
First Bond	Complete	Complete	Preliminary
Si_3N_4 Coating	In Process	In Process	Preliminary
Second Bond	In Process	In Process	In Process
Nickel Plating	In Process	In Process	In Process
Couple Preassembly	In Process	N/A	In Process
Cold Stack Assembly	In Process	N/A	In Process
Unicouple Assembly	In Process	N/A	In Process
Wrapped Unicouple	In Process	N/A	In Process

WE = Week Ending

EMQ (Engineering, Manufacturing, and Quality) teams completed reviewing all drawings and specifications and made recommendations to the Management Steering Committee during this six month period. A detailed accounting of EMQ team accomplishments is provided in the next section, followed by a description of process readiness activities for unicouple production start-up.

Continued review of tooling has identified 404 tools for use on unicouple fabrication. Of these, 326 have been inspected, accepted and are available for use, 74 are being reworked or replaced, and 4 are in inspection.

Unicouple hardware production status at the close of this reporting period is shown in Table 2.4-2.

18 couple module assembly piece part fabrication and subassembly activities continue. The molybdenum foil for the insulation assembly was delivered in late February 1992 allowing foil shearing work to begin. Molybdenum foil was the last material procurement item waiting to be resolved. Completed unicouples are the pacing item for finishing the first 18 couple module assembly.

Test activity started at the end of the reporting period. A schedule has been established for the design of the test fixtures and preparation of the test plans, starting in March 1992 and running to the end of May 1992.

Table 2.4-2. Unicouple Hardware Production to Date

	Started	Accepted ✱					
	First Lot	Qual Lot		E-6		E-7	
		Qty	Yld%	Qty	Yld%	Qty	Yld%
Vacuum Castings	211*	81	100	50**	100	8	100
Powder Blends	87*	31	96.9	18	100		
Hot Pressings	272*	82	98.8	34	100		
N-P Bonds	39*	10	100				
Pellets	4428*						
Segments	5764*						
Hot Shoes	1570*						
First Bonds	631						
Coated First Bonds	384						
Coated Spacers	230						
Nickel Plating	550						
Couple Preassembly	48						
Brazed Rad. Assembly	249						
Cold Stack	48						
Unicouple	138						
Wrapped U/C	118						

✱ *Accepted for continuing production. For some items, final lot acceptance requires additional testing of samples later in the production process.*

* *No more first lot hardware in process, subsequent to process readiness approval, all hardware is being processed under flight quality criteria.*

** *Planned quantity of hardware is completed.*

Unicouple EMQ Campaigns

Introduction

During this reporting period, teams of engineers from Engineering, Manufacturing, and Quality Assurance (EMQ) completed review of all unicouple drawings and specifications. The goal was to generate documentation that will replicate the results achieved on the GPHS-RTG program with minimum change. Recommendations were reviewed with the EMQ Steering Committee (comprised of the Program Manager, and managers of Thermoelectric Materials Engineering, Thermoelectric Design Engineering, Thermoelectric Manufacturing, and Quality Assurance) for appropriate action. Unicouple EMQ teams directed successful process readiness fabrication trials for Thermoelectric Parts Machining, SiMo Hot Pressing, and N-P Bonding. In conjunction with machining process readiness, a series of TGA weight loss tests was completed, demonstrating that updated machining techniques do not affect Si_3N_4 coating lifetimes. Trials for First Bonding and Radiator Attachment Process Readiness demonstration, also led by unicouple EMQ teams, were in progress at the end of the reporting period. Highlights are described below.

Accomplishments: Document Review

In conjunction with reestablishment of the unicouple manufacturing line, EMQ teams have reviewed all unicouple drawings and specifications. At the end of the previous reporting period, approximately 70% of the 54 drawings and 144 specifications had been reviewed by EMQ teams. The remaining 30% were reviewed by EMQ teams in this reporting period and all recommendations have been reviewed by the EMQ Steering Committee. As a result, planned activities of the EMQ Steering Committee are complete.

The processes reviewed this period included all documentation associated with Nickel Plating, as well as items from Hot Pressing, First Bonding, Si_3N_4 Coating, Second Bonding, Couple Preassembly, Cold Stack Assembly, and Wrapped Unicouple Assembly. Specifications reviewed included materials, process, and quality specifications. In general, fewer modifications were recommended for these documents as compared with those reviewed in the last reporting period.

Significant drawing changes identified included:

- Adding previously unspecified grain orientation onto all tungsten and molybdenum part drawings.

- Specifying maximum burr sizes on all metallic part drawings.
- Deletion of a former GPHS-RTG Program-obsoleted part from the Machined Couple Preassembly drawing.

Significant process changes identified included:

- Elimination of redundant labeling on machined hot shoes.
- Transferring requirement for final cleaning of tungsten parts from outside vendor to in-house.
- Modifying the requirement for electrical connector de-burring to reflect actual burr measurements.
- Merging Nickel Plating work station planning instructions into the Nickel Plating process specification.
- Allowing the use of non-destructive methods, (x-ray fluorescence) XRF for the measurement of plating thicknesses.

Only the grain orientation requirement and plating thickness measurement proposed changes were found to require verification testing before incorporation into the unicouple drawings and specifications. Definition of grain orientation was obtained from metallographic inspection of GPHS-RTG residual hardware. Demonstration of XRF plating thickness measurement will take place concurrently with Nickel Plating process demonstration, using side-by-side destructive vs. XRF comparison tests. The GPHS-RTG program practice of sectioning the part to determine nickel plating thickness will continue to be used until data verifying XRF technique is accumulated and the XRF technique is approved for implementation.

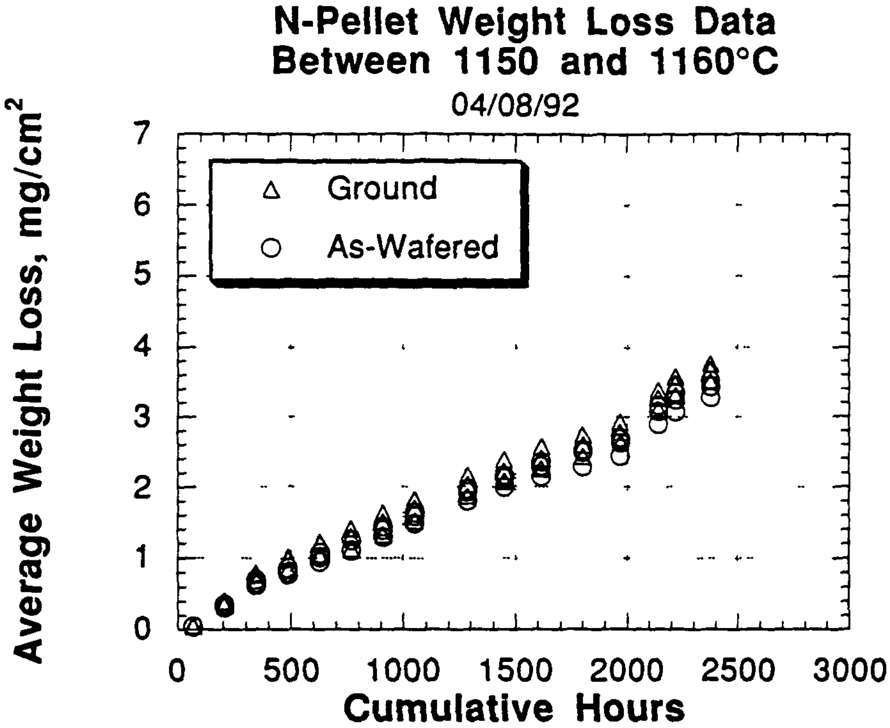
Accomplishments: Machining Verification Testing

The unicouple manufacturing plan is based on utilizing updated equipment and products for machining thermoelectric parts. During the GPHS-RTG program, all SiGe and SiMo parts were cut oversized from hot pressed compacts and ground to final dimensions. Improvements in equipment design now allow SiGe (pellets and segments) to be cut ("sliced and wafered") to final size. By eliminating the final grinding operation, the fabrication time is significantly reduced. The only effect produced by the modified machining procedures is a difference in surface roughness. The assessment of the EMQ teams was that Si_3N_4 coating lifetime is the only unicouple performance attribute that would be affected by this difference.

To determine the influence of final machining operation (ground or wafered) on Si_3N_4 performance, a series of accelerated life tests were performed. Tests consisted of aging coated parts in vacuum at temperatures exceeding normal operation limits and monitoring weight loss. These thermogravimetric analysis (TGA) tests were patterned after tests performed during the MHW and GPHS-RTG programs. Three pellets of each category (sliced/wafered vs. ground, N and P types) were Si_3N_4 coated, thermally cycled to simulate subsequent processing, and aged for up to 2500 hours at 1150°C. As shown in Figure EMQ-1, the performance of sliced/wafered pellets was equivalent to ground pellets. Coating loss rates are equal to or lower than MHW results (MHW TGA results are considered more reliable than GPHS-RTG TGA results from the 1981 GPHS-RTG reports).

Accomplishments: Process Readiness Support

During the start-up of the GPHS-RTG program, demonstration of an acceptable N-P bonding process was undoubtedly the most challenging technical problem in unicouple manufacturing. In this reporting period, acceptable N-P bonding and SiMo processes were concurrently demonstrated. Results from a final demonstration group of 10 N-P bonds were equivalent to those from the early portion of GPHS-RTG prime production (Figure EMQ-2). Difficulties in reproducing GPHS-RTG hot shoe and first bond strengths were overcome by increasing hot pressing control point temperature ~20°C above GPHS-RTG measured values. Note that available documentation does not provide detailed definition of the GPHS control temperature measurement. The CRAF/Cassini configuration is defined in detail. In addition, requirements for SiMo flatness and parallelism were tightened to ensure maximum contact during N-P bonding. Based on these results, process readiness approval was granted for both N-P bonding and SiMo hot pressing.



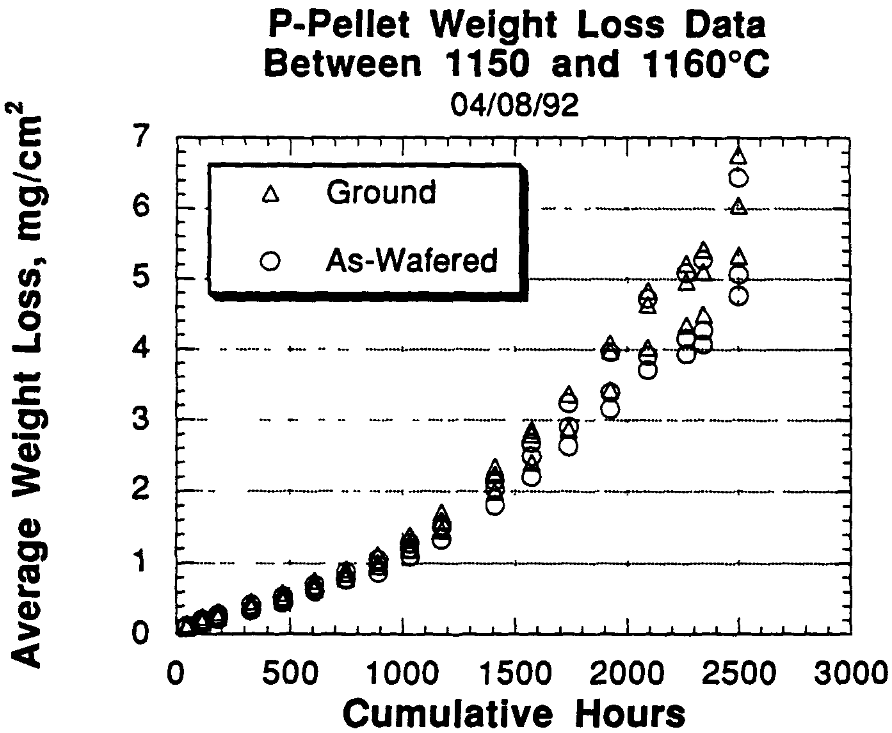


Figure EMQ-1. Results of Life Tests

N-P Bond ET#	Hot Shoe Machining ET#	N-SiMo Hot Pressing Temp(C)	P-SiMo Hot Pressing Temp(C)	Ti lot #	N-P Bonding Temp (C)	N-P Bond Reaction %	Avg. Hot Shoe Elect. Resist. (mohms)	Qty of Hot Shoes Failing Proof Load Test	Avg.Hot Shoe Load at Failure (kg)	First Bond Reaction %	Avg. First Bond Load at Failure (kg)
3209-4	3275-1	1420	1425	D847	1285	32	0.084	1	34	46	11.3
3209-6	3209-6*	1420	1425	D847	1300	32	0.098	0	37*	38	9.6*
3209-9	3275-4	1420	1425	1603	1300	32	0.082	1	40	39	10.6
3209-10	3275-5	1440	1445	1603	1300	33	0.084	2	29	39	10.8
3209-11	3275-2	1440	1445	D847	1300	34	0.090	1	34	47	10.0
3209-12	3275-8	1420	1425	1603	1285	31	0.086	2	33	35	10.2
3209-14	3275-7	1440	1445	1603	1300	30	0.088	0	37	25	12.3
3209-15	3209-15	1440	1445	1603	1285	31	0.089	0	34	35	11.0
3209-16	3209-16	1420	1425	1603	1300	26	0.090	0	37	36	11.0
3209-17	3209-17	1420	1425	1603	1285	24	0.095	0	37	43	12.1
				Average		***31***	***0.086***	***0.7***	***35.2***	***38.0***	***10.8***
				GPHS Avg.** N = 27	***FROM.......... 2/81-5/81***	***22***	***0.116***	***0.5***	***41***	***39***	***10.2***
				N = 22	***10/82-2/83***	***26***	***0.081***	***0.5***	***44***	***38***	***14.9***
				N = 20	***2/83-4/83***	***24***	***0.079***	***1.0***	***42***	***37***	***15.2***
				N = 24	***5/83-2/84***	***25***	***0.088***	***1.0***	***39***	***36***	***15.4***
	GPHS SPEC LIMITS	1420 (±15 if Eng'g & QAE apprv)	1425 (±15 if Eng'g & QAE apprv)		1265±10	35 max. (process control limit)	0.135 max	Test all at 22 kg	30 min. (process control limit)	45 max.	7.5 min.
	MODIFIED SPEC LIMITS	1420 (±20 if Eng'g & QAE apprv)	1425 (±20 if Eng'g & QAE apprv)		1285 (±15 if Eng'g & QAE apprv)	NO CHANGE	NO CHANGE	NO CHANGE	NO CHANGE	NO CHANGE	NO CHANGE

* ET 3209-6 hot shoes undersized in length by 4%.
** N = quantity of hot shoe lots

NOTES:
1. Ti lots from GPHS residual material.
2. All N-P bonds made in hot press HP-3.
3. Hot shoe load-at-failure data for each C/C lot represents the average of 4 to 6 hot shoes.
4. First bond load-at-failure data for each C/C lot represents the average of 3 to 5 first bonds.
5. Hot shoe load-at failure data for both GPHS and C/C lots do not include data from any hot shoes failing 22 kg proof test.

Figure EMQ-2. SiMo N-P Bond Process Readiness Results

Ongoing Activities

Demonstration of first bond process readiness has been delayed because post bonding inspections show "stains." These are believed to be due to contamination effects which appeared after bonding. A cleaning procedure believed to have been performed during GPHS-RTG (but not identified in the specifications) has improved post-bond cleanliness, but yields remain below the 65% goal. Efforts have been placed on improving handling methods and handling materials as well as the cleanliness of hot shoes before assembly.

Radiator attachment process readiness is proceeding with post-training hardware demonstration runs. Significant EMQ activities include clarifying the calibration procedure for the hydrogen brazing furnace and refining grit blasting techniques.

Process Readiness

Background

Startup of the unicouple production line has been separated into 13 separate campaigns or processes. Figure PR-1 shows these campaigns and their sequence for unicouple assembly. Prior to producing qualification lot and then flight lot hardware from a particular campaign, process readiness of that campaign must be achieved. A timeline showing the phases of unicouple production as established in the contract in relationship to process readiness is shown in Figure PR-2. A full description of process readiness requirements is provided by GE document GESP-7233, Process Readiness Review Plan.

Expanded detail of activities during the training lot production leading up to final process readiness is shown in Figure PR-3. The last portion of the training lot is the production of hardware items to demonstrate that the campaign is ready for final process readiness and hence the production of qualification lot hardware. In instances where results from the demonstration runs show that the process yields are not sufficient and/or a technical problem needs to be resolved, Engineering, Manufacturing and Quality (EMQ) team involvement is employed to investigate and provide a course of corrective action. Following EMQ team interaction, demonstration runs are repeated to prove process readiness.

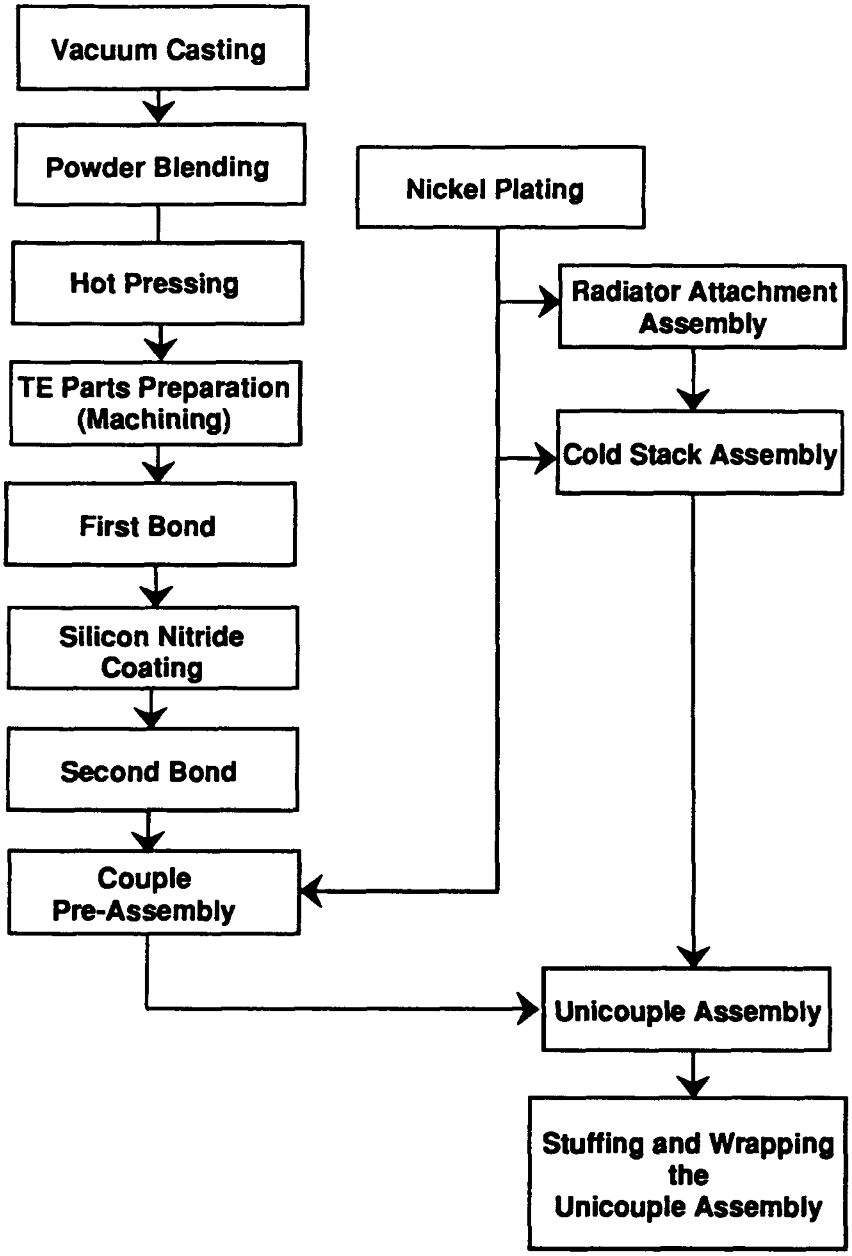


Figure PR-1. Process (Campaign) Assembly Sequence for Unicouple Fabrication

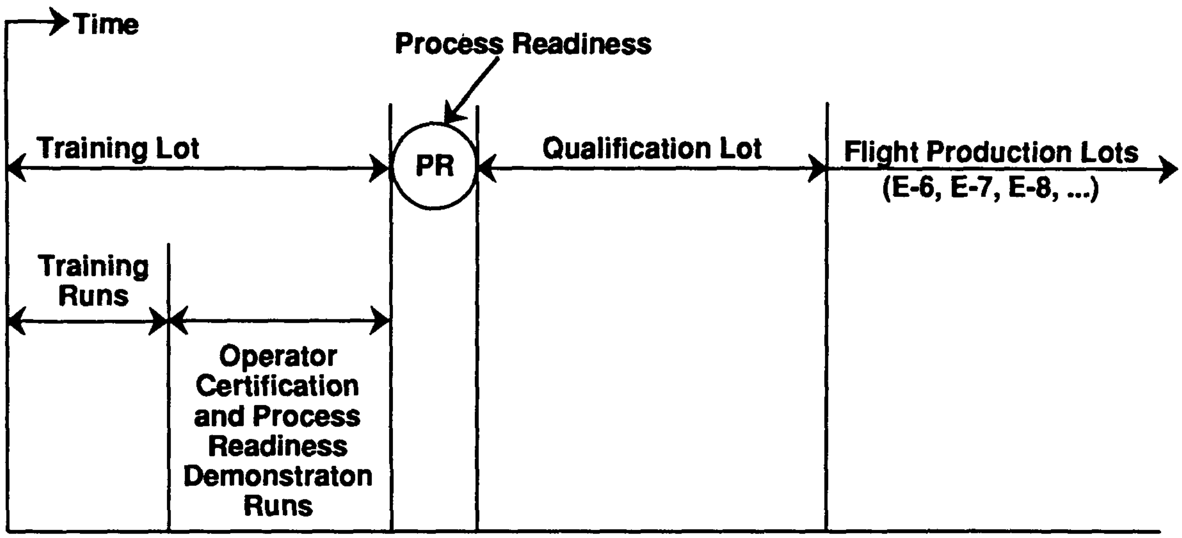


Figure PR-2. Relationship of Process Readiness in Unicouple Production Line Startup

Schedule Considerations

The sequential relationship of the unicouple campaign shown in Figure PR-1 is significant, since it identifies that the late finish of one campaign has a direct impact on the completion of process readiness for subsequent (or downstream) operations. As an example, the delay in completing vacuum casting final process readiness, caused a corresponding delay in powder blending which resulted in delays for hot pressing and subsequent campaigns. This series relationship between campaigns is an important aspect to recognize, since it leads to an understanding of the progress gained in unicouple process readiness.

During this reporting period, technical difficulties were encountered in hot pressing, thermoelectric parts preparation and first bond assembly operations, which resulted in a delay of achieving process readiness not only for these operations but also downstream operations. Details of those problems and their resolutions is addressed in the previous EMQ section of this report.

Through the months of October 1991 to February 1992, the impact of the technical problems in the various campaigns on the process readiness schedule was shown by projecting the slip dates for completion against the original dates in the plan.

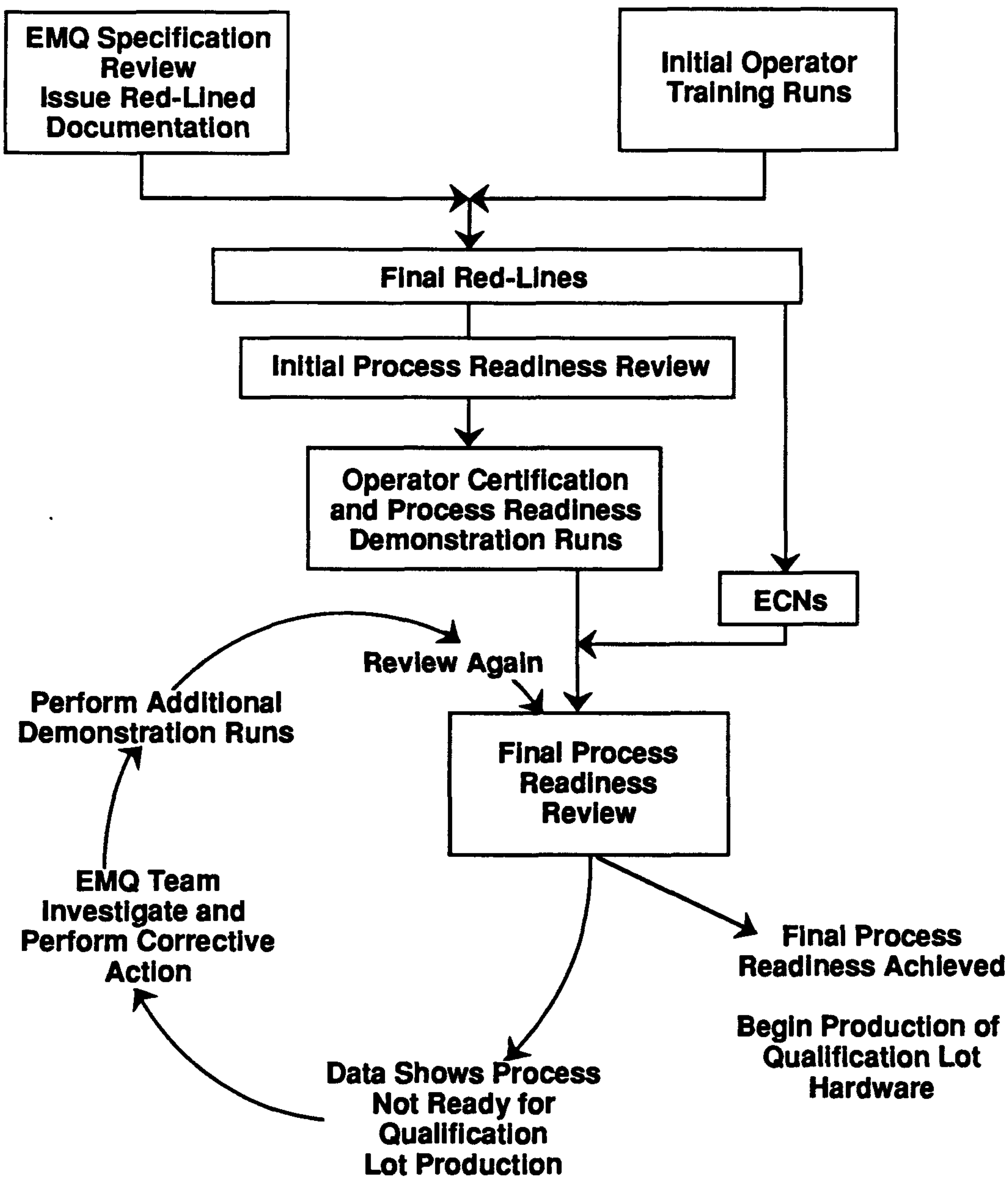


Figure PR-3. Progression Towards Final Process Readiness

Due mainly to the cumulative effects of technical problems, the status of unicouple process readiness at the end of February 1992 was four months behind the original plan. The startup of the unicouple production line was taking more time and requiring more support than initially planned. The continued presence of the EMQ team was required to resolve difficulties and provide successful demonstration runs. While this high level of support was not planned, the close relationship and thoroughness of the EMQ team has enhanced the process by adding detail and clarifying specifications. The enhancements reduce operator dependent actions and should improve product repeatability.

In March 1992, the unicouple process readiness schedule was replanned as a consequence of DOE funding constraints for GFYs 1992, 1993 and 1994. The funding constraints limited the amount of support that could be provided to the CRAF/Cassini program. The original plan for unicouple start-up was based on a larger staff and extensive use of overtime. With the reduced funding levels, this was no longer achievable. As a result of the lower level of support being applied to unicouple production startup, the duration to solve technical problems would be increased, and work on process readiness for the uncompleted campaigns could only proceed in a serial nature. The overall result of the funding reduction is a stretch-out of the process readiness schedule. Figure PR-4 shows the replanned process readiness schedule that was presented to DOE at the March 1992 monthly DOE review.

Progress Summary

Prior to this reporting period, process readiness had already been achieved for vacuum casting and powder blending operations. In October 1991, the major activities underway were hot pressing and thermoelectric parts preparation (machining). Final process readiness for hot pressing and thermoelectric parts preparation were completed during this reporting period. In March 1992, process readiness activities were well in progress for three campaigns: (1) First Bond Assembly; (2) Silicon Nitride Coating; and (3) Radiator Attachments Assembly. Expanded detail of process readiness status by campaign is provided in the following section.

Detailed Process Readiness Status by Campaign

Vacuum Casting

Final process readiness was completed on 3 September 1991. During this reporting period, castings were produced for qualification lot and flight lots.

Powder Blending

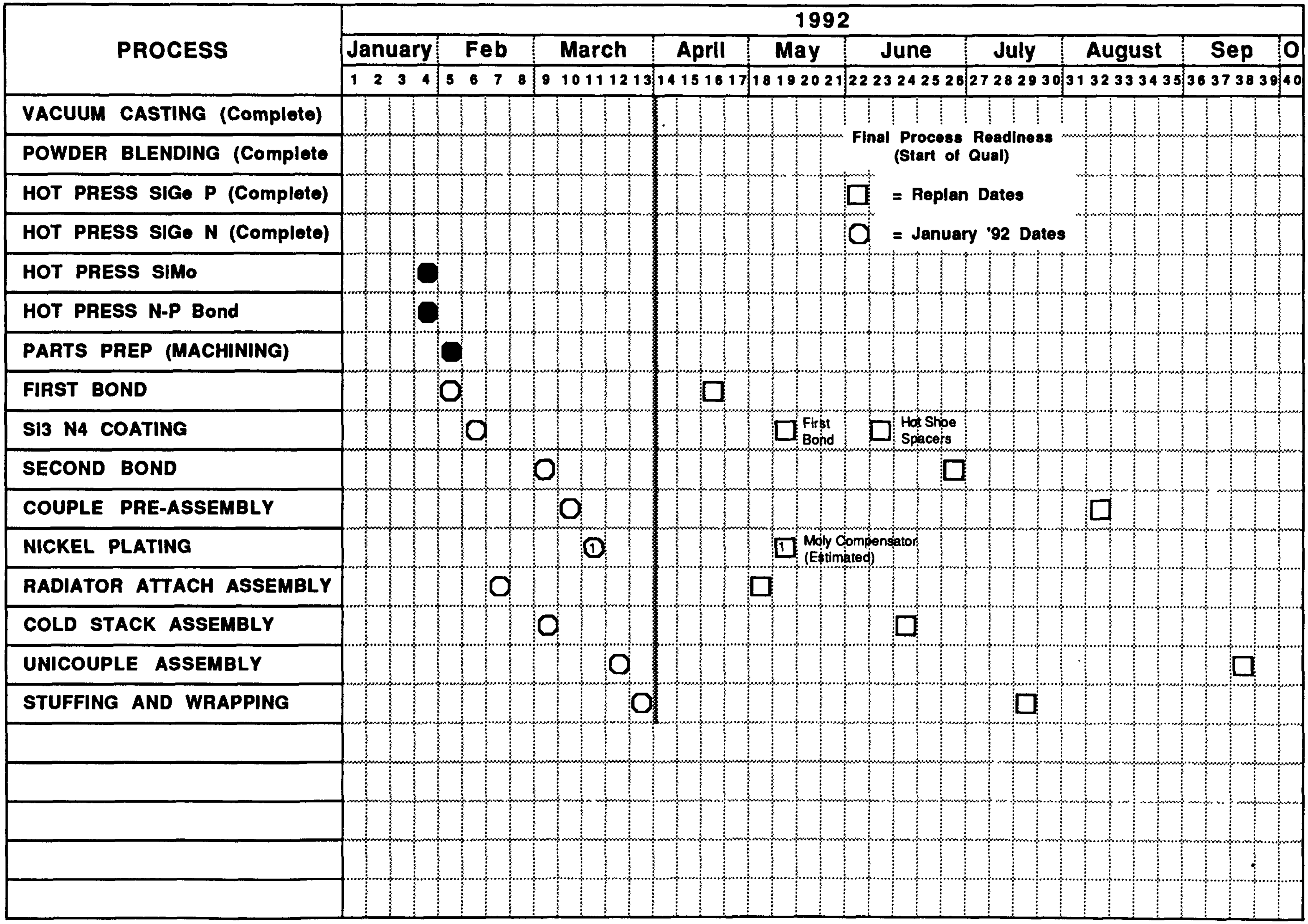
Final process readiness was completed on 3 September 1991. During this reporting period, blendings were produced for qualification lot and flight lots.

Hot Pressing

Hot pressing of SiGe P-type material (78% and 63.5%) was completed on 16 October 1991. No technical difficulties were encountered in readying the hot pressing operation of P-type SiGe for process readiness during this reporting period.

As discussed in the EMQ section of this report, difficulty in producing N-type SiGe material (78% and 634.5%) within the specification requirements for electrical resistivity delayed the completion of process readiness. Following continued oversight from EMQ members and additional demonstration runs, final process readiness for N-type SiGe hot pressing was achieved on 29 October 1991. The delay in completing process readiness for N-type SiGe hot pressing caused a subsequent delay in the thermoelectric parts preparation (machining) operation since N-type SiGe parts were not readily available for machining certification runs.

Process readiness for SiMo hot pressing, and N-P SiMo bond were linked together. Due to a problem in replicating N-P bond (hot shoe) strengths achieved in the GPHS-RTG program, both SiMo hot pressing and N-P bond processes were delayed. The hot pressing of SiMo compacts was being accomplished satisfactorily, but since the N-type and P-type SiMo compacts were feed material for the N-P bond, assurance that the SiMo compacts were acceptable could not be achieved until N-P bonds (hot



sak PMO:Process Readiness

Figure PR-4. Unicouple Process Readiness - Replanned Schedule (3/92)

shoes) were fabricated that met the specification requirements and were equivalent to hot shoes prepared in the GPHS-RTG program. As described in Figure PR-3, repeated cycles of EMQ corrective action and demonstration runs identified the cause of the problem and made the necessary adjustments. Reference the previous EMQ section for details of the problem resolution. Process readiness for SiMo hot press and N-P bond were jointly achieved on 21 January 1992. The delay in SiMo bond operation was significant, approximately two months, and caused a subsequent impact in thermoelectric parts preparation and first bond.

During this reporting period, refurbishment of Hot Press #2 (HP-2) was initiated and completed. An individual process readiness plan is being prepared and will include demonstration runs to ensure that HP-2 is ready for production of qualification and flight lot materials.

Thermoelectric Parts Preparation

The emphasis in the TE parts preparation (machining) operation to produce pellets, segments, and hot shoes was certification of the operators and the EMQ acceptance testing of the new slicing and wafering techniques through examination of Si_3N_4 coating life. Operators were being certified for 1) radius grinding of pellets and segments, 2) end grinding of pellets and segments, and 3) machining of hot shoes. From a dimensional standpoint, data from the certification runs showed that the TE parts were being acceptably produced within drawing tolerances. These results demonstrated the capability of the new slicing and wafering equipment to effectively machine TE parts. One problem that occurred during the certification runs was staining on the pellets, segments, and hot shoes. This staining problem had to be resolved prior to achieving process readiness. EMQ personnel investigated the problem and took the necessary steps to resolve the staining issue. The staining on the pellets and segments was due to fixture marks acquired during grinding operations. Removing sharp edges from the fixtures and returning to the coolant used in the GPHS-RTG program in place of deionized water, remedied the staining problem on these parts. Process readiness for machining of pellets and segments was completed on 27 January 1992. The hot shoe staining problem was solved by preventing the wafer machine coolant from drying on the parts and removing epoxy from in-process hot shoes by mechanical rather than chemical (solvent) means. Process readiness for hot shoe machining was completed on 14 February 1992. The duration required to solve the pellet, segment, and hot shoe staining issue and then demonstrate that the problems were eliminated added roughly one month to the schedule delay.

In a parallel path with the machining training, certification and demonstration runs, EMQ acceptance testing of the new machining techniques (*wafering and slicing) was also underway. As described in the EMQ section of this report, silicon nitride coating tests showed no adverse impact of the new machining methods.

First Bond Assembly

Due to the combined impact of the delay in hot pressing and in TE parts preparation, progress in the first bond assembly campaign was approximately four months behind the original plan. Significant hardware activity for first bond process readiness did not start until early February 1992 following machining process readiness. By the end of March, activities were still underway to achieve process readiness for first bond assembly. In the time span of February through March approximately 100 demonstration first bond assembly runs have been made with an overall inspection acceptance yield of 40%. This yield is less than the desired yield of 65% for final process readiness. The principal defect preventing process readiness for first bond assembly is contamination or staining on the hot shoe. Inspection data shows that the bond (pellet to hot shoe interface) and electrical characteristics of the assemblies are acceptable. EMQ team investigation of this problem has been and will continue to be performed until the problem is eliminated and the yield is improved.

Silicon Nitride Coating

The start of silicon nitride coating certification and demonstration runs was delayed due to the unavailability of sufficient quantities of first bond assemblies. Despite the fact that first bond process readiness has not been achieved, first bond assemblies made as part of process demonstration and accepted through inspection have been utilized in silicon nitride process readiness activities. Significant hardware activities in silicon nitride coating did not start until mid-March 1992. During March, the EMQ team issued the red-lined documentation required to begin demonstration runs. The first of two certification runs for one operator on first bond coating was successfully completed. Initial preparations were also in progress to begin certification runs for coating hot shoe spacers. At the end of March, no significant technical problems had been encountered in the silicon nitride coating campaign.

Second Bond

EMQ team and Steering Committee review of documentation for this campaign has been completed. Hardware activity related to second bond process readiness during this reporting period has been at a very low level. Substantial hardware progress will not begin until process readiness for first bond and silicon nitride coating is completed. An example of the impact caused by the funding constraints can be seen in this campaign since additional staff can not be provided to conduct advance second bond runs in parallel with first bond activities.

Couple Preassembly

Outside of the EMQ and Steering Committee review of documentation, no significant progress was achieved in the couple preassembly campaign during this reporting period. Consistent with the sequence of unicouple assembly and the replanned "stretched-out" schedule (Figure PR-4), hardware activities for this campaign will not begin until second bond process readiness is completed.

Nickel Plating

The status and accomplishments of the nickel plating campaign during this reporting period are closely linked with the delivery of new unicouple parts and the availability of plated residual material from the GPHS-RTG program. Due to difficulty in the procurement cycle in finalizing arrangements with vendors willing and capable to provide parts for the unicouple assembly (primarily parts in the cold stack subassembly) new parts were not available for nickel plating training, certification, and process readiness demonstration runs. On average, the delivery of unicouple parts ranges from six to eight months behind the original plan. Direct interaction of GE Manufacturing, Engineering, Quality and Purchasing staff with the vendors, including site visits, was implemented to improve vendor performance and initiate delivery. To further compound the impact of late delivery, some new parts require tumbling prior to nickel plating. Since new hardware was not available for plating, only minor progress related to the EMQ review of the process documentation was made in the nickel plating campaign during this reporting period. For the tumbling process prior to plating, engineering development work to define the parameters for tumbling was initiated. This engineering development effort was required since the tumbling data from the GPHS-RTG program was both inconsistent and insufficient to directly reestablish the process.

The availability of plated residual materials accepted in the former GPHS-RTG program has been essential in maintaining progress in campaigns dependent upon the nickel plating operation (radiator attachment assembly, cold stack assembly, and unicouple preassembly - refer to Figure PR-1). Use of residual items has negated the schedule delay which would have resulted in preparing (tumbling and plating) new hardware for use. A continual engineering effort has been ongoing this reporting period to verify that residual GPHS-RTG material is acceptable for use in the CRAF/Cassini RTG program. At the end of this period, all of the plated residual components needed for radiator attachment assembly were available for use in process readiness and qualification lot assemblies.

Radiator Attachment Assembly

EMQ and Steering Committee review of the documentation has been completed. EMQ team issuance of final red-lined documentation is required before process readiness demonstration runs can be initiated. Fabrication of radiator attachment assemblies for engineering evaluation purposes using fully trained operators has provided acceptable results. Activities undergoing EMQ team review at the end of March 1992 were 1) defining sand blasting techniques to remove burrs after the brazing operation, and 2) calibration of the hydrogen furnace to obtain the correct braze temperature. These issues must be resolved before process readiness can be obtained.

Cold Stack Assembly

EMQ and Steering Committee review of documentation complete with no other significant progress this reporting period.

Unicouple Assembly

EMQ and Steering Committee review of documentation complete with no other significant progress this reporting period.

Stuffing and Wrapping

EMQ and Steering Committee review of documentation complete with no other significant progress this reporting period.

2.5. ETG

Procurement activity continued for ETG hardware and detail procurement and in-house fabrication schedules are being finalized.

Continued review of tooling has identified 290 tools for use on ETG fabrication. Of these, 198 have been inspected, accepted and are available for use; 60 are being reworked or replaced; 12 are in inspection; and 20 are being inventoried and readied for inspection.

EHS activity to retrofit a unit for use with Q-1 is progressing. Planning and procedures for use with Q-1 have been initiated.

Procurement activity and piece parts fabrication have been initiated on the new PRD design.

2.6 GSE

A review of existing GSE was completed. Items requiring refurbishment were identified. Estimates for the recommended refurbishment are being prepared before submitting the refurbishment plan. Items needed immediately for use with Q-1 have been identified and permission to start work on these items has been requested.

2.7 RTG Shipping and Launch Support

RTG Shipping Package

Support was provided for the development of the new RTG transportation package. The program schedule was reviewed with comments provided to WHC. In addition, the thermal model was reviewed with suggested improvements forwarded to WHC for consideration. Information, data and drawings were provided on RTG features and characteristics to support the development of the new package.

Launch Support

GE supported launch site personnel planning launch activities by evaluating various prelaunch operations, environments and procedures under consideration for RTG processing, transfers, spacecraft mating and actual launch.

2.8 Designs, Reviews, Mission Studies

The latest Galileo/Ulysses power data (approximately 800 days for Galileo and 450 days for Ulysses) continues to indicate operation similar to previous space flights.

A review of the RTG power output data for Ulysses provided by JPL has been completed. During the very early days of the flight, the power appeared to be decaying at a faster rate than had been expected. However, the Ulysses data was inconclusive since wide variations in the data existed due to the method used in deriving RTG power output. The power output is inferred from various readings of a number of onboard components and not measured directly at the RTG output source.

When the entire body of data for the one year operation was examined and compared with the power time profiles from Voyager and LES 8/9, it is found that the power profile behaves similar to those and lies within the flight data derived envelope. Using this derived envelope, the power at end-of-mission (EOM) is within specification for Ulysses. For the Design Review, the analytical model and predictions were updated. The Ulysses telemetry data behaves according to the updated model and EOM performance within specification is predicted. Figure 2.8-1 shows the updated prediction in comparison to the Ulysses telemetry data. To explain the steeper-than-expected decline in the Ulysses (F-3) RTG power output early in the mission, parametric studies were performed using the GE analytical model. Results of the analyses have shown that the steep early decline is attributable to dopant redisolution which occurs due to prelaunch operation of the RTG. The analyses further show that the dopant redisolution affects only the initial portion of the mission and EOM power remains unchanged. Similar analyses and results were obtained in an investigation of Galileo RTG performance.

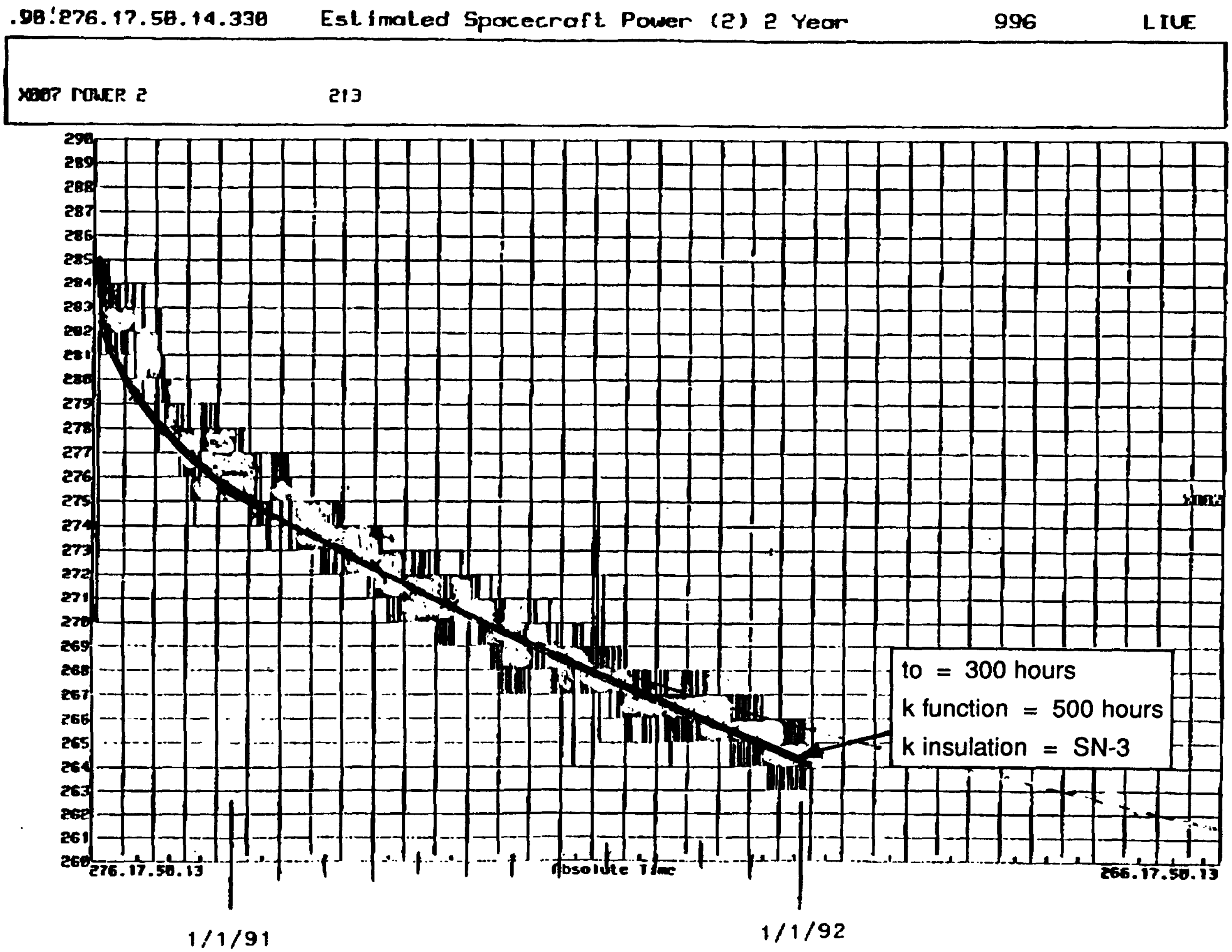


Figure 2.8-1. Update Using Lower Dopant Age at Launch

2.9 Project Management, Quality Assurance and Reliability

2.9.1 Project Management

During this period, the Program was managed with the Management System established for the CRAF/Cassini RTG Program. It includes a Control Room where detailed work schedules are posted on the walls and daily meetings are held to review current priorities and resolve problems. Weekly meetings are held to review the overall status of the Program. Government representatives regularly attend the weekly operations review and the weekly status briefing on topics selected by the in-house DOE representative.

Contract Modification M009 was received this period. The significant changes include:

a) Delete fabrication of thermal and mass model added by contract change A004;

b) Add refurbishment of electric heat source for Q-1 ETG (in effect, this adds one EHS to the contract work scope);

c) Substitute fabrication of one new EHS for refurbishment of one existing EHS; and

d) Supersede Proposal VF91065 submitted in response to contract modification A004 with the proposal for M009.

GE Proposal VF92018 was submitted in response to contract modification M009. A fact finding session was held on GE Proposal VF91114 (response to contract modification M006) and the requested information has been forwarded to the COTR.

Schedule management activity during this period included completion of the planned annual update to the Milestone Schedule Plan, monthly status report submissions, additional detailed schedule planning, and the incorporation of Contract Modification M009 into the Milestone Schedule Plan.

The annual update of the Milestone Schedule Plan (Revision A), dated 18 October 1991, incorporated Contract Modifications A004 and M006. In addition, development and use of the detailed schedules had uncovered minor errors in the duration and logic flow of some activities in the network schedule database. These errors were corrected and incorporated into the schedule plan. The plan was further revised to reflect contract changes per Contract Modification M009 and submitted as Revision B, dated 24 February 1992.

Note: Revision B does not reflect the program modifications anticipated as a result of the elimination of the CRAF mission.

Detailed Control Room schedules for the procurement and manufacture of hardware elements were further developed. Schedule status was updated weekly for the operations reviews. Procedures established in the last period to download the GE schedule data (mainframe computer based) into a format compatible with the DOE PMS format (personal computer based) were used to generate the monthly status updates to the Program PMS database.

GE PMS operation continued during this period. DOE representatives reviewed the GE PMS system and its application to the Program. Initial feedback on satisfaction of contract requirements was very positive. The GE scheduling system was examined in conjunction with the DOE review of the GE PMS system and found to meet all the applicable performance measurement system criteria.

Monthly status updates to the Program PMS plan established in September 1991 were submitted during this period. Per the planned approach, the data from the GE PMS system is being adapted to the content and format required by the DOE Program PMS. Results from the two systems have been consistent, although the two systems use different algorithms to calculate earned value.

All contract required reports and data were delivered on schedule. The following documents from the Contact Deliverable Requirements List (CDRLs) were submitted in this reporting period:

- Product Specification for GPHS-RTG (CDRL B.1)
- System Specification for GPHS-RTG (CDRL B.1)
- Environmental Criteria and Test Requirements Specification for GPHS-RTG (CDRL B.1)

DOE approval of the following plans was received during this reporting period:

- Configuration Management Plan (CDRL A.4)
- Quality Assurance Program Plan (CDRL A.3)
- Reliability Program Plan (CDRL A.5)
- 18 Couple Module Test Plan (CDRL B.5)
- Non-Destructive Test Plan (CDRL A.11)
- Procurement Plan (CDRL A.6)
- Property Management Plan (CDRL A.8)

Plans being reworked on the basis of DOE comments include:

- Inspection and Test Plan (CDRL A.12)
- Software Management Test Plan (CDRL A.7)
- Safety Test Program Plan (CDRL A.10)
- GPHS-RTG Interface Working Agreement (CDRL A.21)

Attached is the CRAF/Cassini RTG Program calendar for 3Q91 and 1Q92 which shows program meetings and other important program-related events for this period.

2.9.2 Quality Assurance

Quality Plans and Documents

A List of Special Processes (CDRL B.13) associated with the fabrication and assembly of the unicouples and the ETG converter was compiled and submitted to DOE. The list included the thermoelectric processes, the major assembly operations of the ETG converter, the E-Beam welding of the fin and tube assembly to the converter shell, and the ETG processing.

The following Quality Assurance and Reliability documents were updated to incorporate DOE comments, resubmitted, and approved by DOE:

- Quality Assurance Program Plan (CDRL A.3)
- Reliability Program Plan (CDRL A.5)
- Non-destructive Test Plan (CDRL A.11)
- The 18 Couple Test Plan (CDRL B.5)

Operator Training and Certification

Operator and inspector training and certification continued. Operators and inspectors have completed the certification requirements for the following processes:

Vacuum Casting	2 Operators
Powder Blending	2 Operators
Hot Pressing	2 Operators
Powder Blending	2 Operators
Machining Thermoelectric Parts	
Pellets and Segments	
Radius Grinding	4 Operators
End Grinding	2 Operators
Hot Shoe Fabrication	2 Operators
Diffusion Bonding	
First Bond	2 Operators
Inspection	4 Inspectors
(Seebeck, Density, Resistivity)	

Process Readiness/Production Readiness

Process Readiness Reviews continued during this reporting period. Final Process Readiness Reviews for the vacuum hot pressing of 63.5% and 78% N-type SiGe materials were held and the processes were approved for qualification lot production. The Final Process Readiness Reviews for SiMo hot pressing and N-P bond processes were completed.

The Final Process Readiness Review for pellets, segments, and hot shoe machining was completed and concurrence was reached that the process was ready for production of parts for qualification lot unicouples.

Preliminary Process Readiness Reviews were completed for the first bond process and for the silicon nitride coating process for first bond assemblies. The processes are being checked out and reverified using process specifications updated by the EMQ review team. Operators are being trained and prepared for certification during these operations.

Production readiness reviews are held following the completion of the qualification lot of hardware in each process. Production readiness approval is required to begin the manufacture of hardware for flight RTG units.

Thermoelectric Production Readiness Reviews were completed for the following operations:

- Vacuum Casting Process
- Powder Blending; 63.5% and 78% SiGe
- Vacuum Hot Pressing; 63.5% and 78% SiGe
- SiMo Powder Blending
- SiMo Hot Press

The plan being followed for the Production Readiness Reviews is to present a synopsis of the results of the internal Process Readiness Reviews for each of the individual thermoelectric processes as they are completed. The results of the qualification lot production yield data are reviewed and evaluated. For these early processes, yield has been 100%. Objective for the Production Readiness Reviews is to reach concurrence with DOE that we have demonstrated that the process is ready for production of material suitable for the flight RTG unicouples.

Receiving Inspection/Mechanical Inspection

The materials for thermoelectric production are being received and checked against the requirements of the purchase order. The material certifications are verified and compared against the specifications. Parts for the converter and the EHS are being inspected.

Thermoelectric Production

The product from thermoelectric production is being inspected and measured. In-process checks are being made, and the characteristics of the castings and hot pressings are being measured. Machined thermoelectric parts are being inspected with optical microscopes, and dimensional checks are being made. Product characteristics such as density, Seebeck coefficient, resistivity, and yield data are being plotted and monitored on a regular basis.

Quality Assurance and Reliability Status Meetings

Quality Assurance and Reliability Status Meetings were held on 13 November 1991 and 26 February 1992. Results of the meetings were summarized in published meeting minutes.

DOE Audit

DOE conducted an NQA-1 program audit on 22-24 January 1992. The audit covered most of the 18 elements of NQA-1. Emphasis was placed on the handling of traceability data, nonconforming material control, documentation of the thermoelectric process controls, and quality records. Follow-up action to reach consensus on the definition of quality records is required.

2.9.3 Reliability Engineering

The Reliability Analysis Report, including FMECA analyses, was completed and submitted to DOE as CDRL B.9. Reliability inputs, including FMECA analyses, were completed for the RTG Design Review in November.

The Reliability Assessment Report (CDRL B.15) was reviewed and DOE comments were incorporated.

2.H CAGO Acquisition

2.H.1 CAGO: Unicouple Equipment

The following CAGO activity was completed during this six month period:

- The third rebuilt surface grinder was received, installed, and checked out.
- Both hydrogen furnaces were upgraded and put on line.
  A further upgrade to the hydrogen furnaces to meet updated safety guidelines is planned and vendor quotes have been requested.
- A strength test machine was received, installed, and checked out.
- Six new Brew bonding furnaces were received, installed, and checked out.
- A TM vacuum furnace for bakeout of EHS hardware was received, installed, and checked out.
- The large vacuum furnace upgrade was completed.
- Rebuild of Hot Press #2 was completed.
- Two new Si_3N_4 CVD furnaces were delivered and installation of one unit started.
  One of the old units will be left in place until process readiness has been established on the new unit.

2.H.2 CAGO: ETG Equipment

Procurement activity for the Gas Management System (GMS) equipment refurbishment continues with delivery of components expected in April.

2.H.3 CAGO: MIS

The baseline system is in use. A planned feature for data storage (removable hard disk drive) was added this period. MIS equipment was used to convert the DOE PMS Review Plan from DOS format to the Macintosh format so that in-place GE personnel and equipment could provide support during the review. A computer disk with a working draft of the Review/Report, in Macintosh format, was provided to DOE at the close of the review for editing and augmentation.

CRAF/Cassini Calendar

4th QTR 1991

	M	T	W	T	F	S	S	FW
OCTOBER	30	1	2	3 Shipping Container Meeting at Germantown (Reinstrom)	4	5	6	40
	7	8	9	10 Safety Test Program Support Meeting w/Teledyne at VF Anderson/Bradshaw/ Hemler/Giokis	11 Preliminary Process Readiness Review *First Bond Assembly*	12	3	41
	14	15	16 Process Readiness Review *Vacuum Hot Pressing*	17	18 Annual Updates: • Labor Plan • Cost Plan • Milestone Schedule Plan • SF-294 • RD&D Report	19	20	42
	21	22	23 Facilities Review Mehner - Valley Forge	24 Monthly Program Status Meeting Valley Forge Monthly Reports Due to DOE	25 Contracts Meeting - VF Rosenberg/Jones	26	27	43
	28 Process Readiness Review *Vacuum Hot Pressing N-Type*	29 CVS Working Group Meeting (Fairchild Space) Reinstrom	30 GE Safety Program Meeting Valley Forge	31	1	2	3	44
NOVEMBER	4	5 Vacuum Casting Qualification Data Production Readiness Review	6 Quarterly Program Status Review at Fairchild	7	8	9	10	45
	11	12	13 Quality Status Meeting DOE/WAES At Valley Forge	14	15	16	17	46
	18	19	20	21 CRAF/Cassini RTG Design Review [Stouffer's - Valley Forge]	22	23	24	47
	25 Monthly Reports Due to DOE	26	27	28 *HOLIDAY*	29 *HOLIDAY*	30	1	48
DECEMBER	2	3 ← Ground Operations Working Group KSC - Reinstrom	4 →	5	6	7	8	49
	9	10	11	12	13	14	15	50
	16	17 Risk Code DOE Review Valley Forge Hemler, Bradshaw, Giokas CVS Working Group Meeting ORNL - Reinstrom	18 Monthly Program Review - Germantown	19	20	21	22	51
	23 Monthly Reports Due to DOE	24	25 *HOLIDAY*	26 *HOLIDAY*	27 *HOLIDAY*	28	29	52
	30	31	1 *HOLIDAY*	2	3	4	5	1

CRAF/Cassini Calendar

1st QTR 1992

Month	M	T	W	T	F	S	S	FW
JANUARY			1	2	3	4	5	01
JANUARY	6	7	8	9	10	11	12	02
JANUARY	13 ← 9th Annual Symposium on Space Nuclear Power → Albuquerque, New Mexico *Hemler/Braun*	14	15	16	17	18	19	03
JANUARY	20	21 N-P Bond/ Machining Process Readiness Reviews	22 Monthly Program Status Review Valley Forge ← Quality Audit - Valley Forge →	23	24 Monthly Reports Due to DOE	25	26	04
JANUARY	27 Parts Prep Machining of Pellets & Segments Final Process Readiness Review	28	29 Segment Readiness Review Mound *Reinstrom*	30	31 *Due to DOE* • Three Action Items from Design Review • CDRL B.13 - Special Processes Listing • CDRL B.15 - Reliability Assessment Report	1	2	05
FEBRUARY	3 Clad Vent Set Working Group FS- Reinstrom	4 C/C Quarterly Review At Fairchild	5 Fuel Powder Specs FS - Hemler Schedule for Shipping Package DOE HQ - Hemler	6 GOWG Meeting ← Kennedy Space Center → *Reinstrom*	7	8	9	06
FEBRUARY	10	11	12	13	14 Final Process Readiness Review for Parts Prep Machining of Hot Shoes	15	16	07
FEBRUARY	17	18	19	20	21	22	23	08
FEBRUARY	24 Monthly Reports Due to DOE ← PMS-SAR by DOE Review Team →	25	26 Quality Status Meeting Valley Forge	27	28	29	1	09
MARCH	2	3 DOE Review of RSA and Safety Test Plan DOE HQ *Hemler/Bradshaw/Giokas*	4	5 CVS Readiness Review Los Alamos *Reinstrom*	6	7	8	10
MARCH	9	10 Monthly Program Review Status Meeting Los Alamos *Hemler/Reinstrom*	11	12 Shipping Container Quarterly Review Hanford *Reinstrom/Cockfield*	13	14	15	11
MARCH	16	17	18	19	20	21	22	12
MARCH	23	24 Monthly Reports Due to DOE	25 Dynamic Environment Technical Meeting JPL *Kauffman*	26	27	28	29	13