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CWO NO. 6,
RTG USER ACTIVITIES
IN AEROSPACE NUCLEAR SAFETY
AND OPERATIONS—
AN INTERIM RESOURCE
ESTIMATE

CASE FILE
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Hittman Associates, Inc.

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COLUMBIA, MARYLAND

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ABSTRACT

This report describes the work performed by Hittman Associates, Inc. under JPL Contract Work Order No. 6.

TABLE OF CONTENTS

	<u>Page</u>
TECHNICAL CONTENT STATEMENT	ii
LEGAL NOTICE	iii
ABSTRACT	iv
TABLE OF CONTENTS	v
I. SUMMARY	I-1
II. INTRODUCTION	II-1
III. SAFETY DOCUMENTATION SUPPORT REQUIREMENTS	III-1
A. Reference Design Document Inputs	III-2
B. Accident Model Document Inputs	III-5
C. Nuclear Safety Analysis Document	III-6
D. Milestone Schedule	III-7
IV. LAUNCH APPROVAL SUPPORT ACTIVITIES	IV-1
A. Related Documentation Requirements	IV-1
B. Analysis Requirements	IV-2
C. Meetings, Interagency Interfaces, and Other JPL Action Items	IV-3
D. Milestone Schedule	IV-4
V. DESIGN SUPPORT ACTIVITIES.	V-1
A. Nuclear Safety Activities	V-1
B. Operations Activities	V-4
C. Milestone Schedule	V-6
VI. ON-LAB AND LAUNCH SITE OPERATIONS	VI-1
A. On-Lab Sequence of Events	VI-2
B. Launch Site Sequence of Events	VI-4

TABLE OF CONTENTS (Continued)

	<u>Page</u>
C. Operations Activities	VI-7
D. Operations Hazard Evaluation	VI-9
E. Nuclear Operations Working Group Support Activities	VI-10
F. Milestone Schedule	VI-10
VII. EMERGENCY PROCEDURE MANUAL	VII-1
A. Emergency Procedure Manual Outline	VII-1
B. Discussion of Content within Manual Sections	VII-3
C. Milestone Schedule	VII-7
VIII. USER'S SAFETY ANALYSIS REPORT	VIII-1
A. User's Safety Analysis Report Outline	VIII-1
B. User's Safety Analysis Report Description	VIII-3
C. Milestone Schedule	VIII-8
IX. NEW TECHNOLOGY	IX-1
X. REFERENCES	X-1

I. SUMMARY

This report describes the efforts which the Jet Propulsion Laboratory (JPL), as the radioisotope thermoelectric generator (RTG) user, will have to perform as part of an outer planets spacecraft program. The report is both an elaboration of the work areas covered for CWO No. 5 (Ref. 1) and a description of user tasks not heretofore presented. Taken together, this report and the data in Reference 1 supply the general scope of a user resource estimate. Six major areas of work have been identified. These are:

- Safety Documentation Support Requirements
- Launch Approval Request
- Design Support Activities
- On-Lab and Launch Site Operations
- Emergency Procedures Manual
- User's Safety Analysis Report

In each work area a general description of user requirements has been presented. The descriptions are one step removed from the point where manpower allocations can be assigned. This work order is the middle of a three-step process to arrive at a complete resource estimate. In the last step (CWO No. 7), it is intended that this report will be included and displayed as discrete tasks and subtasks.

Each of the six areas of work has been broken down to identify those aspects of the task which relate to "nuclear safety" and those which reflect the category of "operations." In addition, the role of various JPL groups has been described. These latter include the Nuclear Power Sources Group (NPSG), the Project Group (Project), and the Nuclear Operations Working Group (NOWG) subcommittee.

II. INTRODUCTION

This report was prepared to satisfy the requirements of JPL Contract Work Order No. 6 (Ref. 2). The contract work order defines the effort for this task as follows:

Elaborate upon the efforts and activities in the area of Aerospace Nuclear Safety and Operations (ANS&O), as they were identified in response to Contract Work Order (CWO) No. 5, that would typically be the responsibility of the user (connotes NASA/JPL) of the radioisotope thermoelectric generator (RTG). Features and characteristics of the outer-planets type of mission and hardware should be used for guidelines, constraints, and orientation. All subsequent activities and the reporting thereof are to be organized to reflect the basic category classifications of "nuclear safety" and of "operations."

The Hittman Associates response to CWO No. 5 is given by Reference 1.

III. SAFETY DOCUMENTATION SUPPORT REQUIREMENTS

This section identifies and discusses the information and data, associated with the primary safety documentation, which JPL is responsible for providing to the AEC and/or the AEC's RTG prime contractor. JPL's role in these activities will range from merely serving as a catalyst in obtaining the data from others, to actually generating the required information. Since the timing element is critical in a nuclear safety program, this section also develops a general span time and milestone schedule for these JPL activities, based on a late 1976 launch.

Safety documentation requirements for space nuclear power systems have been defined by the AEC and have been followed for all recent systems. It is assumed that the same general guidelines will apply to the outer planets' RTG application.

The safety documentation is prepared by the RTG contractor in three volumes. Volume I is the Reference Design Document (RDD) and provides a definition and description of all systems, facilities, equipment, mission profiles and operating conditions, and all basic data which will be used in the safety analyses. Volume II is the Accident Model Document (AMD). Its purpose is to identify all real and potential events which could lead to nuclear safety problems, along with a quantitative assessment of the event probabilities. Volume III is the Nuclear Safety Analysis Document (NSAD) which provides an evaluation of system response to the defined events along with the resulting radiological consequences. The three volumes constitute the Safety Analysis Report (SAR). The SAR is issued in three versions. The Preliminary Safety Analysis Report (PSAR) is submitted within a few months after completion of the conceptual design phase. Its purpose is to describe the system and mission and to identify potential problem areas as early as possible. An interim or updated version (ISAR) is issued a few months prior to delivery of the flight system. The date is variable, and this version is usually timed to include most of the key test and analysis results. It is used as the basis for initiating formal flight approval reviews. The final SAR (FSAR) is issued at least six months prior to flight. It contains final details and data which were not available earlier and changes which have been made as a result of the reviews. In a sense, it is considered a historical document since it is issued after the flight approval proceedings are virtually completed. The following sections identify and describe the data and information which JPL will be required to provide for each volume of the safety documentation.

A. Reference Design Document Inputs

The major portion of JPL's safety documentation inputs will be required for the Reference Design Document.

1. Spacecraft

A complete description of the spacecraft, its systems, and subsystems is required, as the spacecraft can influence both the exposure and response of the RTG to accident environments. Most of the required data will be obtained through the project. The information is required for the preliminary report but often the spacecraft design is not completed in-time for the PSAR. At a minimum, a semi-quantitative description is required for the PSAR. The final detailed design description must be available for the ISAR. Any late modifications are documented in the FSAR. It should be noted that any major changes which occur at any time in the program which could have a significant effect on the safety effort are transmitted immediately to the cognizant groups through established channels. Such major changes do not await the next issue of the SAR. This is true not only for the spacecraft data but for all JPL inputs. The required spacecraft-related data include the following:

- (a) Overall design layout and description including component structures in both the launch and deployed configurations.
- (b) Operational characteristics which can be related to abort and RTG release. These include separation and deployment procedures, guidance, attitude controls, and auxiliary propulsion provisions and equipment.
- (c) Telemetry and other instrumentation, which may reflect RTG characteristics in an abort situation. Ground station locations are to be included.
- (d) Materials, weights, and dimensions of the subsystems including engineering properties of special or unusual materials such as might be required for safety analyses.
- (e) Description of special equipment, devices, etc., such as separation mechanisms, pressure vessels, pyrotechnics, and others which could have a bearing on safety.
- (f) Aerodynamic properties of the spacecraft in all possible deployed and undeployed configurations as required for trajectory and reentry analyses. Depending on the complexity of the configuration and the availability of experimental data for similar bodies, initial estimates might have to be supplemented by later wind tunnel tests.
- (g) Environmental parameters at the RTG location--vibration, temperature, pressure versus trajectory time.

2. Launch Vehicle

Most of the required launch vehicle information will be obtained directly from the manufacturers or through the NASA center which provides the vehicle to JPL. Unless the launch vehicle or one of its major components is new, much of the basic data should be available before the ISAR or perhaps even the FSAR.

The required launch vehicle data includes the following:

- (a) Overall design layout and structure of each stage. Separation characteristics are to be described so that abort configurations may be analyzed.
- (b) Dimensions, weights, and specific locations of major systems and subsystems.
- (c) Materials and materials properties with special emphasis on materials and components of interest to safety. For example, materials which could burn, explode, or form fragments in a pad abort should be characterized.
- (d) Propulsion system details including propellant quantities and properties, and grain configuration for solid propellants.
- (e) Ignition, separation, guidance, and control system details should include special design features, mode of initiation and operation, redundancies, and other safety features, and some insight into possible failure modes.
- (f) Flight weight chronology should include curves of weight versus trajectory time, weights at specific staging points, and consumed weights during various operations.
- (g) Operational and performance characteristics including thrust versus time, burning times of stages, payload capability data, etc.
- (h) Destruct capabilities including instrumentation for detecting vehicle status, transmission and readout of same, destruct system initiation and operating principles (command and automatic), redundancies, safety features, destruct criteria.
- (i) Tracking systems.
- (j) Telemetry and other launch vehicle instrumentation.

- (k) Aerodynamic characteristics for all vehicle configurations in various stages of flight. This should include aerodynamic coefficients and likely reentry mode for the various stage combinations.

3. Reference Trajectories

It is unlikely that the final reference trajectories will be defined until late in the safety documentation sequence. Reasonable estimates will be required for the PSAR and a good approximation of the final trajectory is required for the ISAR. Most of the information will be obtained from the project, with some coming from the launch vehicle manufacturers. (The latter may have to come through DOD.)

The required reference trajectory data includes the following:

- (a) Staging event times and conditions - graphical and tabular form
- (b) Vehicle parameters versus time - including time histories of altitude, velocity, flight path angle, acceleration, attitude, range, and instantaneous impact point

4. Launch Site and Range

Some of the required data in this category will be readily available from earlier programs. Data on new facilities which are specific to the subject mission will be obtained largely from the project and from appropriate NASA and DOD facilities groups at the launch site.

The required launch site and range data include the following:

- (a) Complete description of all JPL/NASA facilities in which a fueled RTG will be housed for any reason while at the launch site. This should include location, facility layout, design, and construction features.
- (b) A listing and detailed description of all JPL/NASA-provided equipment to be used for handling, transporting, storing, or testing the RTG either on or off the spacecraft. This should include design details, planned and maximum ranges of operating conditions, and RTG equipment mounting details. Any special materials of potential interest to safety should be identified. Safety features of equipment should be described and launch pad cooling capabilities included.
- (c) All JPL/NASA-provided emergency equipment and services at the launch site and range should be identified and described. This will include monitoring, decontamination, and recovery

equipment. Numbers, locations, and capabilities should be stressed.

- (d) Responsibilities of JPL/NASA personnel in both normal and emergency operations.
- (e) Tracking and data acquisition systems and equipment which are under JPL/NASA cognizance should be identified and described with respect to function, operating capabilities and span time of operation.
- (f) Special ground support equipment provided by JPL/NASA which is not covered under any of the other categories should be described.

5. Range Safety

In its role as the user, JPL will be responsible for coordinating the range safety data. The NPSG will work closely with project and range personnel as well as with the AEC in developing this information. The PSAR will contain a description of the more-or-less standard methods and equipment used to detect flight malfunctions and terminate flight. It should also list and discuss possible criteria for destruct action. Since these criteria must be developed on the basis of safety analysis results, it is unlikely that they can be quantified until the ISAR issue. The ISAR will contain a detailed and updated description of methods and equipment to be used for the specific mission. It will also present the Range Safety Officer's criteria for destruct action. The Jet Propulsion Laboratory must take an active role in coordinating the requirements of various groups with respect to destruct criteria. In developing optimum destruct criteria, safety, and mission objectives must be considered simultaneously. It might not be possible to finalize these criteria until the final issue of the safety documentation.

6. Reference Operational Procedures

Inputs will be required with respect to what is to be done by JPL/NASA at JPL/NASA facilities during the entire prelaunch phase. This covers the period from heat source fueling through launch and consists of a general description of procedure sequence and time spans.

B. Accident Model Document Inputs

The Jet Propulsion Laboratory will maintain a continuous coordination effort with the AEC and its contractor in connection with the AMD preparation. However, the specific inputs for which JPL is responsible are few and are as follows.

1. Failure Mode Analysis

The failure mode analysis or accident network development and evaluations form the basis of the AMD. The Jet Propulsion Laboratory will be required to provide data concerning launch vehicle failure history, failure mode identification, and both experimental and calculated failure probabilities. As much of this data as possible should be provided for the PSAR but some of the data are not likely to be available before the ISAR. Most of the required information will be obtained through the NASA center which provides the vehicle to JPL.

2. Abort Trajectories

Additional details on the spacecraft and launch vehicle will be required to assist the AEC contractor in generating abort trajectories. These will include physical characteristics, aerodynamic properties and possibly materials properties. Breakup analyses involving the spacecraft and launch vehicle may be the responsibility of the user. These analyses will require a detailed aerothermodynamic evaluation of the many configurations which may reenter (all involving the RTG). Responsibility for breakup analyses will be defined in the program documentation (see Reference 1).

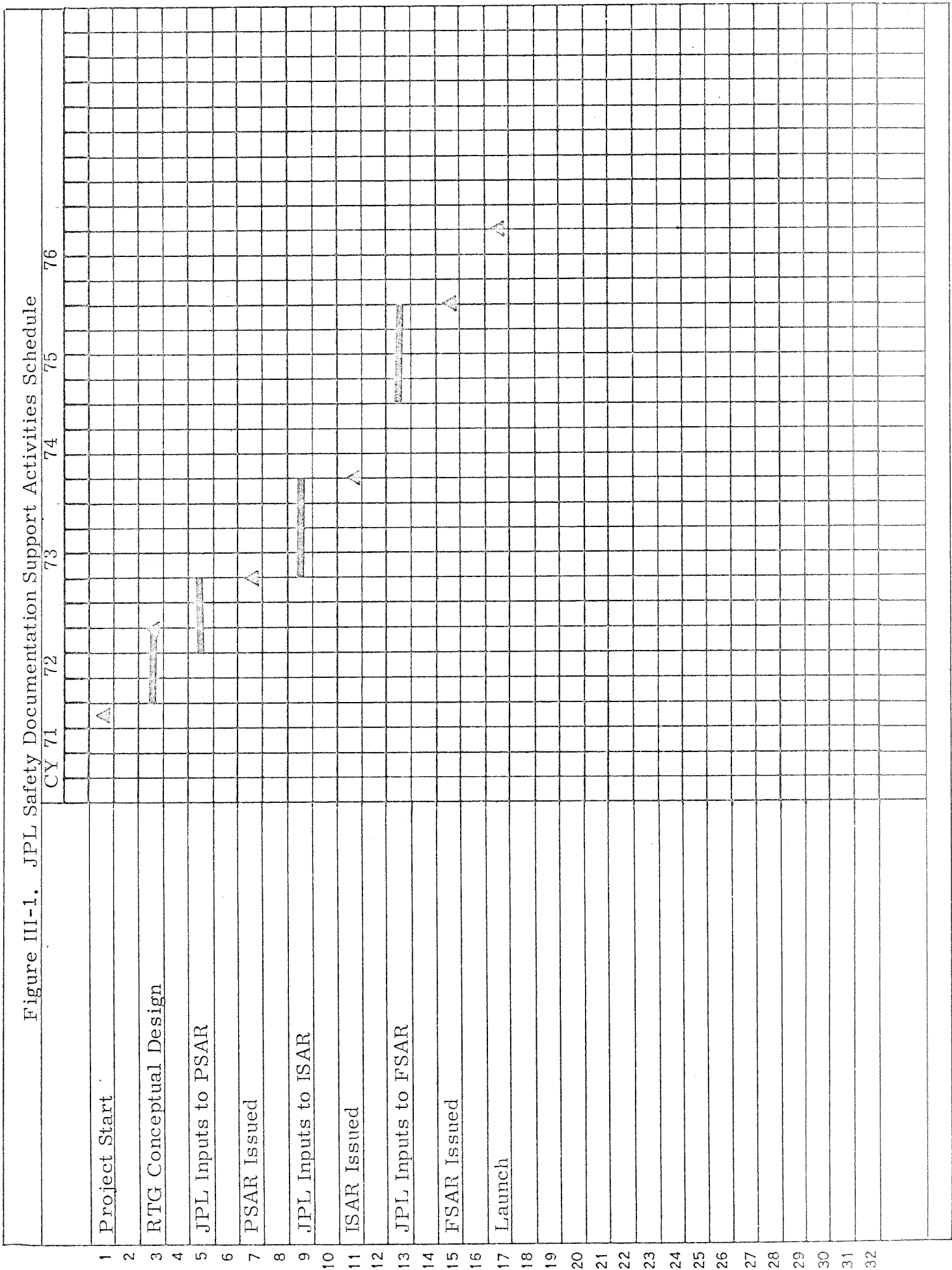
C. Nuclear Safety Analysis Document

The Jet Propulsion Laboratory will be responsible for providing the results of any pertinent tests on the spacecraft, launch vehicle, and ground support equipment. Most of these inputs will probably not be available prior to the ISAR.

D. Milestone Schedule

Figure III-1 shows the typical schedule and major milestones for JPL safety documentation support activities based upon a 1976 launch.

Figure III-1. JPL Safety Documentation Support Activities Schedule



IV. LAUNCH APPROVAL SUPPORT ACTIVITIES

A detailed description of the launch approval procedure has been presented in Reference 1. The exact sequence of events has varied from program to program, and the outer planets mission, too, is likely to have its unique aspects. The extent of JPL participation and the absolute schedule of events will depend upon the safety problems encountered and the progress of the nuclear safety program relative to the total program schedule. These cannot be predicted at the present time. However, the discussions which follow relate to a typical situation and will suffice for resource planning purposes.

A. Related Documentation Requirements

There are four major documentation items associated with the launch approval procedure. This assumes that all nuclear safety activities and documentation are directed toward the ultimate objective of launch approval. The major documentation item is the AEC Safety Analysis Report (SAR), with which JPL will have a significant involvement. This has been covered separately in Section III of this report. Thus, any JPL effort required in support of the SAR preparation and finalization will not be considered within the scope of launch approval support activities.

The second document of interest is an independent evaluation of operational safety by the Air Force Nuclear Power System Safety Group (NPSSG). The evaluation is performed largely by a technical group at Kirtland Air Force Base but represents the coordinated position of the DOD, in general. The NPSSG assessment is concerned with the safety of all operations involving the RTG at the launch site and in the downrange areas under their cognizance. Both personnel and property safety are of importance since the launch will involve Air Force personnel and an Air Force facility. A portion of the data and information required by the NPSSG will be obtained and details during the course of the NPSSG evaluation. This data will involve system design information, details on launch site operations, as well as the liftoff and ascent phases of the mission. JPL might also be requested to confer with the NPSSG and to review certain aspects of the work prior to publication. In general, this task will be essentially one of data transmission and no independent JPL analyses are anticipated.

The Jet Propulsion Laboratory will participate in the preparation of the NASA Staff Paper which presents the official NASA/user position regarding system and mission safety. Such papers are prepared by each of the four participating agencies (NASA, AEC, DOD, DOS) after all analysis, tests, and other supporting information have been reviewed. (DOT will also participate in launch approval but with a restricted role since they are concerned with transport to the launch site.) The support will involve technical and management decisions regarding safety inadequacies, unresolved items, and overall recommendations concerning additional requirements and approval to launch.

Following the preparation of Staff Papers, the Interagency Ad Hoc Safety Panel meets. The product of this Panel is the Safety Evaluation Report (SER). The SER, as described in Reference 2, is distinguished from the SAR in that it is an evaluation of overall mission-related hazards and their consequences rather than an analysis of systems or operations. Much of the basic data required for the SER will be obtained from the SAR and other documents. However JPL, as the user, will assist the NASA panel member in this joint AEC/DOD/NASA effort. This activity will involve manipulation and evaluation of data and possibly some limited additional analysis effort.

Aside from the major documentation items delineated above, it will be necessary for JPL to prepare and issue numerous memoranda, letters, and other minor documents throughout the launch approval span. This can be considered part of an overall low-level support effort.

B. Analysis Requirements

The Jet Propulsion Laboratory launch approval support activities, in the form of analysis, will be primarily related to safety documentation items. The extent of analysis can be as small or as great as JPL program philosophy and funding dictate. At the present time, it is anticipated that a minimum of independent analyses will be performed.

The Jet Propulsion Laboratory will conduct detailed reviews of each issue of the SAR. Some analytical effort should be planned in connection with these reviews, particularly the interim version. It might be necessary to check critical analyses in areas where potential problems are indicated. It might further be desirable to conduct sensitivity analyses to evaluate the effects of certain parameter changes on the results.

Some analysis effort should be planned in connection with preparation of the NASA Staff Paper. As noted earlier, this will be a joint effort between NASA and JPL. Any analytical support will have to come from JPL.

Action items generally result from the Interagency Ad Hoc Safety Panel Meetings. These will generally be in the form of requests for additional information. It is likely that some of these action items will be on JPL. They will entail data acquisition and possibly some analysis in areas pertaining to mission environments, spacecraft design details, and interfaces.

Finally, JPL might be required to perform some analyses in connection with the SER preparation, as noted earlier. Additional minor analysis requirements might arise from time to time, but generally this type of support will be associated with the major safety documentation items.

C. Meetings, Interagency Interfaces, and Other JPL Action Items

On the basis of past history, a rather large number of meetings can be anticipated in connection with the request for launch approval. Some of these will be major meetings involving all the cognizant and supporting groups. Others will be smaller meetings of more limited scope and will involve only some of the parties. As the user, it is important that JPL be represented at most, if not all, of these meetings. The more significant meetings and interface efforts are identified below. In addition, there might be approximately 10 less formal meetings of committees or subgroups on a variety of related topics during the course of the proceedings.

- (1) Planning Meeting - Early in the safety program, a preliminary meeting will be held with the Interagency Ad Hoc Safety Panel and other participants. The purpose is to discuss the system and mission concepts, as well as the planned safety program and approach, and to establish a milestone schedule for the launch approval proceedings. This generally is a very important meeting in that it develops the philosophy and ground rules for all subsequent activities.
- (2) PSAR Review Meeting - Following issuance of the PSAR, all cognizant groups perform reviews to varying degrees. Written comments and questions are submitted to the AEC within one to two months and then a meeting is held to discuss the reviews and the general progress of the safety program to that date.
- (3) Test Plan Meeting - Key safety test plans and procedures are submitted to the launch approval participants as they are developed. These are reviewed for adequacy and then comments, questions, and recommendations are submitted. When all, or most, of the safety test plans and procedures have been issued and reviewed, a meeting is convened for the purpose of discussing and resolving the comments. The prime purpose of this meeting is to assure that all Interagency Panel members and other cognizant groups are in general agreement with the test program before it is run. Test procedures are finalized on the basis of this meeting.
- (4) Test and Analysis Review Meeting - Chronologically, this meeting occurs after the issuance of the ISAR and when the major portion of the system tests and analyses have been completed. The purpose is to present and discuss the results and to identify any marginal or problem areas. Requirements for further work are established. At this point in time the final risk analysis is generally not completed and only preliminary estimates of potential population exposures and probabilities are available. Nevertheless,

the outcome of this meeting should provide a good indication as to whether the approval will be relatively straightforward or whether significant additional work is required to satisfy the Panel.

- (5) NPSSG Evaluation Meeting - A meeting will be held to review the results of the NPSSG safety assessment. This is an important meeting because it provides a forum for resolution of differences between the AEC and NPSSG evaluations. It also provides a good indication as to whether the DOD will approve the launch from their facility without restrictions or will require additional safety verification.
- (6) Final Panel Meeting - At the completion of the safety program, the Interagency Ad Hoc Safety Panel and cognizant supporting groups convene for a series of final review meetings. The overall safety status and results are reviewed in detail and conclusions are formulated and summarized. The Panel prepares the SER on the basis of this meeting.
- (7) NASC Meeting - One of the final steps in the launch approval process is the convening of the National Aeronautics and Space Council to review the safety findings and make a recommendation to the President.

As noted earlier, in addition to these major meetings, there may be several of a less formal nature. Furthermore, JPL should plan to provide a continuous low-level liaison effort throughout the launch approval proceedings.

D. Milestone Schedule

Figure IV-1 presents a schedule for JPL launch approval support activities based on a 1976 launch.

V. DESIGN SUPPORT ACTIVITIES

A. Nuclear Safety Activities

1. RTG Design

The AEC has responsibility for design of the RTG for an outer planets application. As the user, JPL must maintain an awareness of the RTG development effort and indeed will supply some of the parameters necessary for a satisfactory RTG design. The mechanisms governing user involvement in the RTG contractor work will be contained within the AEC/JPL Interagency Agreement and the Technical Interface Requirements Document.

The first step in developing user support of RTG design is for the user, the AEC, and the RTG contractor to agree upon certain program ground rules. The ground rules will be contained in several specifications as noted above. The content of these specifications has been discussed in CWO No. 5 (Ref. 2).

Since the user will typically exercise a minimal role in development of the RTG power supply, RTG safety design support will become primarily a liaison type of task.

a. Systems Liaison. The NPSG must be knowledgeable in all the systems aspects of the program. It is desirable that the following areas of RTG development be monitored, even if on a low-level of effort:

- (1) Material selection and characterization
- (2) Radioisotope fuel form development and studies
- (3) Component design, manufacture, and quality control
- (4) Nominal RTG operating parameters and environments
- (5) RTG qualification testing
- (6) Nuclear radiation dose rates and temporary shielding requirements
- (7) Configuration control

As pointed out in Reference 2, several methods are available to satisfy this monitoring function. For a low-level of effort approach, a continuing document review is appropriate. Interagency program agreements should clarify the documentation requirements.

b. User Safety Studies. Independent studies pertaining to problems of safety will be required to supplement the results of contractor studies. Unfortunately, the exact scope of these studies cannot be determined at this time since they are a function of many unknowns. These unknowns include:

- (1) What the AEC contractor funding level is
- (2) What problems are encountered that relate to any of the RTG interfaces where the user has responsibility
- (3) What type of interagency agreement is worked out

The total number of hours required for independent user safety studies can be worked out on the basis of a number of premises or assumptions and a general feel for how much user involvement is desired. Note that the safety studies referred to in this section are to be differentiated from those already described in Section III. In general, the studies here are special requirements and should not fall into the area of Launch Approval Support noted in Section IV.

2. RTG/Spacecraft Interfaces

a. Mechanical. As part of nuclear safety design support, the JPL NPSG should monitor and support the design of the mechanical interface between the spacecraft and RTG power supply. The mechanical attachment of the RTG to the spacecraft will affect the reentry characteristics of the RTG. (Different attachments produce different RTG release times and hence a variety of RTG reentry trajectories.) Mechanical attachment characteristics are also important inasmuch as they determine the transmissibility of vibration loads from spacecraft to RTG. The vibration spectrum may be a key input for assuring that the reentry protection of the RTG is demonstrated.

b. Thermal. Thermal characteristics of the interface must be defined for the RTG in the launch operational configurations. Thermal interface parameters may be required for reentry safety analyses. As part of the interface will be the responsibility of JPL, the JPL Project Group and NPSG will have to begin by defining responsibilities in an interface document. A thermal interface requirement also exists between the RTG and spacecraft as a result of on-pad cooling requirements. The RTG or RTG enclosure may require cooling to prevent heat shield oxidation and/or to preclude damage to sensitive subsystems and components present in the vicinity of the interface.

c. Nuclear Radiation. An interface requirement for nuclear radiation must be defined in terms of an allowable personnel dose rate from the RTG. The ease of mechanical attachment of the RTG to the spacecraft will be examined in terms of radiation limitations.

3. Mission Planning

An important nuclear safety interface with mission planning exists throughout the program. In general, the NPSG should advise the Project in several key areas of mission planning. Each mission of an outer planet series will have a somewhat different nuclear safety outlook. The following general areas should be covered:

- (a) Political Implications - To date no requirements have been formulated which relate to a release of substantial amounts of radioactive material in an outer planet environment. Some general response to this possibility should be prepared and available prior to the release of the SAR on the RTG.
- (b) Configuration Alternatives - Any change in spacecraft or launch vehicle configuration should be evaluated from a nuclear safety viewpoint. As an example, substitute upper stages may pose a different hazard from propellant explosion.
- (c) Tracking Aids - Requirements for tracking and reentry aids should be established in the event of earth orbit.
- (d) Trajectory Planning - Trajectory alternatives should consider the hazards of an abort over land masses along the trajectory path.

4. User Testing

The formulation of all user tests involving the RTG should reflect concurrence by nuclear safety personnel. An interface between safety and test operations can be achieved by safety approval of all procedural and specification documents involving RTG usage. This includes some of the on-lab operations and many of the prelaunch activities.

As required documents are generated by the outer planet Project Group, nuclear safety personnel will have to act in an advisory capacity, reviewing all tests, recommending and approving those approaches which pose the least nuclear safety hazard. There is an overlap between the activities described in this section and the operations evaluation covered in Section VI.

5. Meeting Attendance and Support

Attendance of key meetings will help implement user design support activities in the nuclear safety area. Some meetings may require planning by the user. The various types of RTG meetings which the user may attend are as follows:

- (a) Planning
- (b) Status
- (c) Formal safety and system review
- (d) Formal system acceptance
- (e) Training
- (f) Inspection and dry runs

Considerable time should be allocated for attending and supporting various meetings. For further discussion, see Page VI-7 of Reference 1 and Page IV-3 of this report.

B. Operations Activities

1. User GSE Requirements

The user GSE requirements will be dependent upon interagency agreements as well as the funding level of the RTG contractor during the program duration. In general, it is expected that the RTG contractor will be responsible for the design and fabrication of all GSE which will normally be necessary for a laboratory test environment, transportation, handling, or launch pad environment. There may be exceptions to this generality, particularly for the launch pad requirements.

At this point in time, a detailed description of GSE is not available. However, it can be assumed that at least the following safety-related items will be required:

- (a) Shipping Containers - for transfer and storage of the heat sources and the converters or RTGs.
- (b) RTG and/or Heat Source Handling Dolly - for moving the RTG within the laboratory or test area.
- (c) Hoist Bar or Equivalent - an appropriate tool for raising and mating the RTG to the spacecraft.
- (d) Test Console - an instrumentation and power supply console will be required for powering electrically heated generators and for monitoring parameters of all RTGs under test.
- (e) Portable Monitoring Package - for measuring temperature, pressure, radioactivity, etc. when the heat source is in a shipping container.
- (f) Portable Radiation Shielding
- (g) RTG Assembly Tools
- (h) Heat Source Cooling and/or Inert Gas Fill Equipment

In addition to the above, a forklift truck and/or hoist will probably be necessary to move the heat source in the shipping container.

For on-lab operations, no activities are contemplated which would require special precautions for radioactive fuel immobilization. Laboratory operations conforming to the general provisions of References 3 and 4 will

be adequate to handle the fueled RTGs. If it is decided at a later date to perform balance tests with the spacecraft and RTG, the requirement for building a protective enclosure around the RTGs should be evaluated.

Items (a) through (e) of the GSE will, in all likelihood, be provided by the AEC contractor. Clearly, the requirements for this GSE at JPL must be made clear at the program outset. A user training program will be required for familiarization and operation of all GSE, regardless of its origin. Part of the training program will have to be safety oriented.

The necessity for Item (f) of the GSE will depend upon several factors including RTG radiation levels compared to allowables, length of time required to perform assembly and/or test operations, and the number of technicians available. Item (f) may be provided by the user, particularly if user radiological standards are more stringent than those of the AEC.

The basic design requirements (Ref. 5) for the MHW RTG indicate that the heat source may be shipped separately from the converter. If this approach is used, assembly and disassembly of the RTG will have to be made both on-lab and at the launch site. To accomplish the assembly/disassembly operation, special handling tools (GSE Item (g)) will be required. This GSE would be supplied by the AEC. An electrically heated generator is desirable for on-lab engineering development tests. These tests are peculiar to developing JPL procedures and may require special handling and assembly tools. This GSE could be the financial responsibility of the user.

In-air cooling requirements of the RTG will depend upon the final RTG design evolved for the outer planets application. Active cooling will require special GSE (Item (h)) which the AEC will supply. Similarly, if an inert gas approach is used to protect the converter and heat source, it is reasonable to expect that any supporting GSE will also be supplied by the RTG contractor.

In planning for GSE support requirements, at least two areas should be carefully investigated to determine whether JPL will have to design and provide the GSE hardware. These are:

- (a) Special requirements dictated by using an electrically heated generator or some type of RTG model to develop procedures
- (b) GSE required only at the launch site. These would accommodate special operations and tests required by JPL at the launch site only. Such equipment would not be used during any other phase of the program.

2. GSE Interfaces

The use of GSE for on-lab operations will involve JPL personnel (or a JPL spacecraft contractor), JPL procedures, and will be under the direction of a JPL test coordinator. At the launch site, the use of GSE will again be a JPL or JPL contractor responsibility under the direction of the spacecraft

test coordinator. AEC contractor personnel will act in an advisory capacity. The user has complete responsibility for checkout and installation of the RTG and hence the accompanying GSE. The primary design interface which must be established is with the RTG contractor who will provide most of the GSE but will not use it at the launch site. Design of the SGE must meet with JPL requirements and will necessitate a considerable liaison effort.

3. Use of RTG Models

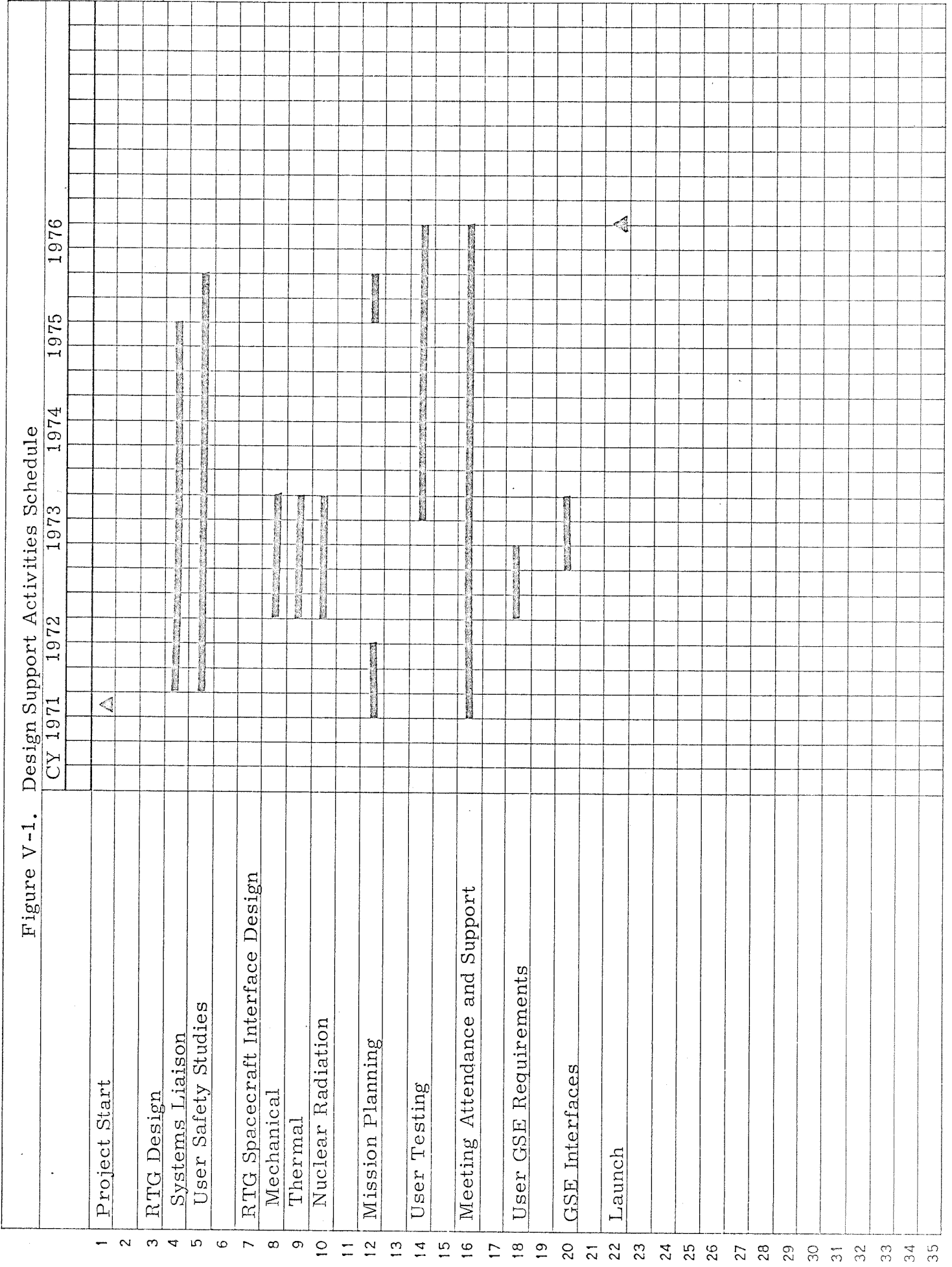
In addition to development and fabrication of fueled RTGs, an RTG program also includes requirements for electrically heated generator and generator models. In Section VI, the use of an electrically heated RTG, or a model simulating the RTG mass, is examined from a sequence standpoint. Depending on the type of procedures which JPL may desire to simulate prior to receiving fueled RTGs, specific design requirements may exist for RTG models. As an example, if the electrical heaters in the generator are to operate for all phases of handling, then the GSE electrical power interface will have to be designed to accommodate considerable movement of this hardware.

Because TOPS will require multiple RTGs in a modular approach, models may be required to simulate mass on the spacecraft. Such hardware would be a specific requirement for TOPS and their design and manufacture might be done completely by JPL groups.

C. Milestone Schedule

Figure V-1 shows a typical schedule and major milestones for JPL design support activities. The schedule is based upon a 1976 launch.

Figure V-1. Design Support Activities Schedule



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35

VI. ON-LAB AND LAUNCH SITE OPERATIONS

As user of the RTG, JPL will have responsibility for activities involving the RTG during two periods of the spacecraft development. These activities are divided here into "on-lab" and "prelaunch." On-lab is defined as those activities which will be carried out at JPL-Pasadena during checkout and testing of the RTG. These will be both separate from and in conjunction with the spacecraft. Prelaunch activities occur at the Eastern Test Range (ETR) and are concerned with storage, assembly, checkout, and testing of the RTG in conjunction with the spacecraft. Whereas JPL will have sole responsibility for developing on-lab activities and procedures, the responsibility for prelaunch operations will be shared with the Air Force test wing, NASA-Lewis, and possibly the AEC or its RTG contractor. In the context used here, JPL includes not only JPL personnel but also any contractor which JPL may choose to develop and test the spacecraft.

An evaluation of on-lab and prelaunch activities will form the basis for a user-oriented Safety Analysis Report. The report (discussed in Section VIII) will serve the purposes of:

- Satisfying the requirements of the JPL Nuclear Operations Working Group
- Providing the AEC with sufficient information so that the AEC will permit the RTG to be stored and tested at JPL and launch site operations

In order to receive and test the RTG at a JPL facility, a nuclear safety capability must be established. The capability involves specially trained personnel, complete health physics coverage, facilities which assure maximum radiological safety, and detailed test procedures. The operational safety program must comply with the provisions contained in the AEC regulations (Refs. 3 and 4).

At the present time no licensing for JPL is anticipated. The regulations contain provisions wherein the AEC may exempt operation at JPL test facilities from special nuclear material licensing. With an exemption, the AEC/ALO Operational Safety Division radiation safety requirements will be enforced. With the above approach, the AEC will maintain control and ownership of the fueled RTG (or heat source alone) at all times. The Jet Propulsion Laboratory will have custody of the RTG during on-lab and most launch site operations. Typically, AEC will be responsible for transportation and will be the custodian during transit. It is probable that while the RTG is at ETR, the Air Force will be responsible for on-site transportation. The details of custody and transportation responsibility should be contained in an interagency agreement (see discussions of "Interface and Program Requirements" in Reference 2). In any event, the user will have to work out the procedures for handling and using the RTG during all phases following acceptance from the RTG contractor, except transportation.

A. On-Lab Sequence of Events

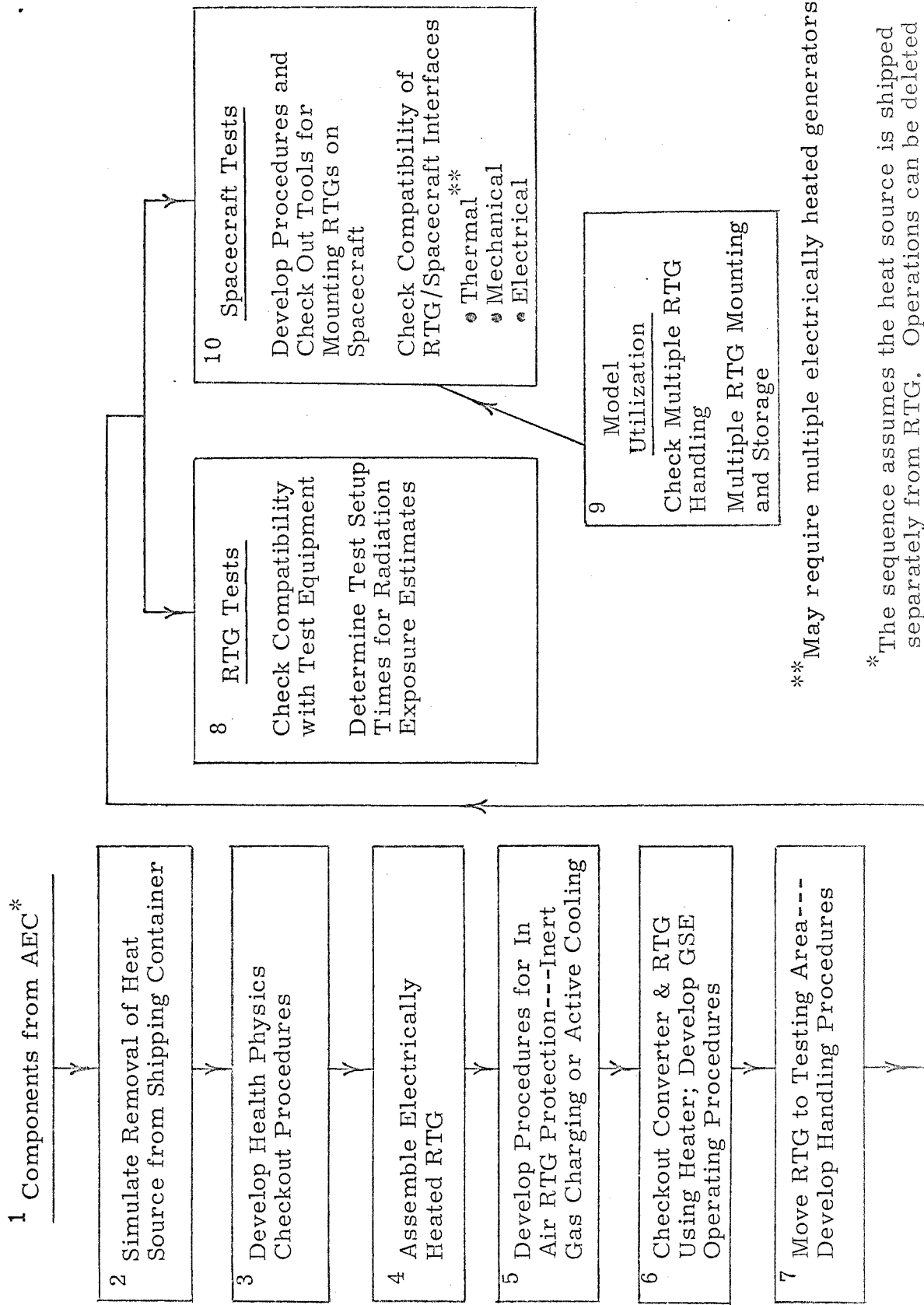
The first step in the JPL on-lab operations program will be to describe the various tests, movements, handling, storage, etc., for the RTG. The purpose of the description is to provide a basis for writing procedures which cover all phases of the on-lab operations. Generally, the description will cover the following:

- (1) Brief physical description and layout of facilities involved in the test
- (2) Detailed chronological layout of all operations involving the RTG from receiving to eventual shipping
- (3) Proximity and time information on personnel movements related to the RTG

Preliminary sequences of events for on-lab operations are shown in Figures VI-1 and VI-2. As early as feasible, this sequence should be expanded into a more detailed form that can include manpower requirements, exposure times and/or expected radiation doses per step, support equipment requirements, etc.

The overall on-lab sequence of events has been divided into two parts to cover engineering development of the fueled RTG operations sequence and the actual handling and testing of fueled RTGs. It is assumed in the sequences that the heat source may be shipped separately from the converter and power conditioning unit. (The term "converter" is loosely taken herein to include both converter and the power conditioning unit.) Clearly, the requirement to assemble the RTG on-lab introduces a number of steps and requirements that can be eliminated only by having the RTG contractor ship the RTG as an assembly.

The first on-lab sequence is shown in Figure VI-1. At least one electrically powered heat source simulator is assumed to be utilized for this phase of the operations. Alternatively, an inoperative RTG model could be used but would lack the temperature simulation which is important to developing an entire sequence of handling procedures. Certain portions of the spacecraft interface checkout will probably have to utilize models since the spacecraft will be powered by multiple RTG units. The RTG models will simulate mass, size, and attachment characteristics of the actual RTG. An operational RTG model could permit the use of inert gas charging procedures and a realistic simulation of checkout by GSE. Insofar as possible, the development test steps should simulate the major steps of the fueled RTG sequence. In this way, it will be possible to predetermine test setup times, derive reliable exposure estimates, and check out many of the RTG/spacecraft interface characteristics. A complete evaluation of test requirements using the spacecraft may disclose that more than one electrically heated RTG is required.



** May require multiple electrically heated generators

*The sequence assumes the heat source is shipped separately from RTG. Operations can be deleted if assembled RTG is delivered to user.

FIGURE VI-1.
ON-LAB SEQUENCE OF EVENTS FOR ENGINEERING DEVELOPMENT

Steps 1 and 2 of Figure VI-1 require a carefully worked out procedure and an adequate knowledge of the shipping container construction. Health physics personnel should be in attendance during all phases of the simulated test series.

Figure VI-2 identifies the steps which pertain to on-lab operations with a fueled RTG. The heat source is received in its sealed shipping container. The shipping container is opened and a complete health physics check made to assure that no radioactive contamination exists. Assuming the converter is received separately from the heat source, converter checkout procedures are run prior to assembling the RTG in an appropriate assembly area. The heat source can be stored in the assembly area, thus eliminating the need for Step 5. In Step 6, the heat source is completely removed from its shipping container and subjected to a health physics survey. An alternative sequence has been noted on Figure VI-2 to cover the situation where the assembled RTG is received from the AEC contractor. At this time, it is not clear what number of tests will be run with the fueled RTG. Typical tests and checks have been indicated in Step 12 for the RTG alone and in Steps 13 and 14 for the RTG and spacecraft. Proper management of the test series with the fueled RTG should be able to hold handling and movements to a minimum. A thorough and detailed preparation of the on-lab operation sequence in combination with a hazards evaluation will identify the optimum approach for minimizing exposure time and enhancing overall nuclear safety.

Step 16 of the fueled sequence pertains to the use of models for spacecraft tests. It should be pointed out that a complete performance and characterization test (Step 14), such as determining magnetic moments, may preclude the use of models. Instead, a complete complement of RTGs may be required.

B. Launch Site Sequence of Events

Figure VI-3 shows a projected sequence of events for launch site operations. Although this sequence will utilize flight hardware, there is no major difference through the first nine steps from the on-lab sequence discussed previously. It should be noted that multiple RTGs may be involved as the power system for the outer planets spacecraft. Procedure development must anticipate any potential problems encountered in storing, moving, and handling multiple fueled units.

Following spacecraft tests in NASA/JPL buildings at ETR, the spacecraft must be moved to the launch pad area for assembly onto the launch vehicle. Step 12 may be made with the RTGs on the spacecraft or with RTGs demated and moved separately.

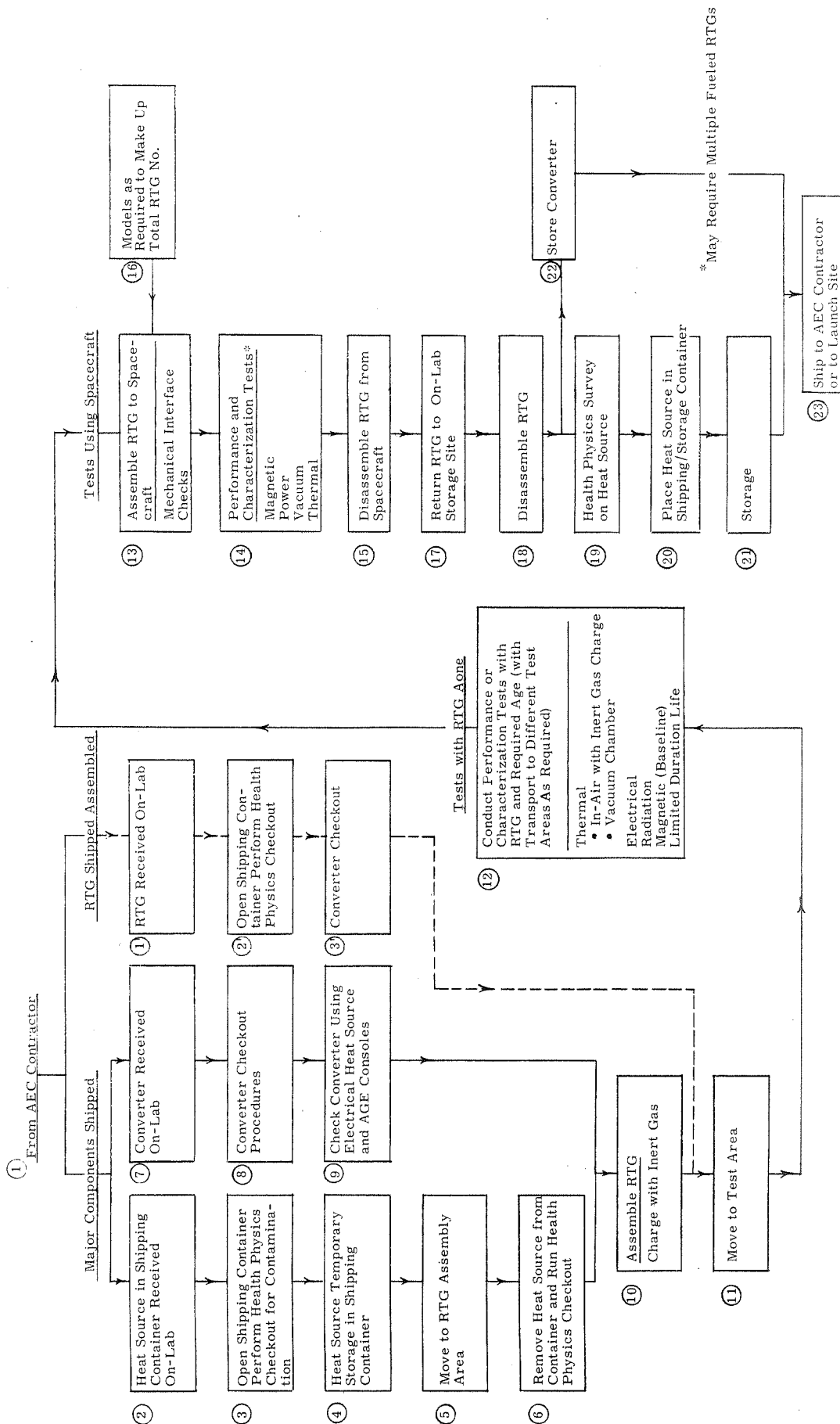
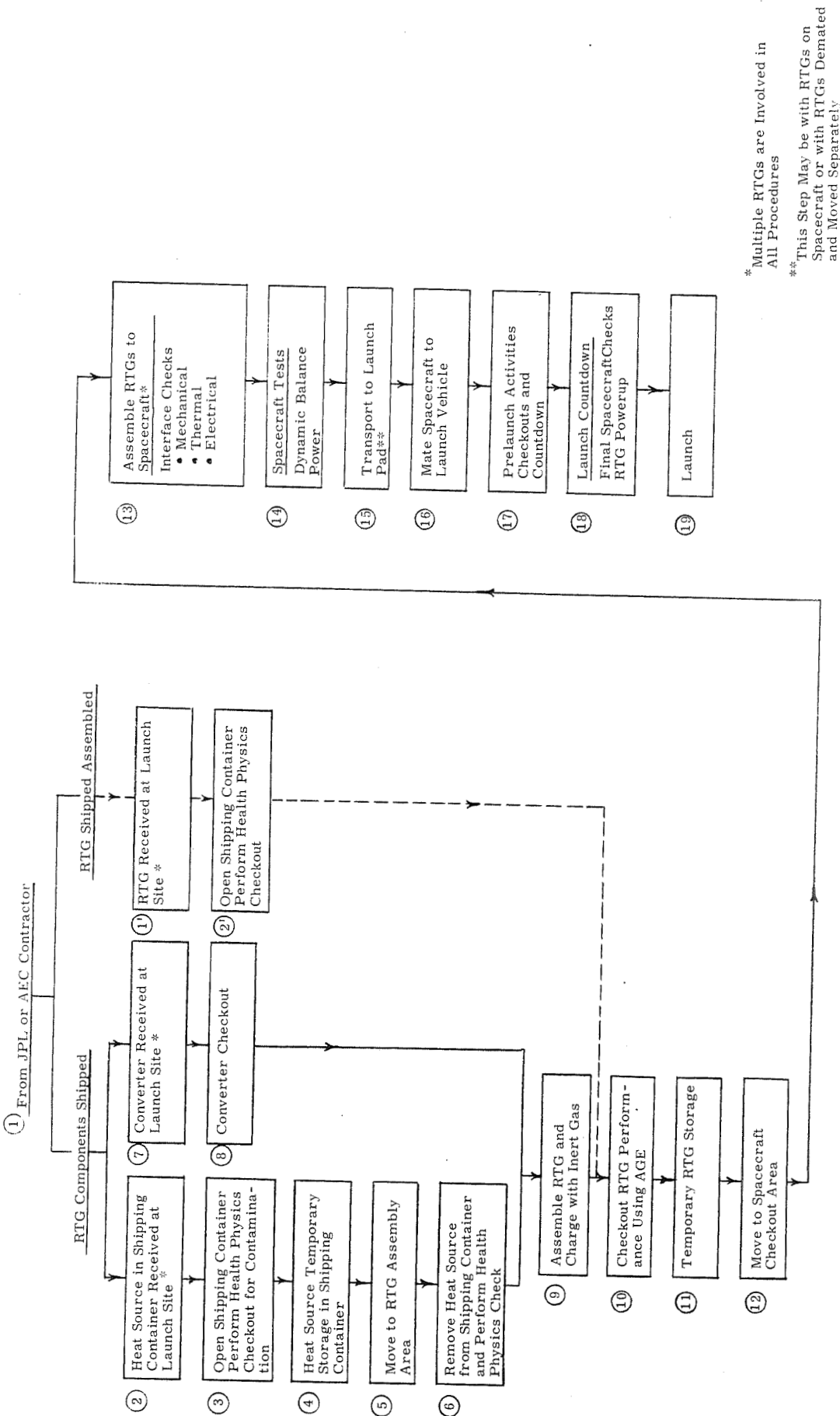


Figure VI-2. On-Lab Sequence of Events for Fueled RTG Testing



* Multiple RTGs are Involved in All Procedures

** This Step May be with RTGs on Spacecraft or with RTGs Demated and Moved Separately

Figure VI-3. Launch Site Sequence of Events with Fueled RTGs

C. Operations Activities

1. NPSG On-Lab Operations Procedures Requirements

From the point of view of scope, the NPSG is concerned with all operations involving the RTG, not just those which have some relationship to nuclear safety. The NPSG role is construed to be that of a support group performing the following general tasks:

- (a) Write specific sections of the on-lab RTG procedures which deal with nuclear safety.
- (b) Advise the Project on the best way to perform a particular function which involves the RTG. This consulting service should be reflected in the writing of all procedures.
- (c) Review and critique all procedures where the RTG is involved. These on-lab procedures should have an approval by the NPSG.
- (d) Coordinate health physics group participation in the various on-lab procedures.
- (e) Participate in or witness the actual performance of the on-lab operations with the RTG.

At the present time, the depth to which JPL will carry procedures is not known. A review of a few typical JPL procedures should enable manpower requirements to be estimated with sufficient accuracy for planning purposes.

The engineering development tests suggested by Figure VI-1 could be run without the use of formal procedures, but this is not considered advisable. Probably the NPSG would have a substantial role in performing the development tests.

The following general areas of procedure inputs must be prepared and will be common to all major procedures involving the RTG:

- (a) Removal of the heat source from its shipping container, if applicable
- (b) Movement of the RTG on-lab in the shipping container
- (c) Movement of the RTG on-lab when the RTG is not in the shipping container
- (d) Storage procedure
- (e) Lifting the RTG
- (f) Nuclear safety precautions, including dose rate limitations

- (g) Criteria for health physics personnel attendance
- (h) Emergency procedure applicability (see Section VII)
- (i) Role of the AEC during all procedures
- (j) GSE interface procedures, including checkout steps for the RTG components
- (k) An overall plan/procedure covering the approach to the on-lab engineering development tests, the data desired, personnel required, and general procedure to be utilized

The number of individual procedures which JPL prepares will depend, of course, upon management policy and the number of tests involved. As a preliminary planning estimate, the following procedures are assumed to be required:

- (a) Heat source receiving, inspection, and storage
- (b) Converter receiving, inspection, and storage
- (c) Converter checkout
- (d) A single procedure covering (a), (b), and (c), if the RTG is shipped as a complete unit
- (e) Heat source (or RTG) handling and on-lab transportation
- (f) RTG assembly and checkout
- (g) Single procedure for each major test used to characterize RTG performance

2. Project On-Lab Operations Procedures Requirements

The JPL spacecraft project group is assumed to be the responsible authority for generating all spacecraft procedures. These include any tests on the spacecraft which involve the RTG.

3. Launch Site Operations Procedures Requirements

Procedural inputs covered in previous Section C. 1 and C. 2 also apply to the launch site. The number and type of tests at the launch site will center around the spacecraft. Scoping these tests will require a rough knowledge of the spacecraft operations which involve the RTG.

4. RTG Development Model Considerations

Previous sections have identified the need for utilizing models of the RTG for engineering development. Operations and procedures with either an electrically heated RTG or mass simulating models will be part of the regular test sequence.

For the most part, it is expected that models used for engineering development (see Figure VI-1, Section VI. A) will be discussed in one general plan. A detailed breakdown in the plan will be necessary to cover operations with an electrically powered heat source simulant and/or RTG.

D. Operations Hazard Evaluation

The use of one or more fueled RTGs on-lab and multiple fueled RTGs at the launch site clearly requires a hazard evaluation. A good hazard evaluation is the crux of the justification for utilizing the radioisotope fueled RTG on-lab. Additionally, the hazard evaluation serves a practical purpose by identifying the operations which produce the greatest risk. Previous RTG hazard evaluation programs have concluded that on-lab and launch site operations present no significant problems when compared to the launch and ascent phases of the mission. This will probably be true for this program as well. For this reason, a JPL hazards evaluation should be practical in approach and make full utilization of information gained through AEC contractor liaison (see Section V. A. 1).

For planning purposes, the bulk of the hazard evaluation will be considered to fall under this operations task. Other parts of the overall effort will deal with liaison and formal documentation. A nuclear safety hazards evaluation could typically be carried out in the following steps:

- (1) Perform an analysis by constructing accident networks for the various operations involved during a particular phase of the RTG program, namely, on-lab or launch site.
- (2) Determine the failure mode and probability of occurrence and response for each accident or branch of the accident network
- (3) Determine the probabilities associated with population density and fuel uptake in the accident surroundings
- (4) Evaluate plausible source terms for all fuel release modes
- (5) Calculate fuel activity transport characteristics using the source terms
- (6) Determine interaction of activity with man via the usual routes of ingestion, inhalation, and direct exposure
- (7) Combine results into a hazard presentation

Since the hazards surrounding on-lab operation are undoubtedly small and a fuel release will be virtually impossible with proper RTG design, the on-lab hazards evaluation should not be too broad. It is suggested that the single most likely and severe accident be examined and a fuel release postulated as might result from severe fire or explosion. The effects of the release should be determined by examining the physical characteristics of the building and surroundings where the release is assumed to take place. This will include the ventilation system, filters, emergency protection, surrounding population characteristics, etc.

The results of less severe accidents will not lead to a nuclear safety hazard but may be of interest from an operations viewpoint. Therefore, a complete hazards investigation can start with the same basis as used in the nuclear safety analysis (the accident models) but examine results with the objective of providing revised handling and disposition information for damaged RTGs.

A launch site hazard evaluation will be related to that of the on-lab investigation. The maximum credible accident chosen for evaluation will be different than on-lab and might, for example, be postulated to result from a test fixture malfunction while tests are being run in the ESF. The AEC RTG contractor will evaluate launch site operations in detail and this analysis should neither be overlooked nor repeated. Again, the liaison task noted in Section V. A. 1 will be of value for this aspect of operations.

E. Nuclear Operations Working Group Support Activities

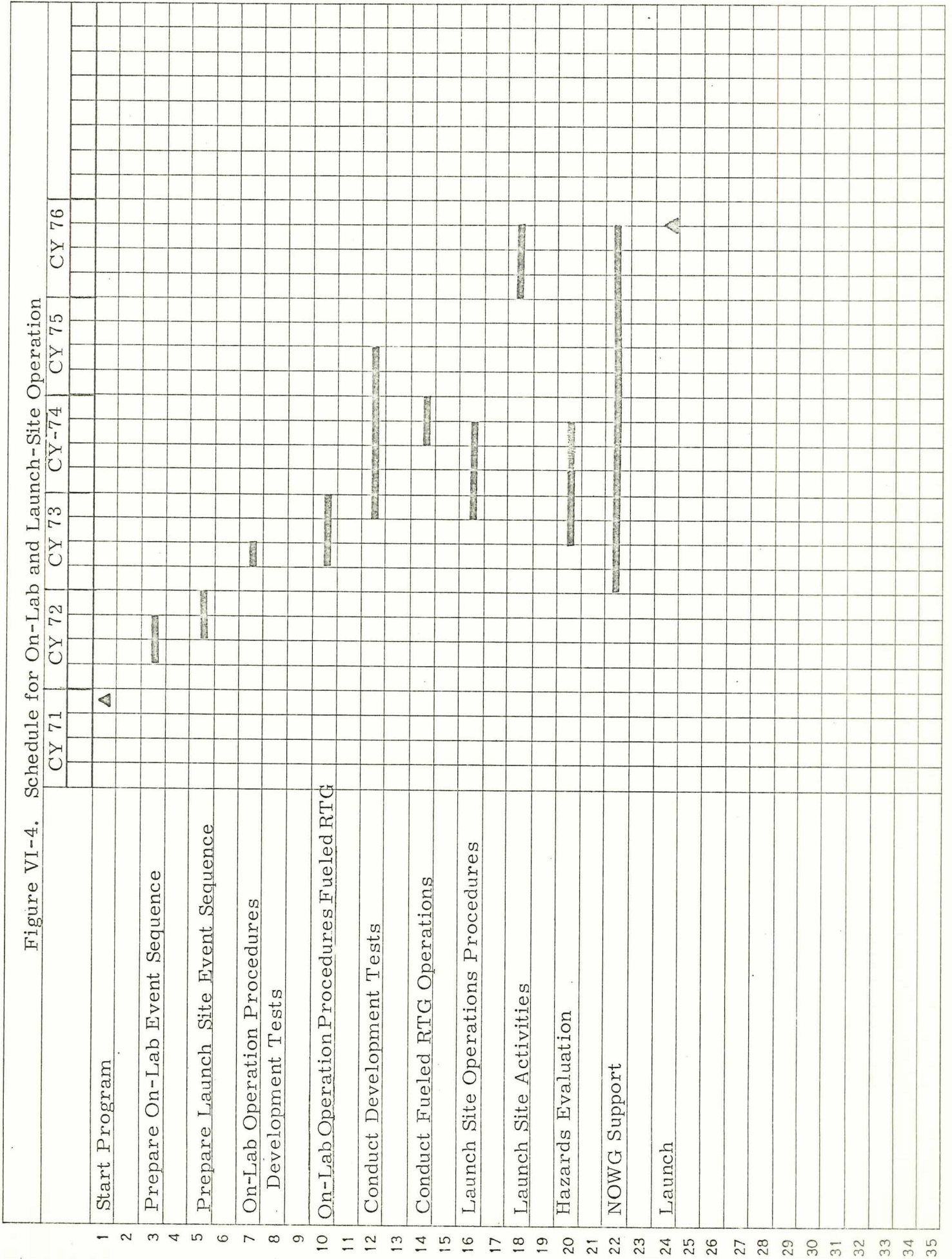
The Nuclear Operations Working Group (NOWG) is a subcommittee of the Safety Steering Committee instituted on each flight project as a JPL requirement. The NOWG is concerned with the integration aspects of using the RTGs as a subsystem of the spacecraft.

The NOWG subcommittee will obtain its inputs through normal project channels and will have access to project documentation. Support of this group's activities will require a block of time set aside by the NPSG to prepare presentations, attend periodic meetings, and respond to action items as a result of NOWG direction.

F. Milestone Schedule

The major milestones and events in support of on-lab and launch site operations are shown in Figure VI-4.

Figure VI-4. Schedule for On-Lab and Launch-Site Operation



VII. EMERGENCY PROCEDURES MANUAL

An emergency procedures manual will find application when it becomes necessary to describe emergency procedures for accidents occurring during the JPL on-lab activities and launch site activities. One manual will suffice for both the on-lab and launch site activities. However, the detailed emergency procedures, such as the evacuation route followed to a safe area, are unique for a given custodial activity within the sequence of activities in the on-lab and launch site operations. A custodial activity is defined as being a specific handling, storage, or test operation wherein the responsibility for the integrity of the RTG has been assigned to a group of individuals. The scope of the manual can be ascertained from the outline appearing in Section A on the next few pages and the succeeding discussion of the outline under Section B.

To fully utilize the manual, it must become part of the formal program documentation system. It should be subject to formal approval procedures and regular changes for updating and revision.

A. Emergency Procedures Manual Outline

1. General
 - a. Scope
 - b. Description of RTG Activities and Sites
 - (1) General description of system
 - (2) JPL on-lab areas and activities
 - (3) Launch site areas and activities
 - c. Definition of Radiological Accidents
 - d. Potential Hazards
 - (1) External radiation exposure
 - (2) Internal radiation exposure
 - e. Responsibilities
2. Radiation Exposure Guides for Radiation Workers
 - a. External Exposures
 - (1) Accidental high exposure
 - (2) Emergency exposure

- b. Internal Exposures
 - (1) Accidental high exposure
 - (2) Emergency exposure
 - (3) Short-term exposure
 - c. Contamination Level Guides
 - (1) Threshold levels in controlled areas
 - (2) Exclusion areas
 - (3) Respiratory protection
 - (4) Skin surfaces
 - (5) Clothing and shoes
 - (6) Item surfaces
3. Pre-Planning for Emergency Procedures
- a. Time Divisions for Planning
 - (1) Immediate emergency period
 - (2) Post-emergency period
 - b. Responsibilities
 - c. Preparedness Check List
 - d. Emergency Instrumentation and Equipment
 - e. Practice Drills
 - f. Special Precautions
4. Immediate Emergency Procedures During Handling, Storage, and Test Operations
- a. Criteria for Determination of the Existence of an Accident
 - b. Alarms
 - c. Evacuation of Area and Immediate Actions
 - d. Notification of Authorities

- e. Personnel Decontamination and First Aid
 - f. Emergency Area Surveys
5. Post-Emergency Procedures
- a. Responsibility
 - b. Contamination Control
 - c. Recovery of Radioactive Material
 - d. Decontamination of Area and Equipment
 - e. Radioactive Waste Disposal
 - f. Continuous Biomedical Examinations
6. Records
7. References and Applicable Documents

B. Discussion of Content within Manual Sections

1. General

In Section 1 of the manual, the scope of the emergency procedures manual will be defined to encompass those emergencies occurring during the JPL on-lab activities and the launch site activities. A general description of the outer planet spacecraft RTG system will be given. Performance and physical characteristics, photographs, and the mission will be described to provide an overall familiarity with the RTG system. The RTG-to-spacecraft interface must also be described.

The JPL on-lab activities involving the RTG are to be described completely. These may or may not be in conjunction with the spacecraft. Physical characteristics of the areas in which these activities take place must be described in detail including layout and dimensions. The handling, storage, and testing activities include the initial receiving and inspection of the RTG and performance checks. The testing program for the RTG system includes vibration tests, thermal performance tests, radiation measurements, magnetic field measurements, dynamic balance testing, performance testing in vacuum, and other tests defined in the on-lab sequence of events.

The launch site activities involving the RTG system will be described completely. The physical characteristics of the launch site are to include

layout and dimensions. Initially after reception, the RTG system is inspected and preliminary performance checks are made. The launch site sequence of events may include installation of the RTG into the spacecraft. Performance checks are made throughout the integration of the RTG system with the spacecraft and launch vehicle configuration.

The accidents which are considered to be radiological emergencies are to be defined. The worse case will be an accident resulting in escape of radioactive fuel from an RTG fuel capsule. However, an emergency need not require breach of the capsule.

The potential hazards due to exposure of personnel to external or internal radiation must be defined following an accident. External radiation dose rates are determined in mrem/hr attributed to various non-nominal configurations of the RTG, e. g., the bare fuel capsule. Internal radiation exposure results from the deposition of radioactive material within the body by the three principal modes:

- (a) Inhalation
- (b) Ingestion
- (c) Absorption through wounds

A procedure manual must define responsibility during the various activities contemplated for the RTG both on-lab and at the launch site. Generally, the NPSG, in conjunction with health physics, will have responsibility for pre-emergency planning, emergency procedures, and post-emergency operations. Coordination and allocation of responsibilities between the project and the NPSG will be necessary as the project will be running the majority of all of the tests and operations where the manual is applicable.

2. Radiation Exposure Guides for Radiation Workers

In Section 2, the radiation exposure guides or thresholds for radiation workers should be defined. Maximum permissible doses are set forth by the International Commission on Radiological Protection (ICRP). The accidental high exposure level and the emergency exposure level are two classifications defined when describing both external and internal exposures. In addition, a short-term exposure classification is included under internal exposures. Each classification of exposure is comprised of a dose magnitude and an exposure time period.

In controlled areas, the threshold levels are presented for airborne contamination, direct reading surface contamination and transferrable surface contamination due to alpha and beta-gamma radiation. An exclusion area is defined as being one in which an accident has taken place. This area is assumed to be contaminated to a level such that all personnel have been evacuated and the area has been sealed off.

A guide for respiratory protection from airborne contamination consists of the radiation levels and the corresponding respiratory equipment required. Maximum permissible contamination levels based on direct surveys and transferables (smears) are postulated for skin surfaces, clothing, and shoes. Permissible contamination guides must also be defined for the surfaces of miscellaneous items, which must be given a radiation or contamination clearance, i. e., these items are decontaminated until surface measurements are below the guide level.

3. Pre-Planning for Emergency Procedures

The pre-planning for emergency procedures is defined in Section 3. Two time divisions or spans are defined for planning purposes:

- (a) The period of the emergency
- (b) The post-emergency period

The plan of action for the emergency requires the clarification and integration of specific responsibilities between management, the health physics group and the medical group. The responsibilities of each of these groups must be delineated and coordinated by the NPSG.

Instrumentation and equipment required in the event of an accident must be defined. This list should include special portable survey instruments and laboratory counting equipment required to detect radiation associated with accidents involving plutonium. The equipment also includes various apparel and breathing apparatus worn to reduce contamination to personnel. Special kits required for the purpose of emergency monitoring only need to be determined and optimally deployed.

Provision should be made for the periodic practice of the emergency plan through drills. Personnel and equipment are thus in a state of readiness.

Special precautions need to be spelled out due to peculiarities of the RTG system. Thermal shock limitations of the system restrict the time rate of change of temperature due to external perturbations to an allowable magnitude. The system may require storage in an inert atmospheric environment. Special precautions may arise as a result of cooling system requirements. There may be a severe restriction on the time of exposure of the system to air.

4. Immediate Emergency Procedures During Handling, Storage, and Test Operations

The immediate emergency procedures to be followed must be spelled out in detail for an accident taking place during the handling, storage, and test operations. Initially, criteria are set forth defining the existence of an emergency. These would include positive results from:

- (a) Surface contamination checks
- (b) Airborne radioactivity measurements
- (c) Leak testing of the fuel capsule

An alarm from a continuous air monitor of particulate alpha activity is an emergency. Emergencies also include:

- (a) Impact which may have damaged the RTG
- (b) Fire or explosion involving the RTG
- (c) Natural disasters, such as earthquakes, involving the RTG

Adequate alarm devices are established in the facility to signal an emergency. Personnel must then immediately follow specific evacuation routes to a designated safe assembly area. While leaving with all possible speed, one should alert others in the area who may not be aware of the emergency situation. The contaminated or exclusion area must then be sealed off after all persons have been evacuated.

Authorities to be notified must be specified. The JPL on-lab and the launch site authorities would include the radiological safety officer, the group leader and director of the facility. Notification of local, state, and federal agencies might include health, fire, or police departments. The AEC must be notified immediately. In some situations, radiological emergency assistance is available from the AEC and the Department of Defense. Notification of the news media may also be necessary.

Personnel involved in the accident must undergo decontamination and receive medical attention.

Provisions should be made for an initial survey to determine the extent and magnitude of airborne and surface contamination in those areas of special interest outside of the exclusion area. Such areas would include the evacuation assembly area.

5. Post-Emergency Procedures

Post-emergency procedures will be defined for the time period following the emergency. Respective JPL on-lab and launch site agencies would be responsible in most cases for the necessary decontamination and recovery operations. Contamination control procedures are formulated to prevent unnecessary exposures and dispersal of the contaminant. These controls include posting of signs, setting-up of control points for entry and exit, and issuing protective apparel to persons entering the exclusion area.

The radioactive material is recovered according to the specific instructions. Decontamination operations are then carried out in order to restore the area and equipment to normal. Radioactive wastes in the packaged form

and effluent form shall be disposed of in accordance with applicable regulations. Continuous biological and medical examinations involving injured persons shall be carried out as deemed necessary by the medical authorities.

6. Records

The importance of an accurate log and complete records during and following an emergency incident cannot be emphasized enough. Records for the post-emergency period shall be as specified in the Code of Federal Regulations.

7. References and Applicable Documents

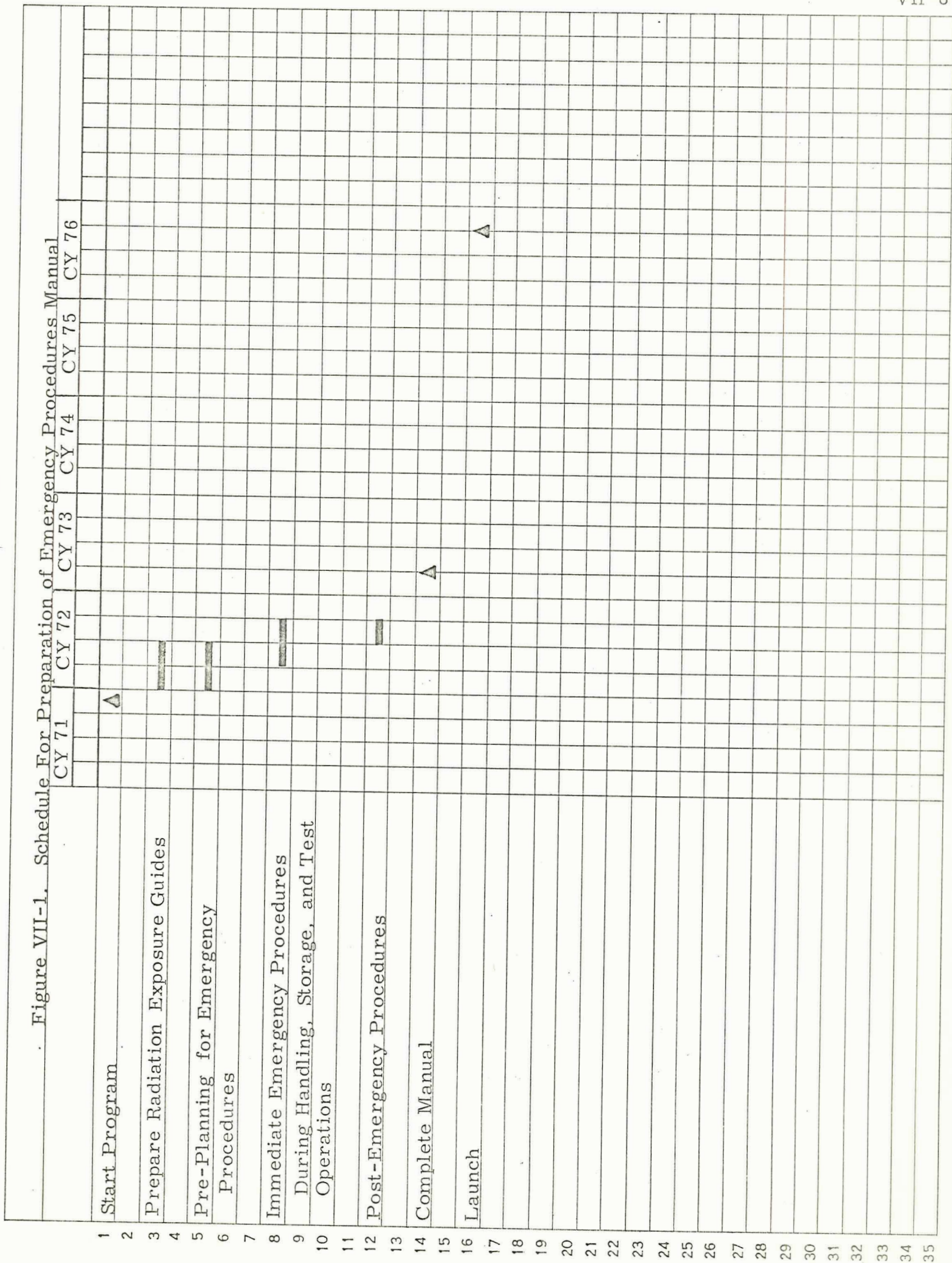
The references supplied in the Emergency Procedures Manual shall include those addressed to the various regulations and international recommendations for radiological hazards.

Applicable documents may include the program specification, an inter-agency agreement, and an appropriate technical interface specification.

C. Milestone Schedule

The major milestones and schedule for preparing the Emergency Procedures Manual are shown in Figure VII-1.

Figure VII-1. Schedule For Preparation of Emergency Procedures Manual



VIII. USER'S SAFETY ANALYSIS REPORT

This section defines and discusses the effort and documentation necessary to establish and justify JPL's qualifications for acquisition and use of RTGs, both on-lab and at the launch site. The major product of this effort will be an SAR type of report which will demonstrate the safety of planned operations as well as identify and quantify the nature and magnitude of any associated risks. The user SAR will serve several purposes. First, it will satisfy the AEC's minimum health and safety requirements for activities involving special nuclear material. Second, it will satisfy JPL's internal health and safety requirements. Finally, it will provide the necessary backup and justification for conformance with the health and safety requirements of the Air Force and other cognizant groups at the launch site. While the report will be adequate as a vehicle for licensing of JPL facilities for special nuclear material, no need for licensing is anticipated.

The document and the type of effort required for its preparation are best described by first presenting an overall outline and then providing brief descriptions of each of the outline elements. This is the approach taken in the two subsections herein. It should be noted that while the scope of this document is broad, large portions of the required information and analysis can be referenced to the AEC Safety Analysis Report, the NPSSG evaluation, and other pertinent safety documentation. Thus, JPL can prepare a comprehensive and multipurpose safety document without expending excessively large manpower resources.

A. User's Safety Analysis Report Outline

1. Introduction
2. Summary
3. System Descriptions
4. On-Lab Facility Description
 - a. Physical Facilities
 - b. Site
 - c. Normal and Emergency Equipment
5. Launch Site Facility Description
 - a. Physical Facilities

- b. Site
 - c. Normal and Emergency Equipment
6. On-Lab Operations Analysis
- a. Description of Operations
 - b. Accident Networks
 - c. Failure Mode Analysis
 - d. Source Term Definition
 - e. On-Lab Activity Release Summary
7. Consequences of On-Lab Accidents
- a. Personnel Exposures
 - b. Property Exposure
8. On-Lab Responsibilities
- a. Responsibility Assignments
 - b. Emergency Plans
 - c. Personnel Qualifications
9. Launch Site Operations Analysis
- a. Description of Operations
 - b. Accident Networks
 - c. Failure Mode Analysis
 - d. Source Term Definition
 - e. Launch Site Activity Release Summary
10. Consequences of Launch Site Accidents
- a. Personnel Exposures
 - b. Property Exposure

11. Launch Site Responsibilities
 - a. Responsibility Assignments
 - b. Emergency Plans
 - c. Personnel Qualifications
12. References
13. Appendices

B. User's Safety Analysis Report Description

1. Introduction

This section describes the purpose, philosophy, and scope of the report. It should include a brief resume of the report contents.

2. Summary

The findings of the safety analysis are summarized in as concise a manner as possible. Particular emphasis should be given to conclusions regarding the safety of the operations and the consequences of accidents. Tables are useful in summarizing this type of information. The summary should be sufficiently comprehensive so that the reader can obtain from it a good overview of the risks attendant to the planned operations and need not read the entire report unless further details are required.

3. System Descriptions

This includes a description of the RTG, the spacecraft, and any ancillary or ground support equipment which will be involved in the on-lab and launch site activities. The radioisotope fuel and its encapsulation should be described in some detail as should any other components or subsystems which could influence safety. Other portions of the system and equipment need only be described in general terms.

4. On-Lab Facility Description

a. Physical Facilities. Descriptions should be provided for all buildings and areas where fueled RTGs or heat sources will be stored, tested, or transported. These will include: layouts, construction features, test and handling equipment, air circulation system details, access to areas, identification of nearby explosive or inflammable materials.

b. Site. Description of the site surrounding the JPL facility should be limited to those features and characteristics which can affect the occurrence of an accident or its consequences. It should include the following.

(1) Population Distribution. Population density and location of centers (day and night) both on-lab and as a function of distance around the facility.

(2) Land Use. Categorization of land use in areas surrounding the JPL facility with respect to residential, farming, grazing, industrial, commercial, etc.

(3) Meteorology. Routine meteorological characteristics, such as wind rose and stability data.

(4) Seismology. History of seismic activity in the area.

(5) Topography. Topographic characteristics which could influence deposition and transport of released radioactive material.

(6) Geology and Hydrology. Characteristics which could influence activity absorption and transport, including surface and groundwaters.

The depth of coverage in the above areas should be minimal.

c. Normal and Emergency Equipment. This includes identification and description of all health physics and emergency equipment. The number and types of radiation monitoring equipment which will be used for normal health physics surveillance and to detect a release will be described, together with their capabilities. The same type of information will be provided for emergency equipment such as alarms, fire fighting apparatus, retrieval devices, temporary storage containers, etc.

5. Launch Site Facility Description

a. Physical Facilities. The type of information contained in this section is similar to that provided for the on-lab facility description. A complete description of the launch pad and its associated equipment should be included.

b. Site. The same categories of characteristics which were discussed for the JPL site will be provided in this section.

c. Normal and Emergency Equipment. This section too will parallel that for the JPL facility. As is also the case for the physical facilities and site, the information required for this section can be taken directly from the AEC's SAR with minimal modifications and additions.

6. On-Lab Operations Analysis

a. Description of Operations. A complete description of all events and operations will be provided covering the time from arrival of a fueled unit on-lab until its removal. These operations have been discussed generally in

Section VI of this CWO No. 6 report. The description should include a sequence and schedule of events and the range of conditions for all tests. Where on-site transport or handling is required, the modes should be described. Special safety and handling precautions should be identified and discussed, as should the health physics operations.

b. Accident Networks. Detailed accident networks will be developed from the description of operations discussed above. The networks will be in the fault tree-type of format which has been used in most SARs to date. The entire sequence of operations can be presented in one or more networks, as appropriate. It is important that the operations be analyzed thoroughly to identify every credible mishap, the resulting environment and its consequences to the system.

c. Failure Mode Analysis. Analyses will be made, based upon the defined mishaps and environments, to determine which network sequences of events can terminate in activity releases. Wherever possible, system responses should be determined by analogy with similar analyses and situations in the AEC's SAR document. In those situations where potential failures are identified, the mode of failure will be defined. For example, is the failure in the form of containment melting, erosion due to chemical reaction, a small crack due to impact or stress, or a massive and violent rupture? The probability of each type of identified failure should be estimated with the maximum accuracy possible by determining the independent and conditional probabilities of the components in the sequence of events. This will require some knowledge of equipment failure probabilities and modes, resulting environment magnitudes and probabilities, and system response to the environments.

d. Source Term Definition. A source term will be defined for each activity release identified in the failure mode analysis. A source term is defined by the quantity of activity released, the rate of release, and the physical/chemical state of the activity. For example, this will include the total quantity of release in curies, the time over which the release occurs if it is not instantaneous, and whether the activity is in the form of a vapor, small particulate, large solid form, etc. If any chemical reactions have occurred to modify the as-produced chemical form, these must be considered. In some cases, more than one source term might be credible from a given series of events. It will then be necessary to assign relative probabilities to each of the possible source terms. Here, too, much of the source term definition can be accomplished by comparison with analyses in the AEC's SAR.

e. On-Lab Activity Release Summary. This is a brief summarization of the results of the on-lab operations analysis. Its purpose is to tie together the identified release causes, failure modes, source terms and probabilities. As appropriate, the summary will identify a maximum credible accident or perhaps two credible accidents which, by virtue of their consequences and probabilities, are worthy of further study.

7. Consequences of On-Lab Accidents

a. Personnel Exposures. For each of the credible release accidents identified in the previous section, analyses will be made to determine the

numbers of people exposed to given exposure levels and the associated exposure probabilities. Both on-lab personnel and surrounding populations should be considered. Appropriate dispersion mechanisms will be modeled to transport the activity from the point of release to the location of interaction with personnel. It is most probable that only inhalation exposures need be considered. Various multiples of the maximum permissible lung burden for Pu-238 can be selected as the reference exposure levels. While the basic data and models can be borrowed from the AEC's SAR, some independent analysis must be performed by JPL in connection with on-lab personnel exposures because the environment and surroundings are unique.

b. Property Exposure. In addition to personnel exposures, each of the credible release accidents will result in radioactive contamination to the immediate facility, and possibly to the land area downwind of the facility. This section will present the consequences of activity release with respect to property exposure. Contamination areas, magnitudes, and probabilities will be determined. As in the case of personnel exposures, only some of the required data can be borrowed from the AEC's SAR. Some independent JPL analytical effort will be required.

8. On-Lab Responsibilities

a. Responsibility Assignments. This section identifies the functional group and the specific individual(s) having responsibility for each aspect of on-lab activity. This includes the persons with authority to modify approved plans and procedures and those to be contacted in the event of non-nominal RTG behavior.

b. Emergency Plans. Detailed plans and procedures will be presented for radiological emergencies, real or potential. This will include evacuation plans for releases or suspected releases, activity immobilization procedures, source recovery plans and procedures, etc. It will also include procedures and precautions in the event of non-radiological accidents such as earthquakes, explosions or fires. Personnel having cognizance and responsibility in emergencies will be identified along with their roles. AEC and other agency authorities who must be contacted in emergencies will also be named. The Emergency Procedures Manual discussed in Section VII can be referenced and used to prepare this section of the SAR.

c. Personnel Qualifications. Qualifications will be presented for all those personnel who have normal or emergency health physics and radiological safety responsibilities. The qualifications will include pertinent training and experience.

9. Launch Site Operations Analysis

a. Description of Operations. The scope of this section is similar to that of the corresponding section for the on-lab operations. A complete description of all events and operations will be provided covering the time from arrival of the RTGs at the launch site until liftoff.

b. Accident Networks. Detailed accident networks will be developed for the launch site operations. These will be similar in scope and purpose to the networks described in the on-lab operations analysis.

c. Failure Mode Analysis. This will be similar in nature to the failure mode analysis for the on-lab operations.

d. Source Term Definition. This requires a parallel effort to that for the on-lab analysis.

e. Launch Site Activity Release Summary. This is a brief summarization of the results of the launch site operations analysis. It has the same scope and intent as does the corresponding section for the on-lab case. As appropriate, the summary will identify one or two maximum credible accidents which will be evaluated further.

10. Consequences of Launch Site Accidents

a. Personnel Exposures. Personnel exposures will be determined in the same manner and format as those for the on-lab releases. However, the extent of JPL effort will be somewhat less because a greater portion of applicable analysis results can be borrowed directly from the AEC's SAR.

b. Property Exposure. This section will present data corresponding to that developed for the on-lab operations. Here too, the required JPL effort will be less than for the on-lab case because much of the AEC's SAR results will be applicable.

11. Launch Site Responsibilities

a. Responsibility Assignments. This section identifies the functional group and the specific individual(s) with responsibility for each aspect of the launch site activity. Unlike the on-lab activities, the launch site responsibilities may be shared by Air Force, NASA, JPL, and contractor personnel.

b. Emergency Plans. Detailed plans and procedures will be presented for radiological emergencies as in the corresponding on-lab section.

c. Personnel Qualifications. Qualifications will be presented for all those personnel who have normal or emergency health physics and radiological safety responsibilities.

12. References

This section will list all documents referenced in the User's Safety Analysis Report in addition to a bibliography of pertinent documents, as required.

13. Appendices

Any analysis details and data compilations which are too extensive to incorporate into the body of the report will be appended to the report.

C. Schedule

Figure VIII-1 shows the schedule for preparation of the User's Safety Analysis Report.

IX. NEW TECHNOLOGY

No reportable items of "New Technology" have been identified in the performance of the work described in this report.

X. REFERENCES

1. "Engineering Support to JPL TOPS RTG Program Work Order No. 5," Hittman Associates, Inc. Memo Rpt. HA-3908-5-1, dated December 31, 1970.
2. JPL Contract Work Order No. 6, Acknowledged February 9, 1971.
3. Code of Federal Regulations, Title 10 - Atomic Energy, Part 70-Special Nuclear Material.
4. Code of Federal Regulations, Title 10 - Atomic Energy, Part 20-Standards for Protection Against Radiation.
5. "MHW-RTG Design Requirements and Environments Document," General Electric Isotope Power Systems Operation, GESP 7022, November 14, 1969.
6. "Engineering Support to JPL, TOPS RTG Program, Work Order No. 2," Hittman Associates, Inc., Memo Rpt. HA-3908-2-1, dated May 1, 1970.