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Environmental Development Plan Space Applications

September 1979

U.S. Department of Energy
Assistant Secretary for Energy Technology
Assistant Secretary for Environment

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Environmental Development Plan

Space Applications

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FOREWORD

Environmental Development Plans (EDP's) are prepared by the Department of Energy (DOE) to help fulfill the Department's responsibility for the development of environmentally acceptable energy technologies. The EDP provides a common basis for planning, managing, and reviewing all environmental aspects of the energy programs under DOE's jurisdiction.

The EDP is timed to precede key technology program decisions as the technology moves from the research and development stages to an engineering development or technology demonstration phase. Each EDP identifies the environmental concerns and research and development necessary for assessing the potential environmental impacts and mitigating measures associated with an energy technology. Thus, to ensure that environmental, health, safety and socioeconomic (EH&S) considerations will be addressed adequately in the technology decisionmaking process, the EDP (1) identifies and evaluates EH&S concerns; (2) defines EH&S research and related assessments to examine or resolve the concerns; (3) provides a coordinated schedule with the technology program for required EH&S research and development; and (4) indicates the timing for Environmental Assessments, Environmental Impact Statements, Environmental Readiness Documents, and Safety Analysis Reports.

The initial EDP for the Space Applications Program (DOE/EDP-0026) was published in March 1978. This EDP provides a substantial updating of the 1977-78 document and is being released under authority of DOE Order 5420.1 dated August 10, 1978. It was prepared jointly by the Advanced Nuclear Systems and Projects Division and the Technology Assessments Division, with assistance from the research and support divisions under the Assistant Secretary for Environment.

This EDP is now being distributed so that everyone having interests and responsibilities may have the opportunity to review and provide suggested changes for future updates.

Ruth C. Clusen
Assistant Secretary
for Environment

Charles E. Williams
Acting Assistant Secretary
for Energy Technology

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ENVIRONMENTAL DEVELOPMENT PLAN

FOR

SPACE APPLICATIONS

1979

Department of Energy
Washington, D.C. 20585

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Technology Program:	Advanced Nuclear Systems and Projects
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ABBREVIATIONS

ALAP	As Low as Practicable
ANL	Argonne National Laboratory
ANSP	Advanced Nuclear Systems and Projects Division
ARAC	Atmospheric Release Advisory Committee
ARL	Atmospheric Research Laboratory (NOAA)
ASET	Assistant Secretary for Energy Technology
ASEV	Assistant Secretary for Environment
Be	Beryllium
BNL	Brookhaven National Laboratory
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
Ci	Curie, a measure of the quantity of radioactive material
CY	Calendar Year
D&D	Decontamination and Decommissioning
DHEW	U.S. Department of Health, Education and Welfare
DIPS	Dynamic Isotope Power System
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DP(SS)	Defense Programs-Office of Safeguards and Security
EA	Environmental Assessment
ECC	Environmental Coordinating Committee
ECT	Environmental Control Technology Division
EDP	Environmental Development Plan

EH&S	Environmental, Health, and Safety
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
EPA-LV	U.S. Environmental Protection Agency--Las Vegas
ERD	Environmental Readiness Document
ESAPP	Energy System Acquisition Project Plan
ET-N	Office of Energy Technology-Nuclear Programs
FMA	Future Mode Analysis
FSA	Fuel Sphere Assembly
FY	Fiscal Year
GDS	Ground Demonstration System
Ge	Germanium
GSAR	Ground Safety Analysis Report
HARC	Human Affairs Research Center (Battelle Memorial Institute)
HASL	Health and Safety Laboratory (New York City; now the Environmental Measurements Laboratory--EML, part of DOE)
HEHF	Hanford Environmental Health Foundation
INSRP	Interagency Nuclear Safety Review Panel
Kg	Kilogram; g-gram
KIPS	Kilowatt Isotope Power System
LASL	Los Alamos Scientific Laboratory
LBL	Lawrence Berkeley Laboratory
LiH	Lithium hydride
LLL	Lawrence Livermore Laboratory
MHW	Multi-hundred Watt (Nuclear Generator)
MIT	Massachusetts Institute of Technology

Mo	Molybdenum
MRC	Monsanto Research Corporation
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NIEHS- (RTP)	National Institute of Environmental Health Sciences--Research Triangle Park, N.C.
NIOSH	National Institute of Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration, U.S. Department of Commerce
NRC	U.S. Nuclear Regulatory Commission
OES	Operational and Environmental Safety Division
OHER	Office of Health and Environmental Research
ORAU	Oak Ridge Associated Universities
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration
OTI	Office of Technology Impacts
PAG	Protective Action Guides
PMC	Plutonium Molybdenum Cermet
PNL	Pacific Northwest Laboratories (Battelle Memorial Institute)
PPO	Pure Plutonium Oxide
^{238}Pu	An isotope of plutonium with an atomic mass of 238; ^{239}Pu --a plutonium isotope with an atomic mass of 239
PUFF	Plutonium Fuel Fabrication Facility
PuO_2	Plutonium Oxide
R&D	Research and Development

RPI	Rensselaer Polytechnic Institute
RPIS	Research Project Identification System
RTG	Radioisotope Thermoelectric Generator(s)
SA	Space Applications
SAI	Science Applications, Inc.
SAR	Safety Analysis Report
Se	Selenium
SER	Safety Evaluation Report
SRL	Savannah River Laboratory
TAD	Technology Assessments Division
TZM	A designation of a metallic alloy composed of titanium, zirconium and molybdenum
USC	United States Code
USGS	United States Geological Survey, Department of Interior
USAR	Updated Safety Analysis Report
UT-CARL	University of Tennessee-Comparative Animal Research Laboratory

I. SUMMARY

This Environmental Development Plan (EDP) identifies the planning and management requirements and schedules needed to evaluate and assess the environmental, health and safety aspects of the Space Applications Program. Environment is defined in its broadest sense to include environmental, health (occupational and public), safety, socioeconomic, legal, and institutional aspects.

A. Scope

This EDP has been limited to consideration of:

- space nuclear power system nuclear fuel fabrication
- space nuclear power system heat source fabrication
- testing of subsystems and assembled systems
- research and development (R&D) in support of space nuclear system development
- nuclear system responses to launch and reentry accidents
- nuclear system environmental behavior and recovery

The related EH&S concerns and requirements that have not been addressed in this EDP include those associated with;

- production of the plutonium-238 (^{238}Pu) special nuclear material or the reactor fuel production
- transportation of the space nuclear systems
- production and transport of the launch vehicles and their fuels
- conventional launch vehicle and spacecraft EH&S considerations

The first two items are to be covered in other EDP's (References 1 and 2), while considerations related to conventional launch vehicles and spacecraft are independent of the space nuclear system payload and fall entirely under the jurisdiction of other Federal agencies.

B. Technology Program

The Space Applications program is tasked with the development and fabrication of nuclear power supplies for use in space by other Federal agency users; in particular, the National Aeronautics and Space Administration (NASA) for outer planetary missions and the Department of Defense (DOD) for orbital satellite systems for military surveillance, navigation and communications.

The technology being developed is that of thermal energy conversion to useful, reliable, and long-term electric energy. Heat is generated by the decay of radioisotopes or by a compact fission reactor. The thermal energy conversion systems include static thermoelectric systems and a thermodynamic converter system. Ultimate program milestones for system delivery are in large part set by the requirements of the user agency. There are only two set missions at the present time that will utilize space nuclear systems--the Galileo mission in 1982 and the Solar Polar Mission in 1983, both using a plutonium isotopic heat source. The space reactor system components will continue to be designed and developed up to a 1983 decision point of progressing to the ground demonstration phase of the program.

C. Key Environmental, Health, and Safety Concerns and Requirements

Key EH&S concerns identified in this EDP fall into two areas: those associated with environmental criteria standards and guides related to risk decisions, and those concerned with the determination of health and environmental impacts associated with accidental releases of (1) ^{238}Pu from isotopic power systems (factory-to-flight), (2) radioactive materials from space reactor systems, and (3) hazardous chemicals from space nuclear systems (e.g., beryllium).

Key requirements for resolution of these concerns are: (1) the need to develop criteria, standards, and guides on which to base risk acceptability decisions (probability and consequences), (2) identification of quantities of material that could potentially be released, (3) evaluation of behavior of released materials in recipient environments, and (4) determination of health effects of exposure to released materials.

For a number of years, there has been ongoing research regarding the identification and evaluation of risks; that work is continuing under the auspices of the Interagency Nuclear Safety Review Panel (INSRP) with the lead being taken by the user agencies. A vast amount of research dealing with the health effects of radiation, environmental transport characteristics, and monitoring and measurement has been conducted and is continuing; there is ongoing

work at the Los Alamos Scientific Laboratory (LASL) which uses environmental chambers, and a modeling effort is proceeding. However, additional work is needed regarding the establishment of acceptable release limits in the event of an abort or accident. As payload designs evolve, release probabilities and quantities can be better defined.

D. Key Environmental Planning Elements

The key environmental planning elements for the Space Applications Program related to EH&S needs are (1) nuclear power system selection for the Galileo Mission [formerly designated the Jupiter Orbiter Probe (JOP)], (2) Galileo mission system delivery (FY 81), and (3) Solar Polar mission system delivery in FY 82. No mission applications have been identified for the space nuclear power reactor program; when selected, they will be included in future revisions of this EDP. The most important National Environmental Policy Act (NEPA) related milestone is the need for an Environmental Assessment (EA) program for the Space Applications Program development of the reactor system. [Mission applications of the nuclear energy systems are addressed by Environmental Impact Statements (EIS's) prepared by the user agency.]

II. TECHNOLOGY PROGRAM

A. Scope and Goals

The Director of the Office of Nuclear Energy Programs (ET-N), under the Assistant Secretary for Energy Technology (ASET) has the overall responsibility for direction of the Space Applications Program. The Director of the Advanced Nuclear Systems and Projects Division (ANSP) has the responsibility for execution and implementation of this program.

The Space Applications Program provides support to the Nation's military and scientific space programs through research and development in the nuclear energy field. The program is tasked with the development and fabrication of nuclear power supplies for use in space by other Federal agency users; in particular, the National Aeronautics and Space Administration (NASA) for outerplanetary missions and the Department of Defense (DOD) for orbital satellite systems for military surveillance, navigation, and communications.

The specific objectives of the program are to:

- develop safe radioisotope heat sources with greater safety margins, higher specific power, and reduced cost per thermal watt
- evaluate and utilize high efficiency thermoelectric materials for advanced thermoelectric generators
- develop reactor heat source and converter technologies in the 10-100 kilowatt range
- fabricate, test, and deliver system hardware to user agencies
- support mission operations

The strategy and general approach to achieving the program objectives are presented in Appendix B.

The technology being developed is that of thermal energy conversion to useful, reliable, and long-term electric energy. Heat is generated by the decay of radioisotopes or by a compact fission reactor. The thermal energy conversion systems include static thermoelectric systems and various thermodynamic converter systems. The technical development programs are separated into (1) Flight Systems Development for current user agency needs, (2) Power System

Technology and Support for future applications, and (3) supporting safety programs.

The power system technology and support efforts are directed toward providing the basis for meeting future near-term user needs, especially for missions in the early 1980's, which will require radioisotope systems with lower unit costs and improved performance and lifetime potential. The DOD has also identified a future need for a dynamic conversion system with high-power output for projected satellite and surveillance networks. Future NASA requirements for outerplanetary exploration can be achieved with higher performance static or dynamic systems

B. Program Description and Milestones

The Space Applications Program within the ANSP was initiated in 1958 by the U.S. Atomic Energy Commission. A large number of candidate heat sources and power conditioning techniques have been examined, tested, and operated over the past 20 years. Currently, a number of options exist for supplying nuclear-derived power for space missions. In addition, a large number of variations employing the basic principles of these active candidates, but with modifications in structural design and/or materials, are continually being investigated for various purposes.

B.1. The Generic Space Nuclear Power System

Figure II-1 shows a functional diagram of the Generic Space Nuclear Power System. The primary system product is electrical energy, which is produced from thermal energy by a thermal energy to electric energy converter employing thermoelectric (static conversion) or thermodynamic cycle (dynamic conversion) principles.

Figure II-2 shows the basic options for heat sources and power conditioning subsystems. Table II-1 shows a classification of nuclear power system types for Space Applications.

B.2 Radioisotope Thermoelectric Generators (RTG's)

RTG's consist of three functional parts: a source of heat; a thermoelectric converter; and a heat rejection system shown schematically in Figure II-1 with specific technical system options being considered depicted in Figure II-2. Contained plutonium (Pu) (typically, 80 to 84 percent ^{238}Pu) has been used as the isotopic fuel for heat sources in all U.S. space missions using nuclear power. (A reactor was launched and tested in space in 1965.) The long half-life of ^{238}Pu (87.7 years) provides for a long operating life. Also, because its decay process emits mainly alpha radiation of low

FIGURE II-1
GENERIC SPACE NUCLEAR POWER SYSTEM

FIGURE II-2
OPTIONS COVERED IN SPACE NUCLEAR PROGRAM

NUCLEAR POWER SYSTEM TYPE	ELECTRIC POWER RANGE (MODULE SIZE)	HEAT SOURCE	POWER CONDITIONING
RADIOISOTOPE THERMOELECTRIC GENERATOR (RTG)	Up to 200 We	ISOTOPES	STATIC: THERMOELECTRIC
RADIOISOTOPE DYNAMIC CONVERSION GENERATOR	0.5 KWe - 2 KWe	ISOTOPES	DYNAMIC: ORGANIC RANKINE CYCLE
REACTOR SYSTEMS	10 KWe - 100 KWe	REACTOR	STATIC: THERMOELECTRIC, THERMIONIC DYNAMIC: THERMODYNAMIC CYCLES

TABLE II-1
CLASSIFICATION OF NUCLEAR POWER SYSTEM TYPES BEING
CONSIDERED FOR SPACE APPLICATION

penetration capability, shielding requirements are minimized. Presently, ^{238}Pu and possibly a nuclear reactor are the only nuclear power sources planned for future space applications.

The first RTG, SNAP 3A, was launched in 1961. This five pound unit delivered 2.7 watts of electrical power to a Navy transit navigational satellite. In subsequent RTG's, there has been a steady improvement in power output, primarily because of advancements in thermocouple technology. Early RTG's used telluride thermoelectric materials with conversion efficiencies of 3 to 5 percent. Present technology is centered on the multi-hundred watt (MHW) modular unit, using silicon-germanium (Si-Ge) thermoelectrics with conversion efficiencies of 6 to 7 percent. In the future, the MHW-RTG heat source may be coupled with a new class of thermocouple materials made up of selenium (Se) compounds, resulting in energy conversion efficiencies from 10 to 15 percent. Present developmental efforts are directed toward fuel form and process development and production, capsule materials and metallurgy development and encapsulation, and recovery of scrap fuel. The fuel (^{238}Pu) for RTG's will be produced at the new Savannah River Plutonium Fuel Fabrication Facility (PUFF), which replaces the current facility at Mound Laboratory, now being phased out and undergoing decontamination and decommissioning (D&D). [The D&D EH&S considerations are addressed in another EDP (Reference 3).] Mound Laboratory will maintain hardware fabrication and heat source assembly capability. Figures II-3 and II-4 show cutaway views of the MHW-RTG heat source. Appendix C provides details on the evolution of the space nuclear program heat sources and the safety program. There has been a steady power output growth of RTG sources and a decrease in the potential release source terms as technology has improved.

B.3 Dynamic Isotope Power System (DIPS)

To meet increasing power requirements, ANSP is continuing to evaluate dynamic methods of converting heat from radioisotope sources into electricity and has selected the Kilowatt Isotope Power System (KIPS) for further consideration. The KIPS is a Rankine cycle engine in which Dowtherm A, a liquid hydrocarbon, is vaporized to drive the turbine. Thermodynamic converters are capable of about 20 percent conversion efficiencies with envisioned electric power levels in the 500 to 2,000 watt range. The system uses a miniature turbine-generator in which a working fluid, indirectly heated by the nuclear heat source, drives the turbine that powers a mechanical electric generator.

B.4 Space Reactor Systems

The space reactor technology was initially developed in the early 1960's culminating in the flight of SNAP-10A, a zirconium

FIGURE II-3
MHW RADIOISOTOPE THERMOELECTRIC GENERATOR

FIGURE II-4
MHW HEAT SOURCE

hydride fueled reactor, which was launched in April 1965. During this developmental program, extensive safety research, which still has relevance to the current reactor technology program, was carried out. This past work will serve as a base from which to initiate any new EH&S R&D necessary to support the present reactor program applications.

Current technology work on space reactor systems covers the range of 10 to 100 kWe expected to be required for space missions in the late 1980's and beyond. The most likely design is a high-temperature, compact, fast reactor that could be coupled with various electrical power conversion systems.

A conceptual space reactor power plant has four major subcomponents. The nuclear reactor uses controlled fissioning of highly enriched uranium to generate heat; a radiation shield protects other parts of the system from the emitted radiation; the converter produces electricity from the heat produced in the reactor; and a radiator dissipates waste heat to space. The converter, which is discussed in Sections B.2 and B.3, can be either static (thermo-electric) or dynamic (e.g., Rankin cycle).

A conceptual reactor might have a core comprised of slabs of uranium oxide sandwiched between molybdenum (Mo) fins conveying the fission heat to heat pipes* selectively positioned in the core and the core could be surrounded by a thick neutron reflector such as beryllium (Be). The reactor could be controlled by changing the position of a neutron-absorbing material within the reflector. The reactor would not be operated until a safe orbit has been established which would minimize the radiological hazard, through provision of radioactive decay time, in the event of ultimate reentry into the earth's atmosphere.

The likely radiation shield material might be lithium hydride (LiH), which was used in earlier space nuclear missions (SNAP 2, 8, and 20A). The shield mass will depend on reactor power level and geometry. A radiator is used to discharge waste heat. Candidate radiator materials include Inconel-718; TZM-titanium (0.5%), zirconium (0.07%), and molybdenum (99.43%);

*Heat pipes are devices which achieve very high thermal conductances by means of two-phase flow with capillary circulation.

molybdenum; Type 316 stainless steel, titanium, and beryllium. Beryllium and titanium appear the most promising because of their light weight.

C. NEPA Activities

In accordance with the NEPA and implementing regulations by the Council on Environmental Quality (CEQ), DOE, and the user agencies, DOE and/or the user agency prepares Environmental Assessments (EA's), Environmental Impact Statements (EIS's), and Safety Analysis Reports (SAR's) as required for projects in the Space Applications Program. DOE takes the NEPA lead for nuclear systems development while the user agency prepares the NEPA documents to evaluate energy alternatives and the environmental aspects for the specific mission applications. The schedules for NEPA implementation are shown in Figure II-5 along with the significant Space Applications Program milestones. The only DOE-controlled NEPA milestone is for preparation of an EA prior to construction and operation of a ground demonstration unit for the space reactor technology.

**FIGURE II-5
SPACE APPLICATIONS PROGRAM AND RELATED MILESTONES**

Symbols:
 ▲ Milestone
 ◆ Key Decision Point
 — Activity Timeline
 - - - Continuing Activity Timeline

Notes: *NEPA Documentation for Mission Applications Prepared by User Agency as Required.

Milestones

1. Deliver First Galileo Heat Source	15. Complete Technology Development Required Prior to Ground Demonstration Phase
2. Complete Delivery of Galileo Heat Source	16. Complete Design of Development Components and GDS Modifications
3. Complete Fabrication of General Purpose Heat Sources (GPHS) (4)	17. Complete Fabrication and Assembly of GDS Modifications
4. Complete Assembly of GPHS Generator (4)	18. Complete Testing and Evaluation of Development Components
5. Complete RTG Qualification and Acceptance Test Plans	19. Complete GDS Performance/Endurance Testing with Upgraded Components
6. RTG Final Design Review	20. Complete Galileo Safety Test Plan
7. RTG Qualification Test	21. EA for Reactor Ground Demonstration Unit
8. Flight RTG Delivery	22. Complete Galileo PSAR INSRP Review
9. Assembly and Measurements on First Gross Critical Assembly	23. Complete Final Galileo GSAR Review
10. Manufacture of Thermoelectric Converter Module	24. Complete Galileo USAR INSRP Review
11. Selection of Materials for Component Development	25. Complete Preliminary Failure Modes and Effects Analysis for Space Reactors
12. Preparation of Specification for Reactor Power Plant	26. Complete Galileo FSAR INSRP Review
13. Complete Component Development	27. Complete PSAR for Space Reactors
14. Complete Evaluation of Major System Element Verification Tests	28. Complete Solar Polar FSAR INSRP Review

Key Decisions

- A DOE Launch Readiness Review
 B. Selection of Reactor Design Concept for Technology Development
 C Review of Program Status for Continuation into Ground Demonstration Phase in FY 84
 D. Final Design Review of DIPS Flight System
 E. Obtain Galileo Launch Approval by President

III. ENVIRONMENTAL CONCERNS AND REQUIREMENTS

A. Introduction

As a new technology develops, processes and materials employed may impact on both the working environment and the outside environment. Some of these impacts may require EH&S R&D to address these concerns. Failure to conduct such research in a timely manner could result in delays of the technology. It is the purpose of this section to identify concerns which may have an environmental impact as space applications technology develops and to indicate the requirements or actions that can be taken to resolve them during technology development. The space applications EH&S concerns and associated research requirements are shown in Table III-1 where the assigned index numbers (e.g., SA-1.1) are used in order to enable subsequent referencing.

In addressing the EH&S concerns, a qualitative determination has been made of the relative priority of the concern to the progression of the program from the laboratory to mission application and of the importance of the concern to environmental decisions. Thus, for example, before environmental and health effects can be studied or assessed, the space applications processes must be characterized. Further, some concerns are generic to every process while others are process specific.

B. Areas of Concerns

The major EH&S concerns are (1) those related to environmental criteria, standards, and guides associated with risk decisions, (2) those related to accidents resulting in releases of radioactivity and/or toxic chemicals, and (3) those related to the final fate of nuclear power sources. Various failure modes may occur at any time throughout a nuclear power source mission. These accidents, although with low probabilities of occurrence, could potentially lead to dispersal of radioactivity and toxic chemicals into the environment and ultimately to man.

Most significant of the potential accidental releases are those that may occur from RTG ground demonstration system (GDS) tests, from accidents during launch, or from aborted missions in space that result in reentry of the RTG power source to the earth's atmosphere. Present nuclear isotope power sources are designed with a high probability to survive launch pad accidents (including explosion and fire) as well as reentry and impact associated with failure to attain earth orbit. However, a low but finite risk does exist for release of the isotope fuel. Further, for reentry of isotope power generators which are not recovered (lost after reentry), eventual containment failure

TABLE III - 1
ENVIRONMENTAL HEALTH AND SAFETY CONCERNS AND REQUIREMENTS

Program Element, Decision Point, and Date	EH & S Impact Area ¹	EH & S Concern	EH & S Research Area	EH & S Requirements	Status of EH & S Requirements ²	Requirement Time ³
Galileo Flight RTG Delivery, FY 1982	1 2, 3, 4, 5	Concern No SA - 1 Release of ²³⁸ Pu from Isotopic Power Systems During Source Fabrication, Ground Tests Launches, or System Recovery Could Cause Health and Environmental Im pacts A 2.4 kW Source, for Example, Contains Approx imately 4 kg of ²³⁸ Pu	3 4	SA - 1 1 Continue to Evaluate the Potential Health Effects From Acute and Chronic Intake of ²³⁸ Pu	A	Continuing
			1 2 2 3	SA - 1 2 Continue to Evaluate the Potential Acci dental Release of ²³⁸ Pu Including the Physical and Chemical Characteristics of ²³⁸ Pu From Various Accident Scen arios	A	Continuing
			2 1, 4 4	SA - 1 3 Continue to Evaluate ²³⁸ Pu Environ mental Behavior and Transport Mech anisms and Dynamics of ²³⁸ Pu, as well as Its Pathways to Man	A	1 Year
			1 2, 4 4	SA - 1 4 Continue to Determine Applicability of ²³⁹ Pu Data for Evaluation of Environ mental and Biological Behavior of ²³⁸ Pu	A	1 Year
			2 1, 4 4	SA - 1 5 Continue to Develop Models for Pre dicting the Behavior of ²³⁸ Pu in the Environment Following Identified Acci dents	B/C	2 Years
			8 3	SA - 1 6 Continue to Reduce the Risks of Re leases of ²³⁸ Pu by Improving Current Technology	A	Continuing
			1 4	SA - 1 7 Continue to Develop Improved Monitor ing Instruments for Detection of Pluton ium in the Environment and In-Vivo	A	2 Years
			8 3	SA - 1 8 Continue to Evaluate the Adequacy of Health Protection Standards for Plut onium Intake Based on Current State of-Knowledge.	A	Continuing

¹ The EH & S Impact Area and Research Area Refer Respectively to the Taxonomy for Concerns and Requirements Given in Appendix F to Identify Types of Effort Needed

² Status Code A - Projects Funded and Ongoing, B - Projects Programmed, C - Projects Needed But Not Yet Funded or Programmed

³ The Time is an Estimate of the Time Required to Address the Requirement Its Significance is Indicated Through Comparison with the Requirements Schedules Given in Figure IV - 2

TABLE III - 1 (Continued)

ENVIRONMENTAL, HEALTH AND SAFETY CONCERNS AND REQUIREMENTS

Program Element, Decision Point, and Date	EH & S Impact Area	EH & S Concern	EH & S Research Area	EH & S Requirements	Status of EH & S Requirements	Requirement Time
Decision Regarding Continuation Into Ground Demonstration Phase, FY 1983	1, 2, 3, 4	Concern No. SA - 2 The Reactors used in Space Applications Will Produce Fission Products Which, if Released, Could Cause Health and Environmental Impacts. For a Conceptual 100 kWe Reactor, There Would be Approximately 120 kg of ²³⁵ U in the Fuel	8 1 1 2 3 1, 4 2, 8 1	SA - 2 1 Continue to Evaluate Mechanisms for Accidents Resulting in Release of Radioactivity to the Environment SA - 2 2 Determine the Source Terms in Each Accident Scenario and Their Physical and Chemical Characteristics. SA - 2 3 Evaluate Possible Environmental, Health and Safety Implications of Alternative Reactor Fuel Forms and Types	A A	Continuing Continuing
Galileo Flight RTG Delivery, 1982	6	Concern No. SA - 3 There are Uncertainties in the Ability to Predict the Risks to the Public from Space Nuclear System Accidents	8 1 8 1 2 1, 8 1 8 1 8 1	SA - 3 1 Continue to Develop Analytical Models for Assessing the Risks Associated with Launch Accidents and from Reentry of Space Nuclear Systems SA - 3 2 Evaluate Potential Consequences of Reentry as a Function of Time in Orbit and Burnup of Nuclear Fuel SA - 3 3 Continue to Develop Models for Predicting the Area and Extent of Contamination Following Accidents Associated with Space Nuclear Systems SA - 3 4 Continue to Develop Techniques to Combine the Probabilities for Accidents and Exposures and Their Associated Uncertainties for Analysis of Accident Risks. SA - 3 5 Continue to Evaluate the Uncertainties Associated with Various Accident Scenarios for Space Nuclear System Applications from Launch to Reentry	B/C A C A A A	2 - 5 Years Continuing 1 Year Continuing Continuing Continuing

TABLE III - 1 (Continued)

ENVIRONMENTAL, HEALTH AND SAFETY CONCERNS AND REQUIREMENTS

Program Element, Decision Point, and Date	EH & S Impact Area	EH & S Concern	EH & S Research Area	EH & S Requirements	Status of EH & S Requirements	Requirement Time
Galileo Flight RTG Delivery, FY 1982	1, 2, 3, 4, 5	Concern No. SA - 4 Space Nuclear Systems Use Hazardous Chemicals Such as Beryllium and Molybdenum Which, if Released, Could Cause Health and Environmental Impacts. A Conceptual 100 kWe Reactor Contains Approximately 60 kg of Molybdenum and 155 kg of Beryllium and Beryllium Oxide. For Such Chemicals There are Uncertainties Regarding Exposure Pathways, Environmental Transport Mechanisms, and the Synergistic Effects of Chemicals and Radiation.	3.4, 8.1	SA - 3.6 Continue to Evaluate Uncertainties Associated with Health Effects Estimates.	A	Continuing
				SA-3.7 Continue to Study the Health Effects of Chronic, Low-Level Radiation Exposures and the Appropriate Health Effects Models.	B/C	Continuing
			3.1	Concern No. SA - 4 SA - 4.1 Identify Possible Hazardous Chemicals or Chemical Reaction Products Associated with Space Nuclear System Applications.	C	1 Year
			3.4, 4.2	SA - 4.2 Determine Possible Environmental and Health Effects of Exposure to Hazardous Chemicals	B/C	Continuing
			4.2, 4.4	SA - 4.3 Evaluate Environmental Behavior of Hazardous Chemicals Following Release Under Identified Accident Scenarios	B/C	Continuing
			1.4	SA - 4.4 Continue to Develop Improved Systems to Identify and Measure Hazardous Chemicals in the Environment.	B/C	1 - 5 Years
			3.1	SA - 4.5 Determine Possible Synergistic Interactions Between Hazardous Chemicals and the Nuclear Fuel from Space Nuclear Systems in Producing Biological Damage.	B/C	Continuing
Fabrication of Galileo RTG Sources, Currently Underway	5, 6	Concern No. SA - 5 Fabrication of ^{238}Pu Sources Entails the Occupational Risks Associated with Criticality Accidents and Exposure to the Source Material Itself. Existing Information Deals with Criticality Analysis in General, as well as the Health Effects of other Plutonium Isotopes But is Insufficient for the Space Nuclear Program Because of the Uniqueness of the ^{238}Pu and the Facilities Used in Source Fabrication	8.1	SA - 5.1 Evaluate Possible Mechanisms for Criticality Accidents During ^{238}Pu Fabrication and Handling and Determine the Consequences of Such Accidents.	A	Completed
			8.3	SA - 5.2 Develop Design Criteria to Prevent Criticality Accidents Involving ^{238}Pu Sources.	A	Completed

TABLE III - 1 (Continued)

ENVIRONMENTAL, HEALTH AND SAFETY CONCERNS AND REQUIREMENTS

Program Element, Decision Point, and Date	EH & S Impact Area	EH & S Concern	EH & S Research Area	EH & S Requirements	Status of EH & S Requirements	Requirement Time
Fabrication of Reactor Components, FY 1980 and Subsequent Years	5, 6	Concern No. SA - 6 Criticality Accidents Constitute an Occupational Risk During Fabrication, Assembly, and Ground Operation of Space Reactors. The Criticality Accident Analysis and Prevention Techniques Used for Other Types of Reactors are Inadequate for Use with Space Reactors, Because of Their Unique Design	3 4	SA - 5.3 Evaluate Potential Occupational Hazards Associated with ²³⁸ Pu Source Fabrication - Radiological and Chemical.	A	Completed
			1.4	SA - 5.4 Determine the Need for Improved In plant Monitoring Instruments for Hazardous Chemicals and Plutonium Isotopes and Develop Improved Instruments as Needed	B/C	1 - 4 Years
			3 4, 8 1	SA - 6.1 Evaluate Mechanisms That May Cause Criticality Accidents in Space Reactors and Determine the Consequences of Such Accidents	C	1 Year
			8.3	SA - 6.2 Develop Design Criteria to Prevent Space Reactor Criticality Accidents.	C	1 Year
Galileo Flight RTG Delivery, FY 1982	5, 6	Concern No. SA -7 There are Uncertainties Associated with the Adequacy and Acceptability of the Remedial Measures Required in the Event of an Accident Involving a Space Nuclear System	8 1	SA - 7.1 Identify Potential Accident Environments to be Considered in Defining Accident Scenarios	A	Continuing
			1.4, 8.4	SA - 7.2 Develop Improved Instruments and Techniques for Locating Nuclear Sources and for Monitoring Radioactive Contamination Levels.	A	Continuing
			3.3	SA - 7.3 Develop Improved Methods of Removing ²³⁸ Pu From the Body Following Accidental Deposition	A	1 - 3 Years
			8.1	SA - 7.4 Evaluate the Feasibility of Recovery of Space Nuclear Systems to Prevent Reentry, if Necessary.	A	Continuing
			8.1	SA - 7.5 Develop Improved Techniques for System Recovery and Decontamination of the Environment in the Event of an Accident or Reentry Involving a Space Nuclear System.	C	3 5 Years

TABLE III - 1 (Continued)

ENVIRONMENTAL, HEALTH AND SAFETY CONCERNS AND REQUIREMENTS

Program Element, Decision Point, and Date	EH & S Impact Area	EH & S Concern	EH & S Research Area	EH & S Requirements	Status of EH & S Requirements	Requirement Time
Fabrication of Galileo RTG Sources, Currently Underway	6, 7, 8 •	Concern No SA - 8 The Quantities of Plutonium and Enriched Uranium Used in Compact Configurations in the Space Nuclear Program Present Special Challenges in the Prevention of Unauthor- ized Diversion of the Material	8.3	SA - 7.6 Develop Criteria for Remedial Actions Following Space Nuclear System Accidents.	A	Continuing
			8.3	SA - 7.7 Establish Criteria for Acceptable Levels of Environmental and Human Exposures to Hazardous Chemicals Associated with Space Nuclear System Applicators.	B	1-2 Years
			8.3	SA - 7.8 Establish Design Criteria to Limit Hazard- ous Chemical Releases Following Space Nuclear System Accidents	B	Continuing
			8.3	SA - 7.9 Establish Design, Launch and Mission Criteria to Minimize Risks to the Public and the Environment.	A	Continuing
			8.2, 8.3	SA - 8.1 Review Production Processes to Ensure Adequate Protection and Accountability Capability for Special Nuclear Materials	A	Continuing
			8.3	SA - 8.2 Develop Criteria and Specifica- tions for Improved Safeguards and Accountability Provisions	A	Continuing

and release of plutonium and its daughter products to the environment must be considered.

There are two basic concerns involving space nuclear reactor accidents: those accidents resulting in release of the uranium fuel to the environment and those which would involve release of mixed fission products. Except under extraordinary circumstances, only accidents associated with the "cold" (non-operated) reactor system are likely to impact on the environment since the reactor will not be operated until a satisfactory and safe long-lifetime orbit has been established. The risks associated with fission products will be a function of reactor operating time and power level (fuel burnup), time in orbit, and time after reactor shutdown. In addition to mission and orbital limitations imposed to minimize risks, the satellites may be designed to preclude reentry of a space reactor, e.g., atmospheric burnup, self destruct in space or extraterrestrial launch from earth orbit.

In addition to the accident risks associated with launch or re-entry, there is a risk of routine and accidental releases of radioactivity from a space reactor system during ground demonstration testing.

C. Analysis of Concerns and Requirements

The environmental concerns and key requirements are arranged in order of perceived importance in the following section.

C.1 Need for EH&S Criteria, Standards, and Guides

Space nuclear systems are unique in both design and application. Accordingly, while there is conformance to existing standards, there is also a need for additional criteria related to safety and power system design to assure environmental, health, and safety acceptability.

Existing standards and criteria applicable to the terrestrial phases of development and materials handling such as fabrication, testing, and transport, are generally adequate. The major concern in these phases is to assure that those radioactive or otherwise toxic materials for which a depth-of-knowledge or handling experience is limited are properly controlled.

The launch and application phases of space nuclear systems are of particular concern as regards adequate criteria for ensuring acceptable EH&S impacts, primarily due to the hostile environment that may occur in the event of accidents. Temperatures sufficient to vaporize toxic materials or projectiles capable of penetrating

containment structures could result during launch accidents. Also, nuclear power systems which are not recovered following completion of the mission or those lost following a mission failure will eventually experience containment failure and may release radioactive or other toxic materials. Power systems can be designed and missions selected to minimize environmental, health, or safety risk. Criteria to judge acceptability are required to guide systems design and for operations management.

Criteria for acceptance of space nuclear power systems have been developed and utilized. (Current design criteria for heat source containments are included in Appendix B.) Existing criteria should, however, be critically reviewed to assure adequacy and completeness for new systems. Acceptance criteria should also be established for nonradioactive toxic materials where applicable.

C.2 Health and Environmental Impacts from Releases of ^{238}Pu

In the case of RTG fabrication and use, the plutonium oxide (PuO_2) heat source is of primary EH&S concern. Occupational exposures during source fabrication also continue to be an important concern. Much R&D on environmental transport and health hazards of plutonium is in place. Concern over the environmental fate and health hazards of long-lived ^{239}Pu (half-life 24,000 years) used in the manufacture of nuclear weapons and as a waste product of or fuel for power reactors has led to much R&D by DOE (and its predecessors), the Nuclear Regulatory Commission (NRC), and Environmental Protection Agency (EPA), among others. The ^{238}Pu with its shorter half-life (87 years) represents less of a long-term hazard but is radiologically as hazardous as ^{239}Pu on a curie-to-curie basis. Therefore, requirements to identify potential releases, environmental fate and health effects of this specific radionuclide are necessary. Past and current R&D on ^{239}Pu may be applicable to resolution of concerns if it is determined under what conditions its environmental and biological fate can be considered similar to that of ^{238}Pu . A great deal of laboratory work on ^{238}Pu in the environment has been carried out in environmental chambers and continues to be pursued at LASL. In addition, some work has been done on the environmental transport and accumulation of ^{238}Pu (as well as ^{239}Pu) in certain ecosystems and biota (see Appendix D--Environmental Research Summary).

C.3 Health and Environmental Impacts of Releases from Reactor Systems

While there has been a great deal of R&D on EH&S considerations of reactors, as indicated in Section II.B.4, the present space

reactor concepts and designs include use of advanced reactor fuels and materials for the expected future development and use of space reactor system technology. The EH&S considerations relative to the use of the new fuels need to be addressed even though much associated R&D has been carried out on the fuel forms for other nuclear technology applications. Additional EH&S work may be necessary because of the unique applications and risks during launch and possible reentry of the nuclear reactor.

C.4 Predictions and Evaluation of Consequences of Space Nuclear System Accidents

Resolving the concern regarding the consequences of space nuclear system accidents requires the identification of accident scenarios and environs, identification of potential releases and their likelihood, and the evaluation of consequences of accidents related to use of nuclear fuels and applications peculiar to the space program.

Ecological R&D programs exist which will help to identify potential impacts on terrestrial and aquatic ecosystems and will help to establish improved design criteria. A major requirement, however, is the need to better define accident environments and risk assessments for future missions so that source terms may be derived and impacts on ecosystems likely to be affected may be assessed.

Research programs are underway by the user agencies (coordinated by INSRP) to provide greater understanding of potential impacts resulting from unplanned releases of radioactive materials. Continuation of these programs is necessary to assure that possible secondary impacts in the public sector are properly considered.

Extensive efforts have been expended to develop analytical models for the prediction of probability and consequences of accidents. Updating of these models will be required as new data become available or as new power systems are developed.

C.5 Health and Environmental Impacts from Releases of Hazardous Chemicals

Environmental concerns about the space program include the use of hazardous chemicals, although this latter concern is believed to be of less significance than those associated with potential radioactive releases. Because nearly pure beryllium metal is used in the RTG's and reactors, this element has been identified as one toxic chemical of potential EH&S significance. Although its toxicological characteristics and health effects have been established to a large degree, R&D related to environmental transport of beryllium and expo-

sure pathways to man has not been extensive. Similarly, molybdenum and titanium may be used in substantial quantities in the space reactors. Although molybdenum is a required trace element in human and animal metabolism, it can be toxic if ingested in higher quantities. Additional work is needed to better define the environmental behavior and pathways for these metals in the various physical and chemical forms they would exhibit following ground demonstration test, launch or re-entry accidents.

C.6 Occupational Risks from Fabrication, Assembly, and Operation (Ground Testing) of Space Power Systems Containing Radioactivity

The potential for accidents (especially criticality events) needs to be evaluated continually and used to develop criteria necessary to reduce the risk of occurrence of such accidents. Although much related R&D has been conducted, the development of new, highly enriched (85% ^{235}U) reactor fuels for space uses necessitates resolution of these issues. Except for Ground Demonstration System (GDS) testing, hazards resulting from reactors are limited to those associated with "cold" fuel and not with fission products, since the reactor will not be operated until it has been placed in a proper, very long life orbit. This will ensure sufficient decay of most fission products before reentry once a reactor is operated in orbit. However, particular attention is necessary to evaluate and minimize risks associated with reactor GDS testing, which will probably be conducted in a facility at LASL. This safety work generally will be an integral part of the overall system safety analyses and development program. For re-entry risks following reactor operation in space, evaluations will be made to determine the risks from long-lived actinides, as well as fission products. Much R&D in the field of reactor safety was accomplished during the 1960's in the previous space reactor development work. These efforts will serve as points of departure for any new work necessary to ensure resolution of EH&S issues remaining for the future applications of space reactors.

C.7 Adequacy of Remedial Measures Following Accidents

Although the establishment of adequate remedial measures for accident situations is addressed in part by existing regulatory standards, the problem is continuously evaluated by DOE and user agencies. There are several continuing projects which are directed toward development of methods for decontamination of contaminated areas and material and toward improvement of techniques for removing radionuclides from the body (see Appendix D). In addition, some experience has been gained in recovering RTG sources following mission aborts and in decontaminating discrete but large natural surfaces following nuclear weapons accidents. The EPA, under authority transferred from the former Federal Radiation Council, has an

ongoing program to develop Protective Action Guides (PAG's) for use following accidental contaminating events.

C.8 Generic Concerns

A great amount of public concern is associated with the adequacy of provisions for safeguarding special nuclear materials and for material accountability. The space technology program should be closely scrutinized to assure adequate means of safeguarding special nuclear materials (plutonium and uranium) and to provide for secure and practical material accountability systems. This will be particularly important during the development and use of a space reactor system because of its need for highly enriched uranium.

A second generic concern relates to the adequacy of health standards relative to plutonium inhalation and ingestion. Recent studies should be reviewed, and, as appropriate, new supportive studies begun. Then, if necessary, standards should be revised based on the results.

IV. ENVIRONMENTAL STRATEGY

A. Environmental Program Plan--Coordination

To assist in implementation of this EDP, an Environmental Coordinating Committee (ECC) has been established. Environmental Coordinating Committees are special groups constituted under authority of DOE Order 5420.1, composed of representatives of various DOE offices to assist in the implementation of the DOE Environmental Development Plan (EDP) System.

The primary function of an ECC is to monitor and overview the status of environmental R&D programs to ensure that the intent of the EDP is achieved and to promote regular information exchanges and coordination between offices responsible for environmental R&D.

Specifically, the ECC through appropriate subcommittees:

- participates in the preparation and review of EDP's and identifies the need for and recommends revisions in EDP's
- maintains a collective awareness of the content, status, and results of environmental R&D efforts and apprises management periodically of status and issues
- advises management of gaps, redundancies, and potential conflicts in the R&D efforts and recommends corrective options for management consideration
- coordinates between performing offices those necessary physical and institutional arrangements required for conduct of respective research efforts

The ECC membership is appointed by the Assistant Secretary for Environment (ASEV) and the Assistant Secretary for Energy Technology (ASET). In principle, the membership consists of one representative from each performing division and such special designees as assigned by the appointing officers. The chairmanship of the ECC is assigned to the representative from the TAD, Office of Technology Impacts (OTI) under the ASEV.

As the scope and complexity of a technology program warrant, the ECC can exercise the option to authorize the formation of subcommittees for an individual technology subprogram area, e.g., Space Applications. The duties and functions of the subcommittee are commensurable with the ECC. The subcommittee reports its findings, recommendations, etc. to the ECC. The ECC subcommittee also provides the coordination necessary to assure that required environmental and

safety documents are appropriately scheduled. This includes ERD's; NEPA documents--EA's/EIS's; and SAR's. A brief summary of these documents is provided in Appendix E.

TAD is responsible for the day-to-day coordination of the EDP. A fundamental goal of the EDP implementation is getting technical personnel responsible for EH&S activities of DOE actively involved with staff of the technology programs. EH&S concerns will be considered and resolved on a schedule consistent with the space applications technology development. Completion of evaluations identified by requirements may show the concerns to be of no consequence, or on the other hand may reveal unanticipated concerns and new requirements. Health and safety personnel can assist in the resolution of these concerns by close tracking of and involvement with the space applications technology program.

B. Environmental Plan Schedule

In developing the schedules for conducting the EH&S R&D, the R&D milestones have been coordinated with the milestones critical to the technology. Also, an initial identification has been made of the appropriate DOE organization which logically will have the lead responsibility for completing the EH&S R&D requirements of this plan. The schedules and responsibilities indicated in the EDP are recommendations which are subject to modification. The need for modifications in the indicated R&D and schedules will be identified by the responsible program representative to the ECC.

The EH&S milestones and R&D schedules have been developed for the requirements presented in Table III-1 and are summarized in Figure IV-1 against the significant technology and NEPA milestones. Specific schedules for each requirement are indicated in Figure IV-2. While applicable to the Space Applications Program, generic R&D requirements are being addressed by many ongoing, related projects and their resolution is not unique to this technology. The indicated schedules and responsible organizations are tentative since actual initiation and completion of the annual DOE budget cycle establishes priorities for addressing various program needs and levels of funding of specific projects. Likewise, changes in the technology development schedule will influence budgetary priorities and the EH&S schedules. As a consequence, the EDP will be revised periodically to reflect these factors and alterations, as well as those caused by development of new technical information or new concerns.

Table III-1 reveals that the number of requirements needing lengthy advanced study or research is limited. Toxicology, epidemiology, and ecology effects studies require long periods of work before yielding useful data, and they should be started as soon

FIGURE IV 1
ENVIRONMENTAL TASK SCHEDULE FOR SPACE APPLICATIONS

Symbols Δ Activity Initiation ∇ Activity End Point (Program Milestone) $\diamond$ Key Decision Point
— Activity ——— Continuing Activity Timeline

Notes *NEPA Documentation for Mission Applications Prepared by User Agency as Required

- Milestones**
- 1 Deliver First Galileo Heat Source
 - 2 Complete Delivery of Galileo Heat Source
 - 3 Complete Fabrication of General Purpose Heat Sources (GPHS) (4)
 - 4 Complete Assembly of GPHS Generator (4)
 - 5 Complete RTG Qualification and Acceptance Test Plans
 - 6 RTG Final Design Review
 - 7 RTG Qualification Test
 - 8 Flight RTG Delivery
 - 9 Assembly and Measurements on First Gross Critical Assembly
 - 10 Manufacture of Thermoelectric Converter Module
 - 11 Selection of Materials for Component Development
 - 12 Preparation of Specification for Reactor Power Plant
 - 13 Complete Component Development
 - 14 Complete Evaluation of Major System Element Verification Tests

- 15 Complete Technology Development Required Prior to Ground Demonstration Phase
- 16 Complete Design of Development Components and GDS Modifications
- 17 Complete Fabrication and Assembly of GDS Modifications
- 18 Complete Testing and Evaluation of Development Components
- 19 Complete GDS Performance/Endurance Testing with Upgraded Components
- 20 Complete Galileo Safety Test Plan
- 21 EA for Reactor Ground Demonstration Unit
- 22 Complete Galileo PSAR INSRP Review
- 23 Complete Final Galileo GSAR Review
- 24 Complete Galileo USAR INSRP Review
- 25 Complete Preliminary Failure Modes and Effects Analysis for Space Reactors
- 26 Complete Galileo FSAR INSRP Review
- 27 Complete PSAR for Space Reactors
- 28 Complete Solar Polar FSAR INSRP Review

- Key Decisions**
- A DOE Launch Readiness Review
 - B Selection of Reactor Design Concept for Technology Development
 - C Review of Program Status for Continuation into Ground Demonstration Phase in FY 84
 - D Final Design Review of DIPS Flight System
 - E Obtain Galileo Launch Approval by President

FIGURE IV-2
SCHEDULE OF SPECIFIC EH & S REQUIREMENTS

Requirement Number ¹	Requirement	Lead Responsibility ²	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90
	<u>Health Effects</u>														
SA - 1 1	Continue to Evaluate the Potential Health Effects From Acute and Chronic Intake of ²³⁸ Pu	OHER	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	----->
SA - 3 7	Continue to Study the Health Effects of Chronic, Low level Radiation Exposures and the Appropriate Health Effects Models	OHER	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	----->
SA - 1 4	Continue to Determine the Applicability of ²³⁹ Pu Data for Evaluation of Environmental and Biological Behavior of ²³⁸ Pu	OHER	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	----->
SA - 4 2	Determine Possible Environmental and Health Effects of Exposure to Hazardous Chemicals	OHER	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	----->
SA - 7 3	Develop Improved Methods of Removing ²³⁸ Pu from the Body Following Accidental Deposition	OHER	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	----->
SA - 5 3	Evaluate Potential Occupational Hazards Associated with ²³⁸ Pu Source Fabrication Radiological and Chemical	ANSP	COMPLETED												
SA - 1 8	Continue to Evaluate the Adequacy of Health Protection Standards for Plutonium Intake Based on Current State of Knowledge	OHER	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	----->
SA - 3 6	Continue to Evaluate Uncertainties Associated with Health Effects Estimates	OHER/ANSP	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	----->
SA-7.6	Develop Criteria for Remedial Action Following Space Nuclear System Accidents	ANSP	-----	-----	-----	-----									
SA-7 7	Establish Criteria for Acceptable Levels of Environmental and Human Exposures to Hazardous Chemicals Associated with Space Nuclear System Applications	ANSP	-----	-----	-----	-----									
SA-7.8	Establish Design Criteria to Limit Hazardous Chemical Releases Following Space Nuclear System Accidents	ANSP	-----	-----	-----	-----									
SA-7.9	Establish Design, Launch, and Mission Criteria to Minimize Risks to the Public and the Environment	ANSP (NASA/DOD)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	----->

¹Numbers are Keyed to Table III-1 but Grouped Here According to Generic Research Area Classification

²Organization(s) in Parenthesis have Significant Support Involvement

FIGURE IV-2 (Continued)

Requirement Number	Requirement	Lead Responsibility	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90
	<u>Safety - General</u>														
SA - 7 4	Evaluate Feasibility of Recovery of Space Nuclear Systems to Prevent Reentry, if Necessary	ANSP* (NASA/DOD)													
SA - 3 1	Continue to Develop Analytical Models for Assessing Risks Associated With Launch Accidents and From Reentry of Space Nuclear Systems	ANSP (NASA/DOD)													
SA - 3 2	Evaluate Potential Consequences of Reentry as a Function of Time in Orbit and Burnup of Nuclear Fuel	ANSP (NASA/DOD)													
SA - 3 3	Continue to Develop Models for Predicting Area and Extent of Contamination Following Accidents Associated with Space Nuclear Systems	ANSP (NASA/DOD)													
SA - 3 4	Continue to Develop Techniques to Combine Probabilities for Accidents and Exposures and Their Associated Uncertainties for Analyses of Accident Risks	ANSP (NASA/DOD)													
SA - 3 5	Continue to Evaluate Uncertainties Associated with Various Accident Scenarios for Space Nuclear System Applications from Launch to Reentry	ANSP (NASA/DOD)													
SA - 4 1	Identify Possible Hazardous Chemicals or Chemical Reaction Products Associated with Space Nuclear Systems Applications	ANSP													
SA - 7 1	Identify Potential Accident Environments to be Considered in Defining Accident Scenarios	ANSP (NASA/DOD)													
SA - 7 5	Develop Improved Techniques for System Recovery and Decontamination of the Environment in the Event of an Accident or Reentry Involving a Space Nuclear System	ANSP (NASA/DOD)													
	<u>Safety - Space Reactor Systems</u>														
SA - 2 1	Continue to Evaluate Mechanisms for Accidents Resulting in Release of Radioactivity to the Environment	ANSP (NASA/DOD)													
SA - 2 2	Determine Source Terms in Each Accident Scenario and Their Physical and Chemical Characteristics	ANSP (NASA/DOD)													

*ANSP (NASA/DOD) - Indicates ANSP Working Through INSRP Will Achieve the Effort Cooperatively with NASA and DOD Depending in Part on Which is the User Agency

FIGURE IV-2 (Continued)

Requirement Number	Requirement	Lead Responsibility	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90
SA - 23	Evaluate Possible Environmental, Health, and Safety Implications of Alternative Reactor Fuel Forms and Types	ANSP (NASA/DOD)													
SA - 61	Evaluate Mechanisms That May Cause Criticality Accidents in Space Reactors and Determine the Consequences of Such Accidents	ANSP (NASA/DOD)													
SA - 62	Develop Design Criteria To Prevent Space Reactor Criticality Accidents	ANSP													
	<u>Safety - Isotopic Heat Sources</u>														
SA - 15	Continue to Develop Models for Predicting the Behavior of ^{238}Pu in the Environment Following Identified Accidents	ANSP/OHER (NASA/DOD)													
SA - 12	Continue to Evaluate Potential Accidental Releases of ^{238}Pu Including The Physical and Chemical Characteristics of ^{238}Pu From Various Accident Scenarios	ANSP (NASA/DOD)													
SA - 51	Evaluate Possible Mechanisms for Criticality Accidents During ^{238}Pu Source Fabrication and Handling and Determine the Consequences of Such Accidents	ANSP	COMPLETED												
SA - 52	Develop Design Criteria to Prevent Criticality Accidents Involving ^{238}Pu Sources	ANSP	COMPLETED												
SA - 16	Continue to Reduce the Risks of Releases of ^{238}Pu by Improving Current Technology	ANSP (NASA/DOD)													
	<u>Monitoring and Measurement</u>														
SA - 44	Continue to Develop Improved Monitoring Systems to Identify and Measure Hazardous Chemicals in the Environment	OHER/ANSP (NASA/DOD)													
SA - 54	Determine the Need for Improved In plant Monitoring Instruments for Hazardous Chemicals and Plutonium Isotopes and Develop Improved Instruments as Needed	OHER													
SA - 72	Develop Improved Instruments and Techniques for Locating Nuclear Sources and for Monitoring Radioactive Contamination Levels	OHER/ANSP (NASA/DOD)													

FIGURE IV-2 (Continued)

Requirement Number	Requirement	Lead Responsibility	FY 78 FY 79 FY 80 FY 81 FY 82 FY 83 FY 84 FY 85 FY 86 FY 87 FY 88 FY 89 FY 90														
SA - 1.7	Continue to Develop Improved Monitoring Instruments for Detection of Plutonium in the Environment and In-vivo	OHER/ANSP (NASA/DOD)															
	<u>Ecology</u>																
SA - 1.3	Continue to Evaluate ²³⁸ Pu Environmental Behavior and Transport Mechanisms and Dynamics, as well as Its Pathways to Man	ANSP/OHER															
SA - 4.3	Evaluate Environmental Behavior of Hazardous Chemicals Following Release Under Identified Accident Scenarios	OHER/ANSP (NASA/DOD)															
SA - 4.5	Determine Possible Synergistic Interactions Between Hazardous Chemicals and Nuclear Fuels from Space Nuclear Systems in Producing Biological Damage	OHER															
	<u>Socioeconomics - Proliferation Resistance</u>																
SA - 8.1	Review Production Processes to Ensure Adequate Protection and Accountability Capability for Special Nuclear Materials	DP(SS)/ANSP															
SA - 8.2	Develop Criteria and Specifications for Improved Safeguards and Accountability Provisions	DP(SS)/ANSP															

as possible. Equipment development, measurement and monitoring, source characterization, and emission criteria definitions, all of which require shorter lead times, are closely linked to the details of the technology but can be initially estimated based on design criteria and then refined later once the design details are known.

Certain of the EH&S requirements identified in this EDP have already been addressed by R&D conducted previously in support of previous space nuclear applications missions using ^{238}Pu sources and during the early development and flight testing of a space nuclear reactor system. However, due to the evolution of environmental requirements and criteria and the improvement in modeling capabilities, the models and data used for predicting the risks associated with the application of this technology need review and possibly revision before future missions, in particular those using a reactor for a power source. The R&D requirements for the space nuclear reactor systems are time phased to coordinate with the decision point preceding the ground demonstrative phase of the program.

A brief discussion of the strategy for assuring fulfillment of specific EH&S requirements is presented in Appendix A. This information indicates the basis for accomplishing the task and its relevance to the technology program.

REFERENCES

1. "Environmental Development Plan for Special Nuclear Materials Production," in preparation; scheduled for publication in CY 1979.
2. "Environmental Development Plan for Transportation of Nuclear Materials," in preparation; scheduled for publication in CY 1979.
3. "Environmental Development Plan for Decommissioning and Decontamination," in preparation; scheduled for publication in CY 1979.
4. "Safety Analysis Report for the $^{238}\text{PuO}_2$ Experimental Facility," Report Number DPSTSA-700-30, February 1978.
5. "Safety Analysis Report for the $^{238}\text{PuO}_2$ Fuel Form Facility," Report Number DPSTSA-200-5, August 1977.

APPENDIX A

PARTIAL STRATEGY FOR FULFILLING EH&S REQUIREMENTS

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APPENDIX A

PARTIAL STRATEGY FOR FULFILLING EH&S REQUIREMENTS

Health Effects

SA-1.1* CONTINUE TO EVALUATE THE POTENTIAL HEALTH EFFECTS FROM ACUTE AND CHRONIC INTAKE OF ^{238}Pu

Strategy:

Current and past studies in ^{238}Pu and ^{239}Pu health effects will be used to plan any new OHER efforts directed at assessing the potential biological effects resulting from intake of ^{238}Pu . As available, the results will be used by ANSP and user agencies to estimate the risks (health effects times probability) of future space nuclear system missions in the SAR's and EIS's. The next mission is scheduled for 1982; thus, the biological data should be available to complete safety and environmental analyses in 1979.

SA-3.7 CONTINUE TO STUDY THE HEALTH EFFECTS OF CHRONIC, LOW-LEVEL RADIATION EXPOSURES AND THE APPROPRIATE HEALTH EFFECTS MODELS

Strategy:

OHER has a large-scale ongoing program directed at this need. In addition, EPA, NRC, and the Department of Health, Education and Welfare (DHEW) have active efforts directed toward this requirement. DHEW is leading an interagency task force to evaluate Federal efforts in this area and an EPA-sponsored study by the National Academy of Sciences (NAS) is updating the original NAS report on Biological Effects of Ionizing Radiation. Results of the studies are to be used to improve models for predicting health effects of radiation exposure.

SA-1.4 CONTINUE TO DETERMINE THE APPLICABILITY OF ^{239}Pu DATA FOR EVALUATION OF ENVIRONMENTAL AND BIOLOGICAL BEHAVIOR OF ^{238}Pu

Strategy:

OHER will evaluate the differences between the biological, physical, chemical, and environmental behavior of ^{238}Pu

*Numbers are keyed to Table III-1, but grouped here according to the generic research area classification used in Figure IV-2.

and ^{239}Pu to determine the degree to which the extensive ^{239}Pu data may be used to assess health and environmental risks from ^{238}Pu . It is likely that these data will be more applicable to environmental assessments than to the estimation of health effects. The results, as available, will be used to identify additional complementary studies needed to assess ^{238}Pu risks and for assessments in future SAR's and EA's/EIS's prepared by ANSP and the user agencies.

SA-4.2 DETERMINE POSSIBLE ENVIRONMENTAL AND HEALTH EFFECTS OF EXPOSURE TO HAZARDOUS CHEMICALS

Strategy:

ANSP will provide OHER a list of the chemicals which could be dispersed to the environment following a space nuclear system launch accident or reentry. OHER will evaluate the current knowledge of the toxicity and carcinogenic potential of these chemicals. As possible, OHER will provide the new data results in time for decisions on alternative technologies and technology application.

SA-7.3 DEVELOP IMPROVED METHODS OF REMOVING ^{238}Pu FROM THE BODY FOLLOWING ACCIDENTAL DEPOSITION

Strategy:

OHER will initiate R&D as needed to improve techniques for removing ^{238}Pu from the body. The results will be used in improving emergency response plans for launch-phase accidents, recovery operations following reentry-caused contamination, or intake during industrial source fabrication.

SA-5.3 EVALUATE POTENTIAL OCCUPATIONAL HAZARDS ASSOCIATED WITH ^{238}Pu SOURCE FABRICATION--RADIOLOGICAL AND CHEMICAL

Strategy:

A Safety Analysis Report (SAR) was prepared prior to operation of the PUFF at Savannah River. The SAR included evaluation of occupational hazards. Nevertheless, ANSP and OES will continue to review the occupational hazards at the DOE facilities fabricating the nuclear power systems (see Reference 4).

SA-1.8 CONTINUE TO EVALUATE THE ADEQUACY OF HEALTH PROTECTION STANDARDS OR PLUTONIUM INTAKE BASED ON CURRENT STATE-OF-KNOWLEDGE

Strategy:

OHER will review the bases for the present health protection standards for plutonium from ingestion in light of current knowledge. The results of the effort will be made available to appropriate standards-setting authorities who have ongoing activities directed to review of existing health protection standards. Although of generic importance, this task is particularly significant to the Space Applications Program because of its use of ^{238}Pu ; thus, any new data should be available in time to be applied to the 1982 mission evaluations and decisions.

SA-3.6 CONTINUE TO EVALUATE UNCERTAINTIES ASSOCIATED WITH HEALTH EFFECTS ESTIMATES

Strategy:

OHER will evaluate the health effects estimates results and models utilized in the space nuclear program risk assessment and will evaluate current data used to convert integrated dose to potential health effects. The results will be utilized by ANSP or INSRP to develop confidence limits for the SAR and EIS health effect assessments.

SA-7.6 DEVELOP CRITERIA FOR REMEDIAL ACTION FOLLOWING SPACE NUCLEAR SYSTEM ACCIDENTS

Strategy:

ANSP and INSRP will consider the need for and will develop criteria on which to base remedial action following reentry of a space nuclear system. This requirement closely relates to other requirements (SA-1.5, SA-3.1, SA-3.2, SA-3.3). The combination of needs will be used to arrive at an optimal plan of action based on risk/cost/benefit considerations.

SA-7.7 ESTABLISH CRITERIA FOR ACCEPTABLE LEVELS OF ENVIRONMENTAL AND HUMAN EXPOSURES TO HAZARDOUS CHEMICALS ASSOCIATED WITH SPACE NUCLEAR SYSTEM APPLICATIONS

Strategy:

ANSP, based upon information from OHER and OES, will review available information regarding the toxicity and carcinogenic

potential of materials associated with this technology and of the applicable health and environmental standards and will develop criteria for acceptable designs to limit environmental and human exposures. The criteria will be reviewed by OES.

SA-7.8 ESTABLISH DESIGN CRITERIA TO LIMIT HAZARDOUS CHEMICAL RELEASES FOLLOWING SPACE NUCLEAR SYSTEM ACCIDENTS

Strategy:

ANSP, with assistance as needed from OES, will establish criteria based upon DOE Orders to control occupational exposures during system fabrication and testing; and environmental releases during the mission application and, if applicable, during reentry phases. Criteria must be developed prior to completion of system designs.

SA-7.9 ESTABLISH DESIGN, LAUNCH, AND MISSION CRITERIA TO MINIMIZE RISKS TO THE PUBLIC AND THE ENVIRONMENT

Strategy:

ANSP, in cooperation with other agencies through INSRP and in accordance with National Policy, will develop design criteria for the nuclear power sources to minimize risks to the public and the environment. The user agency, in cooperation with INSRP, will establish mission and overall satellite controls to implement National Policy and to minimize risks.

SAFETY--GENERAL

SA-7.4 EVALUATE FEASIBILITY OF RECOVERY OF SPACE NUCLEAR SYSTEMS TO PREVENT REENTRY, IF NECESSARY

Strategy:

ANSP, working with NASA and DOD through the INSRP, will initiate assessments regarding use of the space shuttle to recover orbiting space nuclear power systems. Such recoveries would be made to avoid contaminating the environment upon reentry--either at the end of life or due to an improper orbit.

SA-3.1 CONTINUE TO DEVELOP ANALYTICAL MODELS FOR ASSESSING RISKS ASSOCIATED WITH LAUNCH ACCIDENTS AND FROM REENTRY OF SPACE NUCLEAR SYSTEMS

Strategy:

ANSP, NASA, and DOD have developed elaborate models for risk evaluations of all phases of the space nuclear system missions. However, the models require periodic modification to improve their usefulness and to provide more modeling capabilities.

SA-3.2 EVALUATE POTENTIAL CONSEQUENCES OF REENTRY AS A FUNCTION OF TIME IN ORBIT AND BURNUP OF NUCLEAR FUEL

Strategy:

ANSP, in cooperation with NASA and DOD through INSRP, will evaluate the consequences of reentry as a function of time in orbit to assess the risks to the environment from applications of earth-orbiting nuclear systems, including consideration of decreased containment strength as a result of radiation and heat damage. Results will be used to consider the EH&S tradeoffs of possible recovery of nuclear systems rather than allowing eventual reentry.

SA-3.3 CONTINUE TO DEVELOP MODELS FOR PREDICTING AREA AND EXTENT OF CONTAMINATION FOLLOWING ACCIDENTS ASSOCIATED WITH SPACE NUCLEAR SYSTEMS

Strategy:

ANSP, in cooperation with NASA and DOD through INSRP, will continue to improve analytical dispersion models used for making assessments of launch or reentry phase accidents for use in SAR's, EA's and EIS's.

SA-3.4 CONTINUE TO DEVELOP TECHNIQUES TO COMBINE PROBABILITIES FOR ACCIDENTS AND EXPOSURES AND THEIR ASSOCIATED UNCERTAINTIES FOR ANALYSES OF ACCIDENT RISKS

Strategy:

ANSP, in cooperation with NASA and DOD through INSRP, will sponsor studies on methods of improving the risk assessments by providing analyses of combined uncertainties of the multiple factors which enter the risk analyses models. The results will provide improved bases for judgments on risks and risk acceptability for future missions.

SA-3.5 CONTINUE TO EVALUATE UNCERTAINTIES ASSOCIATED WITH VARIOUS
ACCIDENT SCENARIOS FOR SPACE NUCLEAR SYSTEM APPLICATIONS
FROM LAUNCH TO REENTRY

Strategy:

ANSP, in cooperation with NASA and DOD through the INSRP, will identify and quantify the uncertainties in the risk analyses in order to provide improved risk assessments for future mission applications.

SA-4.1 IDENTIFY POSSIBLE HAZARDOUS CHEMICALS OR CHEMICAL REACTION
PRODUCTS ASSOCIATED WITH SPACE NUCLEAR SYSTEMS APPLICATIONS

Strategy:

ANSP will provide OHER documentation of the chemicals or reaction products associated with space nuclear systems applications so OHER can proceed to screen them and identify areas needing additional biological effects studies, instrumentation development, etc.

SA-7.1 IDENTIFY POTENTIAL ACCIDENT ENVIRONMENTS TO BE CONSIDERED IN
DEFINING ACCIDENT SCENARIOS

Strategy:

ANSP, in conjunction with NASA and DOD through INSRP, will continue to document the physical and chemical environments and time duration of accidents to which a nuclear source may be subjected following a launch vehicle accident. This information is essential to assess the behavior and fate of the nuclear source and any nuclear and toxic materials released to the environment following such accidents.

SA-7.5 DEVELOP IMPROVED TECHNIQUES FOR SYSTEM RECOVERY AND
DECONTAMINATION OF THE ENVIRONMENT IN THE EVENT OF AN
ACCIDENT OR REENTRY INVOLVING A SPACE NUCLEAR SYSTEM

Strategy:

The user agencies have ongoing efforts related to this requirement in addition to DOE programs to develop decontamination methods which are generic in their applicability to many situations involving nuclear accidents. Such needs are closely tied to user agency, EPA criteria, and international considerations for immediate protective actions or long-term remedial activities. ANSP will coordinate DOE efforts in these areas with those of the user agencies and EPA through INSRP.

SAFETY--SPACE REACTOR SYSTEMS

SA-2.1 CONTINUE TO EVALUATE MECHANISMS FOR ACCIDENTS RESULTING IN RELEASE OF RADIOACTIVITY TO THE ENVIRONMENT

Strategy:

ANSP will evaluate mechanisms for accidental release of radioactivity to the environment from space reactor power systems in cooperation with INSRP, as the safety assessments for SAR's and EIS's are carried out. Initial assessments will be made early in the program as part of the decision-making process to proceed with full system development.

SA-2.2 DETERMINE SOURCE TERMS IN EACH ACCIDENT SCENARIO AND THEIR PHYSICAL AND CHEMICAL CHARACTERISTICS

Strategy:

ANSP will develop space reactor power system source terms of radioactive materials from accidents which could occur and their physical and chemical characteristics early so that OHER may utilize the information to identify requirements for specific EH&S R&D and for reactor systems so that design criteria may be developed.

SA-2.3 EVALUATE POSSIBLE ENVIRONMENTAL, HEALTH, AND SAFETY IMPLICATIONS OF ALTERNATIVE REACTOR FUEL FORMS AND TYPES

Strategy:

ANSP will evaluate environmental, safety, and health implications of alternative reactor fuel forms and types including Be reflected fuels, as part of its process to select fuel to be used in the space reactor; the results will be used in the overall safety analyses.

SA-6.1 EVALUATE MECHANISMS THAT MAY CAUSE CRITICALITY ACCIDENTS IN SPACE REACTORS AND DETERMINE THE CONSEQUENCES OF SUCH ACCIDENTS

Strategy:

ANSP, in cooperation with NASA and DOD through INSRP, will evaluate mechanisms for possible criticality accidents involving space reactor power systems and will determine the consequences of criticality events as an inherent part of their safety reviews of the nuclear systems.

SA-6.2 DEVELOP DESIGN CRITERIA TO PREVENT SPACE REACTOR CRITICALITY ACCIDENTS

Strategy:

ANSP will develop design criteria, as necessary, for use in developing space nuclear power systems. OES will review the criteria to assure compliance with general guidance and policy.

SAFETY--ISOTOPIC HEAT SOURCES

SA-1.5 CONTINUE TO DEVELOP MODELS FOR PREDICTING THE BEHAVIOR OF ^{238}Pu IN THE ENVIRONMENT FOLLOWING IDENTIFIED ACCIDENTS

Strategy:

ANSP, with assistance from OHER and in cooperation with INSRP, will improve existing environmental simulation models and develop new ones utilizing information developed through the EH&S R&D efforts. The models will be used by ANSP and INSRP in predicting environmental impacts in the EIS's and SAR's and in the event of environmental releases following an accident.

SA-1.2 CONTINUE TO EVALUATE POTENTIAL ACCIDENTAL RELEASES OF ^{238}Pu INCLUDING THE PHYSICAL AND CHEMICAL CHARACTERISTICS OF ^{238}Pu FROM VARIOUS ACCIDENT SCENARIOS

Strategy:

ANSP, in cooperation with NASA and DOD through INSRP, will complete the determination of the potential accidental releases of ^{238}Pu and their physical and chemical characteristics as part of its safety evaluations. Data on physical and chemical characteristics will be provided OHER through reports and other documentation and through the ECC subcommittee activities. The information pertaining to physical and chemical characteristics will be supplied to OHER and used in evaluating needs for and design of additional biological and ecological studies beyond those currently sponsored by ANSP. The new physical and chemical characteristics should be available to OHER in time to allow completion of OHER work before the SAR's and EIS's are prepared.

SA-5.1 EVALUATE POSSIBLE MECHANISMS FOR CRITICALITY ACCIDENTS DURING ^{238}Pu SOURCE FABRICATION AND HANDLING AND DETERMINE THE CONSEQUENCES OF SUCH ACCIDENTS

Strategy:

Safety analyses have been completed for the Plutonium Fuel Fabrication Facility (PUFF) and the Plutonium Oxide Experimental Facility (see References 4 and 5).

SA-5.2 DEVELOP DESIGN CRITERIA TO PREVENT CRITICALITY ACCIDENTS INVOLVING ^{238}Pu SOURCES

Strategy:

ANSP, with review by OES, and based on general guidance from OES, will develop design criteria, as necessary, to preclude criticality accidents for new plutonium heat sources. Presently, general safety criteria exist for the PUFF.

SA-1.6 CONTINUE TO REDUCE THE RISKS OF RELEASES OF ^{238}Pu BY IMPROVING CURRENT TECHNOLOGY

Strategy:

ANSP, in cooperation with NASA and DOD through INSRP, will continue to improve the RTG technology to reduce the risks associated with space applications of radioisotope power sources. These efforts will be in conformance of criteria developed under requirement SA-7.9.

MONITORING AND MEASUREMENT

SA-4.4 CONTINUE TO DEVELOP IMPROVED MONITORING SYSTEMS TO IDENTIFY AND MEASURE HAZARDOUS CHEMICALS IN THE ENVIRONMENT

Strategy:

OHER will continue its ongoing efforts in this area but will consider specific needs which the Space Applications Program may present. ANSP will coordinate any work and responsibilities with activities of NASA and DOD through INSRP. Such efforts are primarily directed to post accident or reentry contamination detection.

SA-5.4 DETERMINE THE NEED FOR IMPROVED IN-PLANT MONITORING
INSTRUMENTS FOR HAZARDOUS CHEMICALS AND PLUTONIUM ISOTOPES
AND DEVELOP IMPROVED INSTRUMENTS AS NEEDED

Strategy:

OHER will review the need for improved instrumentation and, as needed, will improve in-plant monitoring capabilities to provide a greater degree of protection for the worker and to provide more sensitive and accurate data on facility effluent releases. This effort is primarily applicable to the nuclear source or nuclear fuel fabrication processes which also involve use of toxic chemicals and metals.

SA-7.2 DEVELOP IMPROVED INSTRUMENTS AND TECHNIQUES FOR LOCATING
NUCLEAR SOURCES AND FOR MONITORING RADIOACTIVE CONTAMINATION
LEVELS

Strategy:

OHER, in coordination with ANSP and the user agencies (NASA and DOD), will continue to develop instrumentation for environmental assessments. Specific needs for the Space Applications Program will be identified by ANSP and INSRP with the lead responsibilities designated through normal budget cycles and program responsibilities.

SA-1.7 CONTINUE TO DEVELOP IMPROVED MONITORING INSTRUMENTS FOR
DETECTION OF PLUTONIUM IN THE ENVIRONMENT AND IN-VIVO

Strategy:

OHER has ongoing generic efforts directed to developing improved instruments and techniques for monitoring and measuring plutonium in vivo and in the environmental media. As applicable, the results of OHER-sponsored work will be available to use to meet the Space Applications Programs needs. Also, other Federal agencies, such as EPA and DOD, are also actively involved with similar developmental efforts.

ECOLOGY

SA-1.3 CONTINUE TO EVALUATE ^{238}Pu ENVIRONMENTAL BEHAVIOR AND TRANSPORT MECHANISMS AND DYNAMICS, AS WELL AS ITS PATHWAYS TO MAN

Strategy:

ANSP has a continuing program directed at this requirement. In addition, OHER has ongoing work, some related to ^{239}Pu , which may be applicable to ^{238}Pu assessments. OHER will review the present and planned research in this area and will, as justified, initiate new work to address specific needs of the Space Applications Program.

SA-4.3 EVALUATE ENVIRONMENTAL BEHAVIOR OF HAZARDOUS CHEMICALS FOLLOWING RELEASE UNDER IDENTIFIED ACCIDENT SCENARIOS

Strategy:

OHER, in cooperation with user agencies (NASA and DOD) through ANSP will assess the fate and consequences of toxic chemicals derived from space nuclear system technology. Resulting data will be utilized in preparation of the SAR's and EIS's and, as appropriate, the alternative system process selection.

SA-4.5 DETERMINE POSSIBLE SYNERGISTIC INTERACTIONS BETWEEN HAZARDOUS CHEMICALS AND NUCLEAR FUELS FROM SPACE NUCLEAR SYSTEMS IN PRODUCING BIOLOGICAL DAMAGE

Strategy:

OHER will evaluate the information concerning the chemical and fuel constituents of the space nuclear power systems for identification of areas of possible synergistic interactions. As justified, OHER will initiate EH&S R&D to quantify the interactions. The results will be applied in SAR's and EIS's for specific system analyses applications.

SOCIOECONOMICS--PROLIFERATION RESISTANCE

SA-8.1 REVIEW PRODUCTION PROCESSES TO ENSURE ADEQUATE PROTECTION AND ACCOUNTABILITY CAPABILITY FOR SPECIAL NUCLEAR MATERIALS

Strategy:

ANSP and DP(SS) will review the present procedures and methods used in the Space Applications Program to safeguard

and account for special nuclear material. The results of this review will be required in time to develop, as appropriate, additional criteria for application during future technology development and use.

SA-8.2 DEVELOP CRITERIA AND SPECIFICATIONS FOR IMPROVED SAFEGUARDS AND ACCOUNTABILITY PROVISIONS

Strategy:

Based upon requirement SA-8.1 DP(SS), in cooperation with ANSP, will develop criteria, as necessary, to provide for special nuclear material safeguards and accountability of material used in the Space Applications Program.

APPENDIX B

SPACE APPLICATIONS PROGRAM STRATEGY

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APPENDIX B

SPACE APPLICATIONS PROGRAM STRATEGY

The direction of the Space Applications Program effort, shown in Figure B-1, is determined by both user inputs and technology initiatives found deserving of support. Appropriate cost/benefit analyses are conducted to define development risks and potential benefits. These analyses incorporate nuclear and nonnuclear alternatives; mission requirements; EH&S requirements; and system requirements, such as reliability, longevity, environmental acceptability, safety, and survivability. A joint coordinating group provides the input for the direction of the development activities. Once the development activities are specified, system design and fabrication activities are initiated. The appropriate EH&S plans, operational analyses, safety analysis reports, safety testing, system evaluations, and system fabrication are performed concurrently with the system development. Project specific environmental assessments and impact statements are prepared by the user agencies with ANSP input as necessary. Upon completion of system acceptance testing by DOE, the product is delivered to the user for operational use.

In addition to the above, each nuclear system is reviewed by an Interagency Nuclear Safety Review Panel (INSRP) during the course of system development. For each series of identical missions utilizing identical nuclear systems, the Secretaries of the DOE and DOD, and the Administrator of NASA appoint one review coordinator from each agency; these coordinators co-chair INSRP. The panel meets a minimum of three times for each mission. It has the responsibility of providing a coordinated nuclear risk assessment of the mission. Figure B-2 shows the structure of and participants in ANSP's program designed to fulfill the safety responsibility.

In performing the mission risk analyses, ANSP is responsible for providing nuclear system hardware for tests. The user agency is responsible for providing Failure Mode Analyses (FMA) of mission hardware, including launch vehicle failure probabilities and mission-oriented accident probabilities. Data input to the INSRP and the flow of information are shown in Figure B-3. The product of the review is a signed, summary Safety Evaluation Report (SER).

The INSRP is designed to provide (1) an efficient review process for space launches involving nuclear material, (2) integration of multiagency expertise, (3) participation and review by non-sponsor experts, (4) interagency exchange of pertinent information, and (5) a unified risk assessment for interagency (at least three) and higher approval authorities to use in the decision-making process. Because of statutory requirements, DOE is responsible for the safety of the

Figure B-1
Space Nuclear Program Strategy

FIGURE B-2
SPACE APPLICATIONS OF NUCLEAR ENERGY SUBPROGRAM STRUCTURE

FIGURE B-3
SAFETY REVIEW PROCESS

nuclear system which it designs and produces. The DOD, through the Air Force, and NASA (because of their responsibilities for the safety of launch personnel and facilities), are responsible for evaluating the consequences of mission failures; and NASA or DOD, the users of these nuclear powered systems, are responsible for assuring the safety of the overall mission.

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APPENDIX C

SPACE NUCLEAR PROGRAM SAFETY PROGRAM

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APPENDIX C

SPACE NUCLEAR PROGRAM SAFETY PROGRAM

The space power system safety effort provides for a program to support ground and flight activities, a safety research and development effort, and an environmental analytical and experimental program. These activities include testing and evaluation of nuclear hardware, review and evaluation of postmortem analysis, and participation in interagency review to support the activities of the INSRP. In addition, the safety program provides for (1) continuous monitoring of contractor safety activities to assure compliance with safety regulations and design specifications; (2) all launch support activities; and (3) the development of environmental, health, and safety design requirements for future nuclear devices.

Basically, the heat source is designed to contain the radioisotope fuel form and its radioactive products under all normal, operating, and accident conditions. Since it is difficult to assure absolute containment in abnormal accident situations, criteria for limited release have been provided for the heat source development. These criteria are used as a design goal for the development and evaluation of heat source structures. The current criteria are:

A. In lithosphere accidents

1. Airborne release of fuel and/or daughter products shall be $<10^{-13}$ curies released per curie in the heat source and shall be $<10^{-8}$ curies released per launch, assuming a fuel release probability of 1.0.
2. The allowable release per container (Ci) will be inversely proportional to the release rate, which is dependent on the design of the multiple containment systems.

B. In Hydrosphere Accidents

1. The fuel shall be contained for three years after which fuel release will be controlled by dissolution.
2. ^{238}Pu concentration at 10 meters from the heat source shall be $<3 \times 10^{-5}$ Ci/ml.

Table C-1 provides a comparative analysis of the nuclear source terms, predicted releases, and probabilities for previous space

TABLE C-1
COMPARATIVE SAFETY EVALUATIONS

SYSTEM LAUNCH VEHICLE FUEL FORM QUAN. (Ci) CONTAINERS QUAN./CONT. (Ci)	APOLLO SATURN V PuO ₂ MICROSPHERES 44,500 1 44,500		PIONEER ATLAS CENTAUR PuO ₂ CERMET (PMC) 81,000 4 20,250		VIKING TITAN CENTAUR PuO ₂ CERMET (PMC) 41,200 2 20,600		LES TITAN TRANSTAGE PuO ₂ (PPO) 288,000 96 3,000		VOYAGER TITAN CENTAUR PuO ₂ (PPO) 220,000 72 3,000	
Abort Environment Fuel Condition	Source Term	Release Probability	Source Term	Release Probability	Source Term	Release Probability	Source Term	Release Probability	Source Term	Release Probability
Launch Pad Particulate Vapor	100 10,000	7×10^{-6} 7×10^{-6}	0.05 11	2.2×10^{-6} 2.9×10^{-10}	0.1 115	7.8×10^{-6} 7.1×10^{-8}	1.3 5.2	1.5×10^{-5} 1.4×10^{-8}	1 3	5.3×10^{-5} 5.3×10^{-7}
Upper Atmosphere Vapor	44,500	2×10^{-8}	13,000	8.3×10^{-5}	4,700	1.4×10^{-5}	0.8	2.8×10^{-2}	0.6	1.7×10^{-2}
Worldwide Land Impact Particulate Immediate Eventual	100	3×10^{-3}	0.8 12	6.4×10^{-4} 7×10^{-4}	0.9 19	4.1×10^{-5} 2.1×10^{-3}	0.03	1.7×10^{-4}	0.03	1.7×10^{-4}

missions. The trend has been to larger sources (^{238}Pu) but with improved containments so that quantities expected to be released in the event of an accident have decreased.

The environmental analytical and experimental program being conducted by ANSP includes the development of computer codes to mathematically assess the risk of released plutonium and the experimental exposure of plutonium to various environmental conditions in closed laboratory systems to understand the behavior of plutonium in the ecosphere. These evaluations are designed to develop safer nuclear containment systems and to improve evaluations of the risk of current flight hardware and missions.

The computer programs are designed to provide for a uniform risk analysis which quantitatively assesses the probabilities and consequences of human exposure to radiation (in excess of environmental background) which may occur as a result of use of nuclear fueled power systems. The analysis consists of three basic steps: (1) determination of mission events and their occurrence probabilities, which have the potential for causing human exposure to radiation; (2) determination of the consequence of those events, in terms of number of persons who could be subjected to various exposure levels; and (3) evaluation of the nuclear systems on the basis of the combination of steps (1) and (2) (the expectation of consequences). All of the computer codes are tested, reviewed, and verified before they are applied and are updated when necessary.

The experimental programs include the exposure of flight fuel material to varying environmental parameters, which are used in safety evaluation of hardware systems utilizing plutonium. In such evaluations, the source term, or quantity and form of plutonium present at any given time, is traced through a chain of sequential links starting with the hypothetical accident and ending with a given human concentration. The program has demonstrated that the "as manufactured" form of plutonium may be significantly modified by the circumstances of the accident, by the accident environment, and by the natural environment prior to reaching man. All of the experimental work is long term. The information generated is reported quarterly at which time it is reviewed and evaluated for inclusion in the overall risk models discussed above.

Presently, ten environmental chambers, eight aquariums, four in-situ ocean exposure chambers, and a high pressure hydrostatic chamber are being used in the environmental behavior program.

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APPENDIX D

ENVIRONMENTAL RESEARCH SUMMARY

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APPENDIX D
ENVIRONMENTAL RESEARCH SUMMARY (RECENT AND CURRENT)

Concern Number ¹	Federal Inventory Number ²	Program Title	Performing Organization	Sponsoring Organization	R & D Category ³
		<u>Plutonium Health Effects</u>			
SA-1	80012	Determine the Long-Term Effects of Ra, Pu, Th, and Other Internal Emitters.	ANL	DOE	3
SA-1	86001	Identification of Basic Biological and Biochemical Indices for Detection and Understanding the Primary Effects of Radiation Insult-Sr-90 Induced Leukemia and Lung/ Bone Tumors from Pu-238/Pu-239 Inhalation.	PNL	DOE	3
SA-1	87006	Exposure to External and Internal Radiation, Provide Data and Information to Lifetime Health and Mortality Epidemiological Studies of DOE Contractors	Mound	DOE	3
SA-1	87540	Health Studies Exposure to External and Internal Radiation, Low-Level Plutonium, Transplutonium and Fission Products and Other Elements Studies	Univ. Of Utah, Medical Ctr., Salt Lake City	DOE	3
SA-1	82016	Metabolism of Transuranic Elements (in Monkeys)· Describe Circulatory Transport, Gross and Microscopic Distributions in Tissues and Bones and Temporal Changes of Distributions of Radionuclides, Including Pu-238	LBL	DOE	3
SA-1	87007	Chronic Inhalation Exposures to Radionuclides, (Including Pu-239).	Lovelace	DOE	3
SA-1	87561	A Study of the Translocation of Plutonium and Americium from Puncture Wounds.	Colorado St Univ., Dept of Radiology and Radiology Biology	DOE	3
SA-1	88513	Bioenvironmental Transport of Transuranic Element Metabolism of Curium and Neptunium in Ruminants.	EPA-LV	DOE	3, 4
SA-1	89016	Metabolism of Internally Deposited Radionuclides.	CARL-UT	DOE	3
SA-1	150113	Radiation Exposure and Risk Estimates for Inhaled Airborne Radioactive Pollutants Including Hot Particles.	Lovelace	NRC	3
SA-1	84023	Establish Baseline Levels of Plutonium in Tissues of Population, Determine Uptake and Distribution Patterns in Body, and Evaluate Occupational Exposures of Pu.	LASL	DOE	1, 3
SA-1	84036	Health of LASL Plutonium Workers	LASL	DOE	3

¹Concern Number Refers to Concerns Given in Table III-1

²Inventory of Federal Energy-Related Environment and Safety Related Research for 1976 and 1977 (ERDA 77-50/2 and DOE/EV-002414 Respectively)

³R&D Category-See Appendix F and is the same as the EH&S Impact Area given in Table III-1

APPENDIX D
ENVIRONMENTAL RESEARCH SUMMARY (RECENT AND CURRENT)

Concern Number	Federal Inventory Number	Program Title	Performing Organization	Sponsoring Organization	R & D Category
SA-1	89112	Health and Mortality Study Evaluate Disability and Mortality Experience of Nuclear Workers at Selected Facilities.	ORAU	DOE	3
SA-1	89501	DOE Health Study (Lifetime Health and Mortality Experience of DOE Contractor Employees with Occupational Radiation Exposure)	HEHF	DOE	3
SA-1	89502	U S Transuranium Registry of DOE, DOE Contractor and Licensee Employees	HEHF	DOE	8
SA-1	91081	Health Studies Exposure to External and Internal Radiation, Low-Level Plutonium, Transplutonium, and Fission Products and Other Element Studies.	Univ of Utah Medical Ctr , Salt Lake City	DOE	3
SA-1	86060	Inhaled Transuranics in Rodents (Including Pu-238, Pu-239).	PNL	DOE	3
SA-1	86061	Inhaled Plutonium Nitrate in Dogs (Including Pu-238, Pu-239)	PNL	DOE	3
SA-1	86073	Inhaled Plutonium Oxide in Dogs (Including Pu-238, Pu-239)	PNL	DOE	3
		<u>Monitoring and Measurement</u>			
SA-1, 2, 5, 7	80043	Development of Improved Monitoring Equipment for On-Line Detection and Characterization of Airborne Plutonium Aerosols	ANL	DOE	1,8
SA-1, 2, 5, 7	82034	Physical Methods of Measuring Environmental Contaminants	LBL	DOE	1
SA-1, 2, 5, 7	83029	Intercalibration of Detectors for Measuring Plutonium and Other Transuranium Elements in Man	LLL	DOE	1
SA-1, 2, 5, 7	83065	Application of Prototype TAMS Monitoring System	LLL	DOE	1
SA-1, 2, 5, 7	85092	Liquid Scintillation Measurements of Low Levels of Transuranic Materials	ORNL	DOE	1
SA-1, 2, 5, 7	86027	Radioanalytical Procedure Development	PNL	DOE	1, 8
SA-1, 2, 5, 7	81011	Correlate Body Burdens with Intake Levels and Evaluate the Long-Term Behavior of Radionuclides in the Environment and Man	HASL	DOE	1, 8
SA-1, 2, 5, 7	81027	Radiation Instrument Development	BNL	DOE	1
SA-1, 2, 5, 7	82027	Radiation Detector Materials and Detectors	LBL	DOE	1

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ENVIRONMENTAL RESEARCH SUMMARY (RECENT AND CURRENT)

Concern Number	Federal Inventory Number	Program Title	Performing Organization	Sponsoring Organization	R & D Category
SA— 1, 2, 5, 7	82038	Survey of Instrumentation for Environmental Monitoring.	LBL	DOE	1
SA— 1, 2, 5, 7	83022	Provide ARAC Analytical Services.	LLL	DOE	8
SA— 1, 2, 5, 7	83054	Atmospheric Release Advisory Capability (ARAC)	LLL	DOE	1, 8
SA— 1, 2, 5, 7	85068	Develop Improved Detectors and Techniques for Quantitative Characterization of Natural and Man-Made Radioactivity.	ORNL	DOE	1
SA— 1, 2, 5, 7	86053	Real-Time Measurement of Plutonium in Air at Below MPC Levels	PNL	DOE	1
SA— 1, 2, 5, 7	86062	Aerosol and Analytical Technology, Develop Aerosol Exposure Techniques	PNL	DOE	1
SA— 1, 2, 5, 7	86067	Dosimetry of Internal Emitters.	PNL	DOE	1, 8
SA— 1, 2, 5, 7	86091	Quantitative Aspects of Plutonium Field Studies.	PNL	DOE	1
SA— 1, 2, 5, 7	86101	Plutonium Lung Counting, Appraise State-of-Art.	PNL	DOE	1
SA— 1, 2, 5, 7	86103	Plutonium Dosimetry Studies, Preparation of Guide to Good Practices	PNL	DOE	1, 8
SA— 1, 2, 5, 7	150120	Measurement Technology for Plutonium in Humans and the Environment (Demonstrate Capability to Detect and Measure to 0.1 Max. Lung Burden, Quantify MDL in Lung and Environment.)	PNL	NRC	1
SA— 1, 2, 5, 7	85069	Dosimetry for Human Exposures.	ORNL	DOE	1, 8
SA— 1, 2, 5, 7	86037	Radiation Instrumentation--Radiological Chemistry Development of Radiochemical Instrumentation and Analytical Technology for Low Levels of Radionuclides in the Environment.	PNL	DOE	1
SA— 1, 2, 5, 7	86038	Radiation Dosimetry.	PNL	DOE	1, 8
SA— 1, 2, 5, 7	87819	Develop <i>in vivo</i> Bioassay Technology for Measuring Transuranium Element Skeletal Burdens.	New York Univ Medical Ctr.	DOE	1
SA— 1, 2, 5, 7	86105	Technological Considerations on Emergency Instrumentation Preparedness.	PNL	DOE	1, 8

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ENVIRONMENTAL RESEARCH SUMMARY (RECENT AND CURRENT)

Concern Number	Federal Inventory Number	Program Title	Performing Organization	Sponsoring Organization	R & D Category
		<u>Plutonium Therapy</u>			
SA-1, 5, 7	80010	Combating Detrimental Effects, Therapy of Poisoning by Radioactive and Nonradioactive Metals	ANL	DOE	8
SA-1, 5, 7	80046	Combating Detrimental Effects, Therapy of Poisoning by Radioactive and Nonradioactive Metals.	ANL	DOE	8
SA-1, 5, 7	86004	Removal of Deposited Radionuclides.	PNL	DOE	8
SA-1, 5, 7	86064	Modifying Radionuclide Effects.	PNL	DOE	8
SA-1, 5, 7	87005	Therapy for Inhaled Radionuclides	Lovelace	DOE	8
SA-1, 5, 7	87553	Combating Detrimental Effects	Utah State Univ., Salt Lake City	DOE	8
SA-1, 5, 7	87769	Improve Plutonium Removal with Chelating Agents.	Hope College	DOE	8
SA-1, 5, 7	87781	Health Studies Decorporation, Removal of Transuranic Elements From the Body	Univ of Utah Medical Ctr. Salt Lake City	DOE	8
SA-1, 5, 7	91122	Plutonium Decorporation by Mixed Ligand Chelates	Univ of Pittsburgh	DOE	8
		<u>Meteorology</u>			
SA-3, 4, 7	13018	Atmospheric Transport Models	NOAA-Las Vegas	DOE	4
SA-3, 4, 7	13020	Transport, Deposition and Meteorological Experiments.	NOAA-Silver Spring, MD.	DOE	4
SA-3, 4, 7	13021	Meteorological Transport and Diffusion Studies	NOAA-Silver Spring, MD	DOE/NRC	4
SA-3, 4, 7	87669	Global Transport Processes and Interactions with Trace Contaminants.	MIT	DOE	4
SA-3, 4, 7	87672	Measurement of Airborne Radioactivity and its Meteorological Application	Institute of Atmospheric Research (Federal Republic of Germany)	DOE	1, 4

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ENVIRONMENTAL RESEARCH SUMMARY (RECENT AND CURRENT)

Concern Number	Federal Inventory Number	Program Title	Performing Organization	Sponsoring Organization	R & D Category
SA-3, 4, 7	88502	Meteorological Research Development of Long Range Atmospheric Transport Models.	NOAA ARL-Las Vegas	DOE	4
SA-3, 4, 7	150094	Consequence Modeling for Nuclear Reactor Accidents.	Sandia	NRC	4, 8
SA-3, 4, 7	150190	Evaluation of Atmospheric Dispersion Data	PNL	NRC	4
		<u>Modeling</u>			
SA-1, 3, 4	83015	Nuclear Assessment and Model Development.	LLL	DOE	6
SA-1, 3, 4	85074	Simulations of Radionuclide Transport.	ORNL	DOE	4
SA-1, 3, 4	89119	Determination of Uptake, Transport, and Distribution of Energy-Related Pollutants, Development of Whole-Body Transport Models.	UT-CARL	DOE	4
SA-1, 3, 4	90503	Dose-to-Man	SRL	DOE	3
SA-1, 3, 4	90522	Physical Oceanographic Modeling.	SRL	DOE	4
		<u>Occupational Plutonium Exposures</u>			
SA-5	83031	Personal Plutonium Resuspension Studies (Transfer of Pu from Soil to Man).	LLL	DOE	3,8
SA-5	84032	Preparation and Evaluation of Medical Grade Plutonium-238 Heat Source.	LASL	DOE	8
SA-5	87013	Plutonium Aerosols in Industrial Operations	Lovelace	DOE	3, 8
		<u>Hazardous Materials—Behavior in Humans</u>			
SA-4	84003	Absorption, Retention, and Excretion of Energy -Related Hazardous Materials.	LASL	DOE	3
SA-4	87751	Investigation of the Pulmonary Effects of Intermetallic Beryllium Compounds.	Univ of Cincinnati	DOE	3
		<u>Safety</u>			
SA-2,3,5,6,7	81082	Safety Studies and Development of Operational Guidelines—Operational Safety Reactor Standards Project.	BNL	DOE	8
SA-3	85096	Economic and Environmental Recovery from Severe Reactor Accidents.	ORNL	DOE	5,6
SA-3	86066	Biohazards of Reactor Accidents	PNL	DOE	3,8

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ENVIRONMENTAL RESEARCH SUMMARY (RECENT AND CURRENT)

Concern Number	Federal Inventory Number	Program Title	Performing Organization	Sponsoring Organization	R & D Category
SA-5, 6	86108	Assessment of Criticality Safety.	PNL	DOE	8
SA-5, 6	15004	Monte Carlo Analysis and Criticals Program Planning for Safety-Related Criticals.	ANL	NRC	8
SA-3	150091	Development of a Monte Carlo Method for Calculating the Consequences of Nuclear Power Plant Accidents.	MIT	NRC	8
SA-3	150102	Statistical Theories for Reactor Safety Application.	MIT	NRC	8
SA-5, 6	150173	Critical Experimental Data (Pu Shipping Casks).	PNL	NRC	8
SA-3	150197	Consequence Estimation.	BNL	NRC	8
		<u>Occupational Exposures</u>			
SA-1, 4, 5	86104	ALAP, Technical Guidelines for Maintaining Occupational Exposures as Low as Practicable	PNL	DOE	8
SA-1, 4, 5	150121	Assessment of Respiratory Protection Systems.	Los Alamos Area Office	NRC	8
		<u>Trace Elements — Selenium</u>			
SA-4	33034	Selenium Toxicity Role of Methionyl — TRNA Synthetases	State Univ. of New York, Binghamton	NEIHS (RTP)	3
		<u>Safeguards</u>			
SA-4	150194	Concepts of Integrated Safeguards Systems, Mixed Oxide Fuel Fabrication.	SAI, LaJolla, CA	NRC	5, 8
SA-4	150195	Concepts of Integrated Safeguards Systems, Transport of Nuclear Fuels and High Level Wastes	System Development Corp., McLean, Va	NRC	5, 8
SA-4	150196	Concepts of Integrated Safeguards Systems Irradiated Fuel Reprocessing Plant.	General Research Corp.	NRC	5, 8
SA-4	150198	Safeguards Vulnerability to White Collar Violations.	Battelle-HARC Seattle	NRC	5, 8
SA-4	150199	Safeguards Technical Analysis.	BNL	NRC	5, 8
SA-4	150200	Concepts for Integrated Safeguards Systems for LWR Power Reactors.	Sandia Labs.	NRC	5, 8

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ENVIRONMENTAL RESEARCH SUMMARY (RECENT AND CURRENT)

Concern Number	Federal Inventory Number	Program Title	Performing Organization	Sponsoring Organization	R & D Category
		<u>Environmental Transport</u>			
SA-3, 4	13066	Measurement and Monitoring of Accumulation of Power Reactor Associated Radionuclides in Sediments and Aquacultured Oysters in Montsweag Bay, Maine	Univ of Maine	NOAA Washington D.C.	1, 4
SA-3, 4	54039	Nuclear Energy Hydrology, Basic Research into Principles and Processes.	USGS, Reston	USGS, Reston	4
SA-3, 4	83023	Environmental Behavior of Effluents in the Coastal Environment.	LLL	DOE	4
SA-3, 4	83026	Biogeochemical Cycling of Transuranics and Other Radionuclides in the Marshall Islands.	LLL	DOE	4
SA-3, 4	85048	Radionuclide Cycling in Aquatic Ecosystems	ORNL	DOE	4
SA-3, 4	87657	Fission and Alpha-Track Study of Biogeochemistry of Plutonium and Uranium in Carbonates of Bikini and Enewetak Atolls.	RPI	DOE	4
SA-3, 4	87661	Radioelement Studies in the Oceans	Woods Hole	DOE	4
SA-3, 4	89519	Biogeochemistry of Transuranics - Bikini.	U of Washington, Rad. Ecology Lab.	DOE	4
SA-3, 4	90508	Pu and H-3 Cycling in Coastal Waters.	SRL	DOE	4
SA-3, 4	150104	Distribution Coefficients for Transuranic Elements in Aquatic Environments	U. of Washington, Rad. Ecology Lab.	NRC	1, 4
SA-3, 4	81081	Marshall Islands Radioecological Safety Program	BNL	DOE	4, 8
SA-3, 4	83016	Atmospheric-Terrestrial Exchange of Pollutant Aerosols	LLL	DOE	4
SA-3, 4	83032	Marshall Islands Radioecology Studies and Dose Evaluation I Enewetak	LLL	DOE	4, 8
SA-3, 4	84028	Analysis of the Human Health and Ecological Consequences of Plutonium and Other Transuranics.	LASL	DOE	3, 4
SA-3, 4	85058	Plutonium, Americium and Curium in Terrestrial and Aquatic Environments of Eastern United States	ORNL	DOE	1, 4
SA-3, 4	86035	Potential for Plutonium Complexation in Soil and Uptake by Plants .	PNL	DOE	4
SA-3, 4	88521	Pacific Radioecological Program .	U of Washington, Rad. Ecology Lab	DOE	4, 8
SA-3, 4	89088	Absorption and Diffusion of Plutonium in Soils (Pu-238, Pu-239).	U. of Arkansas	DOE	4
SA-3, 4	90157	Study of Radionuclide Cycling in the Terrestrial-Aquatic Ecosystems and Development of Models	U. of Georgia Savannah River Ecology Lab.	DOE	4
SA-3, 4	90510	Radioecology of Transuranic Elements	"	DOE	4

APPENDIX D
ENVIRONMENTAL RESEARCH SUMMARY (RECENT AND CURRENT)

Concern Number	Federal Inventory Number	Program Title	Performing Organization	Sponsoring Organization	R & D Category
SA-3, 4	RPIS-1329 ⁴	Transuranic Weathering in Soil.	PNL	DOE	4
SA-3, 4	RPIS-1390	INEL Radioecology Program	INEL	DOE	4
SA-3, 4	RPIS-1339	Cycling of Long Lived Radionuclides	SRL	DOE	4
SA-3, 4	RPIS-684	Radioactivity in the Biosphere	EML	DOE	4
SA-3, 4	RPIS-1293	Transuranic Elements in Natural Waters	ANL	DOE	4
SA-3, 4	RPIS-1344	Plutonium Behavior in the Miami River	ANL	DOE	4
SA-3, 4	RPIS-687	Ecological Investigations of Waste Canyons	LASL	DOE	4
⁴ No Federal Inventory Number has been Assigned, the Identifying Number is a DOE Research Project Identification Number					

APPENDIX E

SUMMARY OF PURPOSE OF ENVIRONMENTAL AND SAFETY DOCUMENTS

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APPENDIX E
SUMMARY OF PURPOSE OF ENVIRONMENTAL
AND SAFETY DOCUMENTS

Environmental Readiness Document (ERD)

The ERD is an assessment report prepared by the ASEV with full cognizance of technology program line managers. It provides a state-of-the-art assessment of the environmental status of a technology at the phase of development being considered for management decisions, usually at the key decision points of the Management System. The ERD presents the results of a critical review and scholarly analysis of environmental R&D results carried on in the preceding phase and provides further definition of concerns and research needs for the ensuing period. The ERD provides the basis for the ASEV position on the environmental readiness of a DOE technology at each key decision point.

Environmental Assessment (EA)/Environmental Impact Statement (EIS)

The National Policy Act of 1969 requires that agencies prepare Environmental Impact Statements "...on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment." For all programs and projects which may require EIS's, an EA may be prepared. An EA is a statement that provides the information on which to base a determination of the necessity for an EIS or a finding of no significant impact. EA's may be prepared for any action and at any time in order to assist DOE planning and decisionmaking. EA's and EIS's are prepared by program offices according to DOE procedures and are reviewed by the Office of Environment. They can be prepared at any phase of the Management System as required, but normally will be required beginning at the Technology Development Phase and at appropriate decision points throughout the remaining phases.

Safety Analysis

A safety analysis report (SAR) is prepared by program managers according to DOE procedures specified in DOE Order 5481.1 (March 20, 1979)--Safety Analyses and Review System for DOE Operations. The use of a SAR to identify hazards, to eliminate and control identified hazards, to assess residual risk, and to document management authorization of a DOE operation applies equally to technology base activities and energy system acquisition projects. The purpose is to limit risks to health and safety of the public and employees and to protect property and environment. The SAR preparation and review process ensures that:

- potential hazards are systematically identified
- potential impacts are accurately analyzed
- all reasonable measures to eliminate, control or mitigate the hazards have been taken
- there is documented management authorization of the DOE operation based upon an objective assessment of the residual risk identified in the safety analysis

APPENDIX F

TAXONOMY FOR EDP CONCERNS AND REQUIREMENTS

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TAXONOMY FOR EDP CONCERNS AND REQUIREMENTS

CATEGORY A

LIST OF ENVIRONMENTAL, HEALTH AND SAFETY IMPACT AREAS

1. Air Quality	6. Safety
2. Water Quality	7. Socioeconomic Factors
3. Solid Waste	8. Resources, including land
4. Ecology	9. Other
5. Health	

CATEGORY B

LIST OF ENVIRONMENTAL, HEALTH AND SAFETY RESEARCH AREAS

1. Characterization, Measurement, and Monitoring
 - 1.1 Baseline Inventory on Concentration and Distribution of Pollutants
 - 1.2 Source Term Characterization
 - 1.3 Measurement Technology
 - 1.4 Monitoring
2. Physical and Chemical Effects
 - 2.1 Environmental Transport, Dispersion, and Diffusion of Pollutants
 - 2.2 Transformation of Pollutants
 - 2.3 Physical and Chemical Disturbances
3. Health Effects
 - 3.1 Screening for Hazardous Agents
 - 3.2 Metabolism and Fate
 - 3.3 Dose Effect Toxicity Data
 - 3.4 Human Health Effects
 - 3.5 Health Effects Assessments
4. Ecological Effects
 - 4.1 Baseline Ecological Studies
 - 4.2 Hazardous Materials and Effects Mechanisms
 - 4.3 Physical and Chemical Effects
 - 4.4 Ecological Cycling of Pollutants to Man
5. Socioeconomic Effects
 - 5.1 Social
 - 5.2 Economic
 - 5.3 Political
 - 5.4 Institutional
 - 5.5 Resource Utilization
6. Environmental Evaluations
 - 6.1 Technology Assessments
 - 6.2 Environmental Readiness Documents
 - 6.3 Cost/Risk benefit Studies
 - 6.4 NEPA Environmental Assessment
 - 6.5 NEPA Environmental Impact Statement
 - 6.6 Other Environmental Evaluations
7. Environmental Control Technology (ECT) Development
 - 7.1 Identification and Evaluation of Alternative ECT Options and
 - 7.2 Containment, Storage, and Disposal Technology
 - 7.3 Reclamation and Decontamination
8. Occupational and General Safety
 - 8.1 Safety Assessments and Analysis
 - 8.2 Quality Control and Assurance
 - 8.3 Criteria, Guidelines, and Standards
 - 8.4 Dose Assessment, Measurement, and Monitoring
 - 8.5 Record-Keeping and Protocol Development