25

1

DEPARTMENT OF THE AIR FORCE

2

MCMXLVII

48

Final

*

Environmental Statement

LINCOLN EXPERIMENTAL SATELLITES
8 AND 9 (LES 8/9) PROGRAM
DECEMBER 1975

Air Force
Environmental Planning Division
(HQ USAF/CEVP)

Room 5B269
1260 Air Force Pentagon
Washington, DC 20330-1260

16 Jul 93

MEMORANDUM FOR DTIC (Acquisition)
(ATTN: Pat Mauby)

SUBJ: Distribution of USAF Planning Documents Forwarded on 1 July 93

All the documents forwarded to your organization on the subject date should be considered Approved for Public Release, distribution is unlimited (Distribution statement A).

Jack Bush, GM-14
Mr. Jack Bush
Special Projects and Plans
703-697-2928
DSN 227-2928

FINAL ENVIRONMENTAL STATEMENT

ON

LINCOLN EXPERIMENTAL SATELLITES

SUMMARY SHEET:

This statement was prepared by the United States Air Force. Dr. Billy Welch, SAF/ILE, Washington, DC, 20330, telephone number 202-697-9297 should be contacted for additional information about the proposed action.

1. Type of Action: Administrative

2. Description of Action: The action is the launch of the Lincoln Experimental Satellites 8 and 9 (LES 8/9) and Solrad Satellites 11A and 11B as a single payload by a Titan III-C from Launch Complex 40 at Cape Canaveral Air Force Station, Florida.

The LES 8/9 are to be powered by plutonium-fueled radioisotope thermoelectric generators. They are part of a program to verify the predicted capabilities of new concepts and technologies for application to an advanced military communication system.

3. Summary of Environmental Impact: No significant, unavoidable environmental effects would be expected due to this action. There would be a very small probability of small amounts of plutonium or beryllium being released to the environment and causing exposures greater than existing standards. There would also be a very small probability of human fatality or injury from physical impact of accidentally reentering payload hardware. Either effect could only result from an abort or other malfunction of the Titan III-C launch vehicle.

4. <u>Alternatives Considered Include</u>: No mission, ground-based communications systems, use of only one satellite, changes in nominal mission parameters, alternative satellite disposal (recovery) techniques, alternative power sources, and alternative RTG system.

5. <u>Comments Were Received From</u>:

- a. Federal Aviation Administration
  - (1) Southern Region
- b. National Aeronautics and Space Administration
- c. Department of Commerce
- d. State of Florida
- e. Department of Health, Education and Welfare
- f. Department of the Interior
- g. Nuclear Regulatory Commission
- h. Energy Research and Development Administration
- i. Environmental Protection Agency

6. The Draft Environmental Statement was made available to the Council on Environmental Quality and the public in June 1975.

7. The Final Environmental Statement was made available to the Council on Environmental Quality and the public in December 1975.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

Page

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

TABLE OF CONTENTS (Continued)

LIST OF TABLES (Continued)

1.0 INTRODUCTION AND TECHNICAL SUMMARY

1.1 P74-1 MISSION DESCRIPTION

The P74-1 mission is an Air Force project to launch the Lincoln Experimental Satellites 8 and 9 (LES 8/9) and the SOLRAD satellites 11A and 11B. These four satellites would be launched as a single payload by a Titan III-C from Launch Complex 40 at Cape Canaveral Air Force Station (CCAFS), Florida in February 1976. The LES 8/9, which would be powered by plutonium-fueled radioisotope thermoelectric generators (RTGs), are part of an Air Force program to verify the predicted capabilities of new concepts and technologies for application to an advanced military communications system. The LES 8/9 would be deployed into Earth orbits that are circular, synchronous (35,900 km or 22,300 miles above the Earth's surface), and lie close to the ecliptic plane. LES 8 would be stationed approximately 35° west, and LES 9, 30° east, of Lexington, Massachusetts. From these orbits, the LES 8/9 would be utilized for various tests and experiments intended to demonstrate secure, antijam, satellite-to-satellite, satellite-to-ground, and satellite-to-aircraft communications. Upon completion of the experimental program, the LES 8/9 would offer continued communications service for the remainder of their useful lives (designed to be five years or more). The SOLRAD satellites are part of a Navy program to provide real-time monitoring of solar electromagnetic and particulate radiation emissions. The SOLRAD satellites would operate in circular orbits 109,400 km (68,000 miles) above the Earth's surface.

1.2 SCOPE OF STATEMENT

The purposes of this Final Environmental Statement are to present a description of the P74-1 mission and an assessment of the possible environmental effects associated with it. This Statement concentrates on the LES 8/9 aspects of this mission since most of the potential environmental impacts would be associated with these satellites. Comments on the Draft Statement were received from eight Federal agencies and the State of Florida. These comments and the corresponding responses are contained in Appendices E through M of the Statement.

1.3 LAUNCH APPROVAL

The approval authority for the launch of systems incorporating aerospace nuclear power systems, such as the LES 8/9 RTGs, rests with the President and is implemented through the National Security Council (NSC). The task of evaluating the nuclear safety of such missions is delegated to an Interagency Nuclear Safety Review Panel (INSRP), composed of representatives of the Energy Research and Development Administration (ERDA), formerly the Atomic Energy Commission (AEC), the National Aeronautics and Space Administration (NASA), and the Department of Defense (DoD). The functions of the INSRP are to review the Preliminary, Updated, and Final versions of the Safety Analysis Report (SAR) prepared by the RTG systems contractor, to direct revisions where necessary, and to prepare the Safety Evaluation Report (SER), which transmits the INSRP's recommendations to the NSC and the President.* Presidential approval to proceed with this program was received in October 1975. A final review of the LES 8/9 program will be made two to four weeks prior to launch.

1.4 RTG SAFETY ANALYSIS

The SARs and their supporting documentation identify the possible accidents that might occur during the launch and ascent of the LES 8/9 into their final orbits. A predicted probability of occurrence is associated with each such accident. The SARs then analyze the RTG system's response to such accidents. In those very few situations where release of plutonium to the environment would be predicted to occur, the SARs also present an assessment of the effects of such a release on the surrounding environment. Occurrence

---

* For the LES 8/9, this nuclear safety review has now been completed, with the SER being written and approved by the INSRP in July 1975.

probabilities for such effects are calculated, and the association of these consequences with their probabilities of occurrence constitutes a measure of the risk involved in launching the LES 8/9.

After completing the review process described in Section 1.3, the INSRP prepared its own risk assessment for inclusion in the SER. This Final Environmental Statement has been revised throughout to reflect the various accident probability and plutonium release numbers used in the SER. The INSRP has traditionally made safety-conservative assessments where uncertainties in the SARs existed. Thus, the risk numbers contained in this Final Statement are larger than those described in the Draft Statement. However, as discussed below, the risks associated with undertaking the P74-1 mission would still be very small.

1.5 SUMMARY OF POSSIBLE ENVIRONMENTAL EFFECTS

The investigation of the possible environmental effects associated with the P74-1 mission and the LES 8/9 program falls into four categories. The conclusions for each category are summarized below.

1.5.1 Normal Launch and Mission

No adverse environmental effects would be associated with the P74-1 mission (as distinct from the Titan III-C itself) due to a normal launch and attainment of the final desired orbits. Some very minor, temporary, adverse effects might be associated with the use of the Titan III-C; they are addressed in the USAF Space Launch Vehicle Environmental Statement (Reference 1).

1.5.2 Aborts or Accidents

The launch of the LES 8/9 would involve a very small risk of releasing plutonium to the environment due to the possibility of an abort or other malfunction of the Titan III-C. The total predicted probability of an unsuccessful launch is 0.1 (ten percent) (Reference 2). The RTGs, based on their design and safety verification tests, would be expected to prevent plutonium release in the vast majority of such failures. The total predicted probability of containment failure is on the order of 10^{-4} (0.01 percent). It is considerably less likely that a person would accumulate enough plutonium to exceed current radiation exposure standards. The risk of exposing persons to beryllium concentrations greater than established standards (from accidental oxidation of the RTG's beryllium outer casing) is on the order of 10^{-4} (0.01 percent). The risks of causing a human fatality or injury due to physical impact from accidental reentry of P74-1 payload components are on the order of 10^{-6} (0.0001 percent) and 10^{-4} (0.01 percent) respectively. Thus, the environmental risks associated with the launch of the P74-1 mission would be very small and orders of magnitude smaller than accidental risks associated with many other natural and man-caused events. The environmental effects associated with the Titan III-C itself in accident situations are addressed in Reference 1.

1.5.3 Ultimate Reentry

From their planned orbits, the LES 8/9 might eventually reenter the Earth's atmosphere. The orbital lifetimes of the LES 8/9 would be well in excess of 1000 years. However, significant amounts of radioactivity would remain in the RTGs for times approaching 1,000,000 years. Although no mechanisms have been identified which would be likely to cause reentry before that time, existing analytical techniques are inadequate to support an assertion that the LES 8/9 would not reenter from synchronous orbit before 1,000,000 years. If the RTGs were to reenter between 1000 and 1,000,000 years, this radioactivity might be released and potentially lead to adverse environmental effects, such as radiation exposure exceeding current standards. Any such effects can be considered avoidable, however, since the United States is currently developing the capability, through the Space Transportation

System program, to recover orbital payloads. Thus, the LES 8/9 might be recovered and returned intact and contained, if future information indicates that it would be economically and environmentally desirable. Another technique utilizing the Space Transportation System, or some successor system, might be to send unwanted satellites into solar orbit or deep space by attaching and activating additional rocket motors.

1.5.4 Operational System

An operational communications system may result from a successful LES 8/9 mission. Very few details of this system are formulated yet. There is no reason to expect that the environmental effects associated with the operational system would be significantly different than those very minor possible effects associated with the LES 8/9. However, another Environmental Statement will be prepared in conjunction with consideration of such a system.

2.0 PROGRAM DESCRIPTION

2.1 P74-1 MISSION

The P74-1 mission is an Air Force project to launch the Lincoln Experimental Satellites 8 and 9 (LES 8/9) and the SOLRAD satellites 11A and 11B into high Earth orbits. All four satellites are proposed to be launched as a single payload by a Titan III-C from Launch Complex 40 at Cape Canaveral Air Force Station (CCAFS), Florida in February 1976. The planned payload configuration for the P74-1 mission is shown in Figure 1. Descriptions of the Titan III-C and the launch complex are contained in the USAF Space Launch Vehicle Environmental Statement (Reference 1). As shown in Figure 2, a series of maneuvers is planned to first lead to release of the LES 8/9 at the synchronous altitude (35,900 km or 22,300 miles), then the SOLRAD satellites would boost themselves into very high circular orbits (approximately 109,400 km or 68,000 miles). Figure 3 is a drawing of the various transfer and final orbits. Figure 4 is an instantaneous-impact point trace of the proposed trajectory until initial orbital insertion (into the parking oribit). Appendix A to this Statement provides a glossary of the acronyms and scientific terms used in this document.

2.2 LES 8 AND 9 PROJECT

The LES 8/9 are planned as part of an Air Force program to verify the predicted capabilities of new concepts and technologies for application to an advanced military communications system. The two satellites would be deployed into Earth orbits that are circular, synchronous (about 35,900 km or 22,300 miles above the Earth's surface), and lie close to the ecliptic plane (that of the Earth's orbit around the sun, which is inclined about 23.5° from the Earth's equatorial plane). LES 8 would be stationed approximately 35° west, and LES 9, 30° east, of Lexington, Massachusetts.

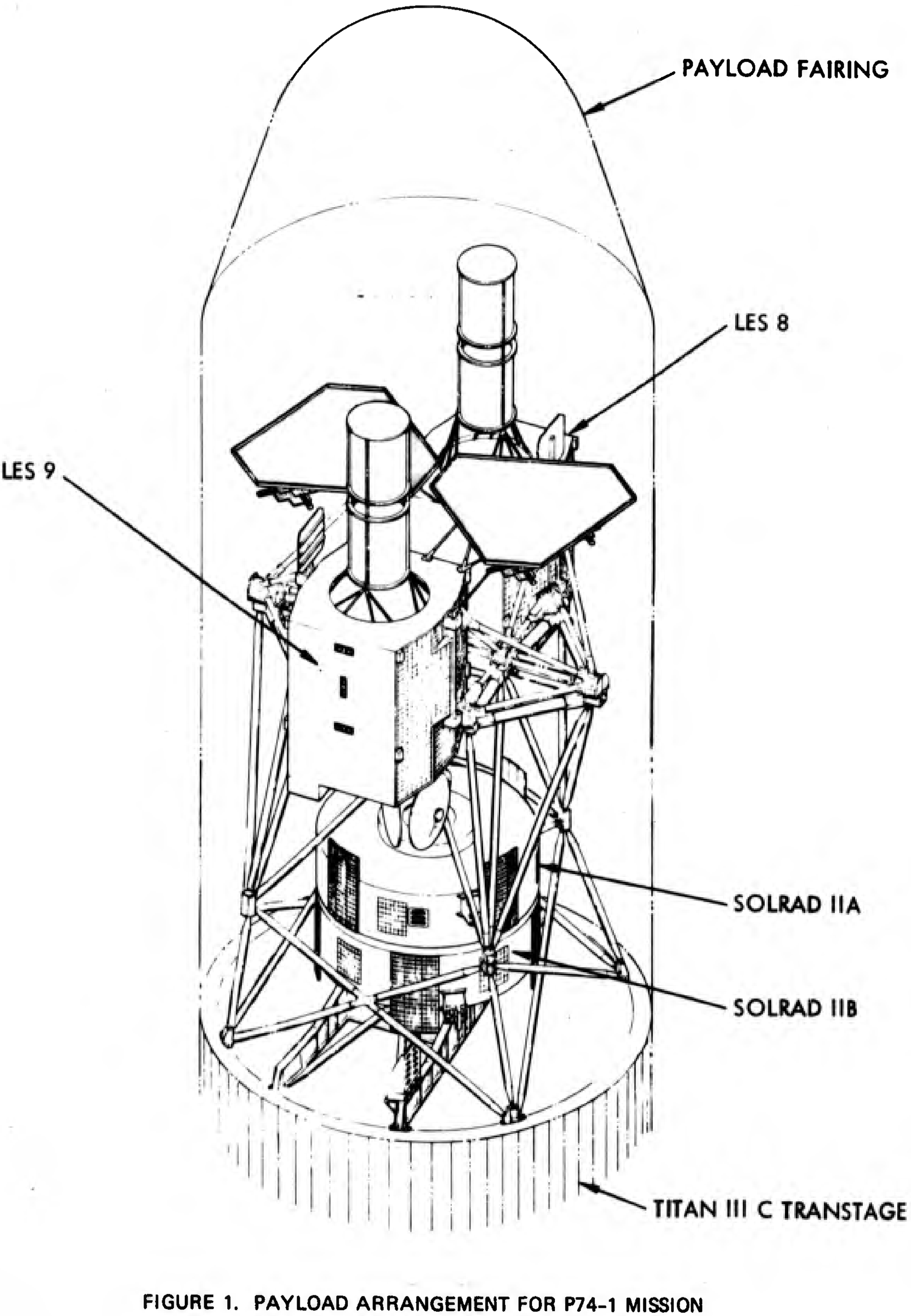

FIGURE 1. PAYLOAD ARRANGEMENT FOR P74-1 MISSION

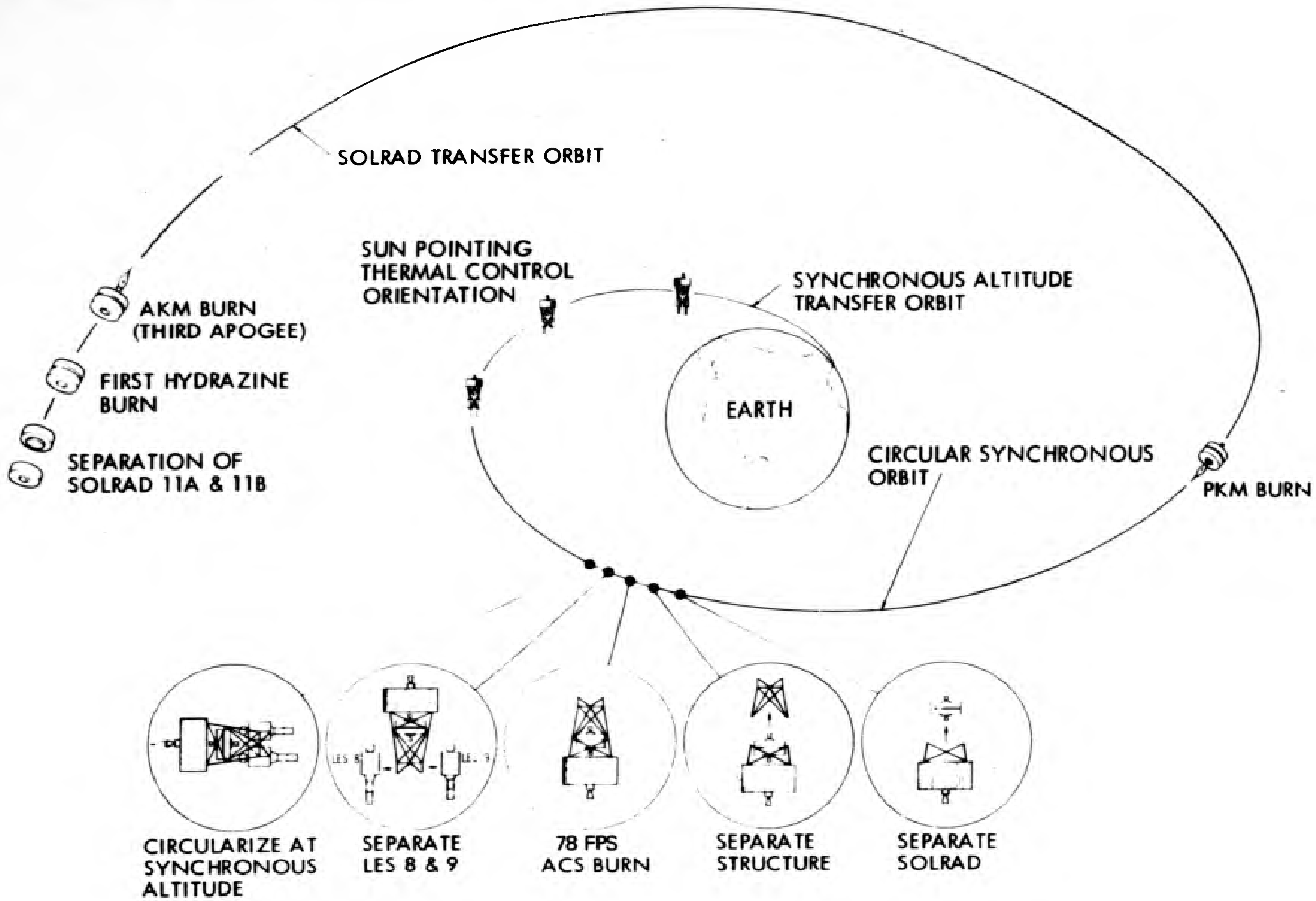

FIGURE 2. PROFILE OF P74-1 MISSION (NOT TO SCALE)

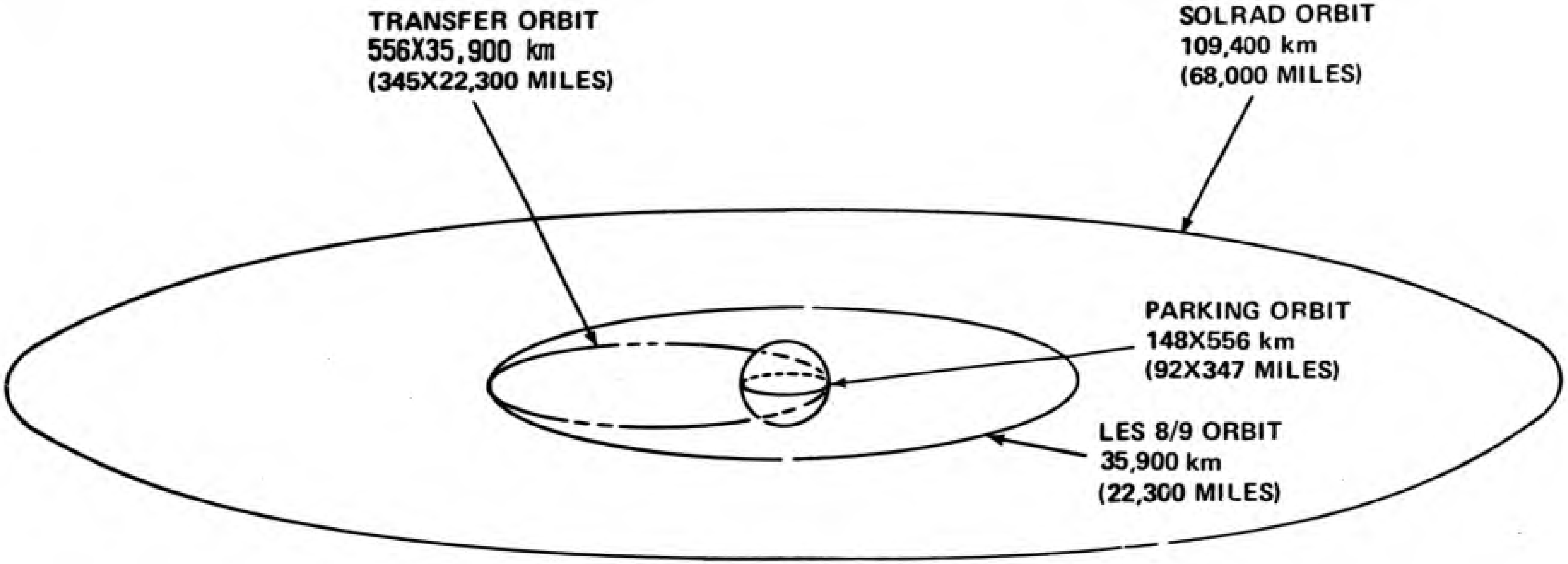

FIGURE 3. LAUNCH TRAJECTORIES AND ORBITS

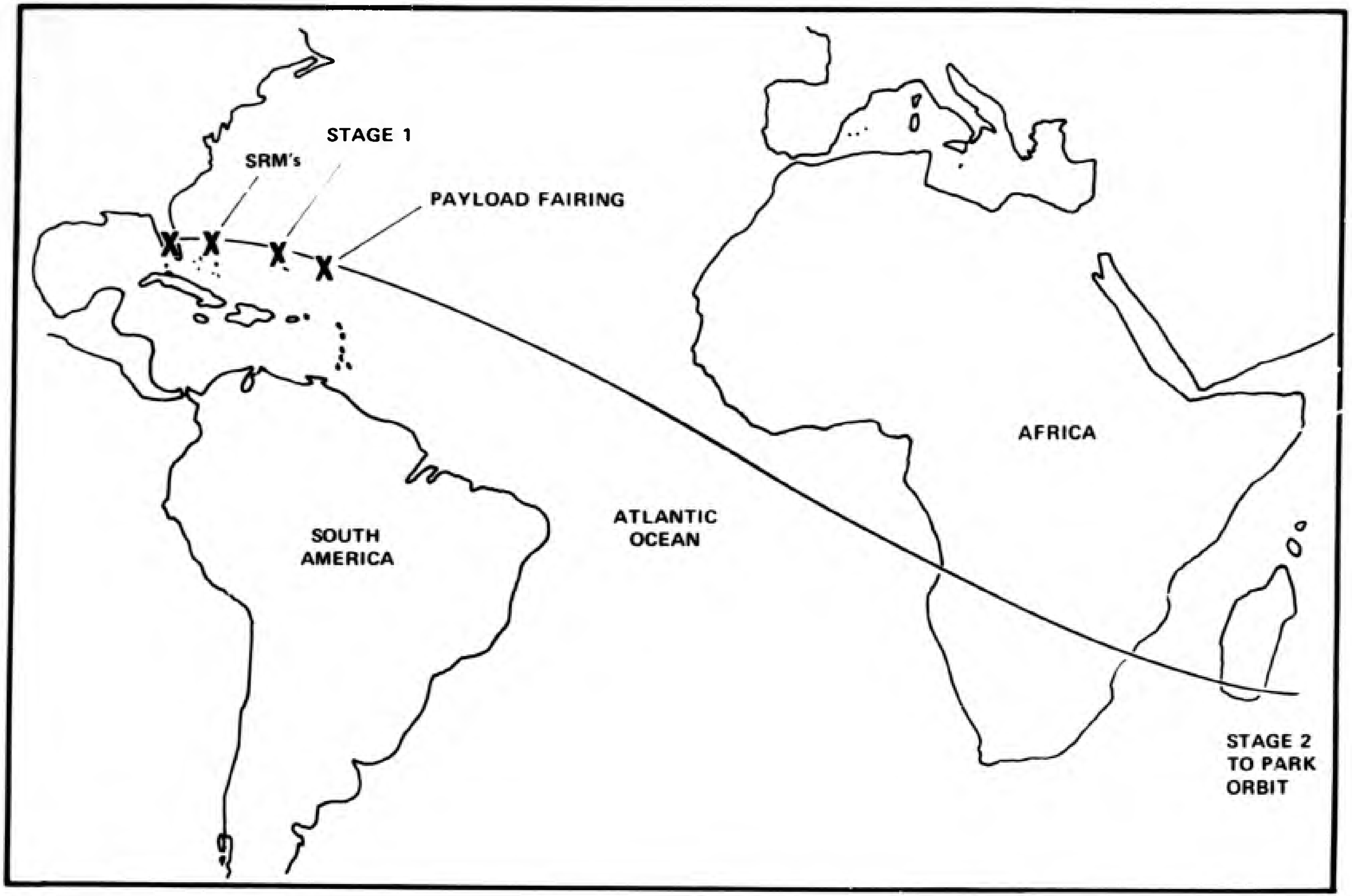

FIGURE 4. INSTANTANEOUS IMPACT POINT TRACE FOR THE P74-1 MISSION

Although at the synchronous altitude, the satellites would not be truly geostationary because of their orbits' inclination to the equatorial plane; their sub-vehicle points (the point on the Earth's surface directly below the satellite) would move about 25° north and south of the equator.

From these orbits, the LES 8/9 would be utilized for various tests and experiments intended to demonstrate secure, antijam, satellite-to-satellite, satellite-to-ground, and satellite-to-aircraft communications (Figure 5). K-band and ultra-high frequencies (UHF) would be employed. Upon completion of the experimental program, the LES 8/9 would offer continued communications service for the remainder of their useful life (designed to be five years or more).

2.3 LES 8/9

Figure 6 is a cutaway drawing of LES 9; LES 8 is similar. Depicted are the various K-band and UHF transmitters and receivers, plus necessary guidance and attitude control systems. The LES 8/9 would be powered by plutonium-fueled radioisotope thermoelectric generators (RTGs), which are described in Section 2.5. Each satellite would have a mass of about 454 kg (1000 pounds) and have overall envelope dimensions (excluding the UHF antenna) of 137.2 cm (4.5 feet) in diameter and 304.8 cm (10 feet) in length.

2.4 SOLRAD SATELLITES

The SOLRAD 11A and 11B satellites would be part of a Navy program to provide real-time monitoring of solar electromagnetic and particulate radiation emissions. The SOLRAD satellites would operate in circular orbits 109,400 km (68,000 miles) above the Earth's surface. Data collected from the SOLRAD satellites would allow assessments and predictions to be made of the space environments which affect the performance of ionosphere dependent systems and space systems.

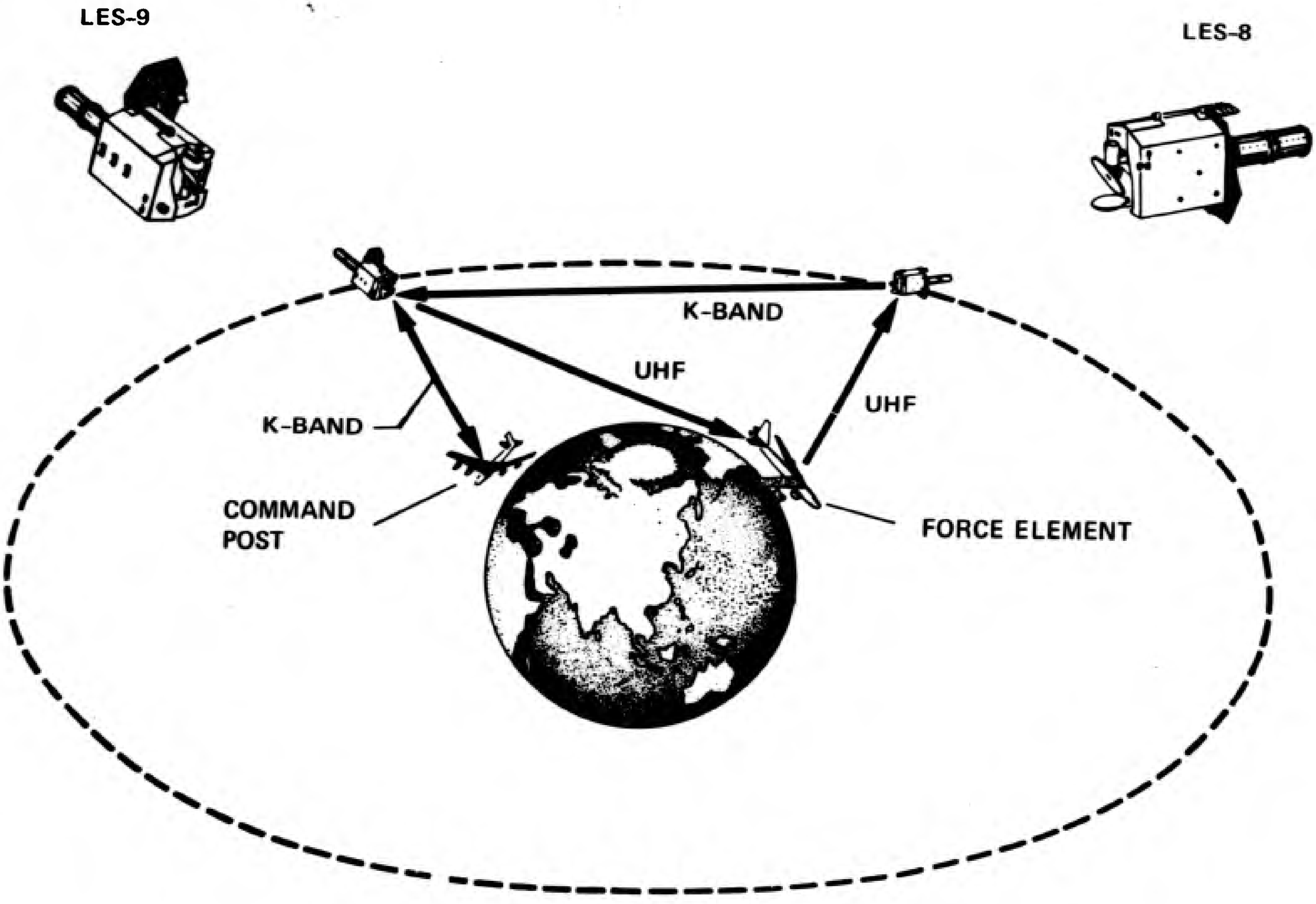

FIGURE 5. DIAGRAM OF COMMUNICATIONS SYSTEM OF WHICH LES 8/9 SATELLITES ARE STEPS IN DEVELOPMENT

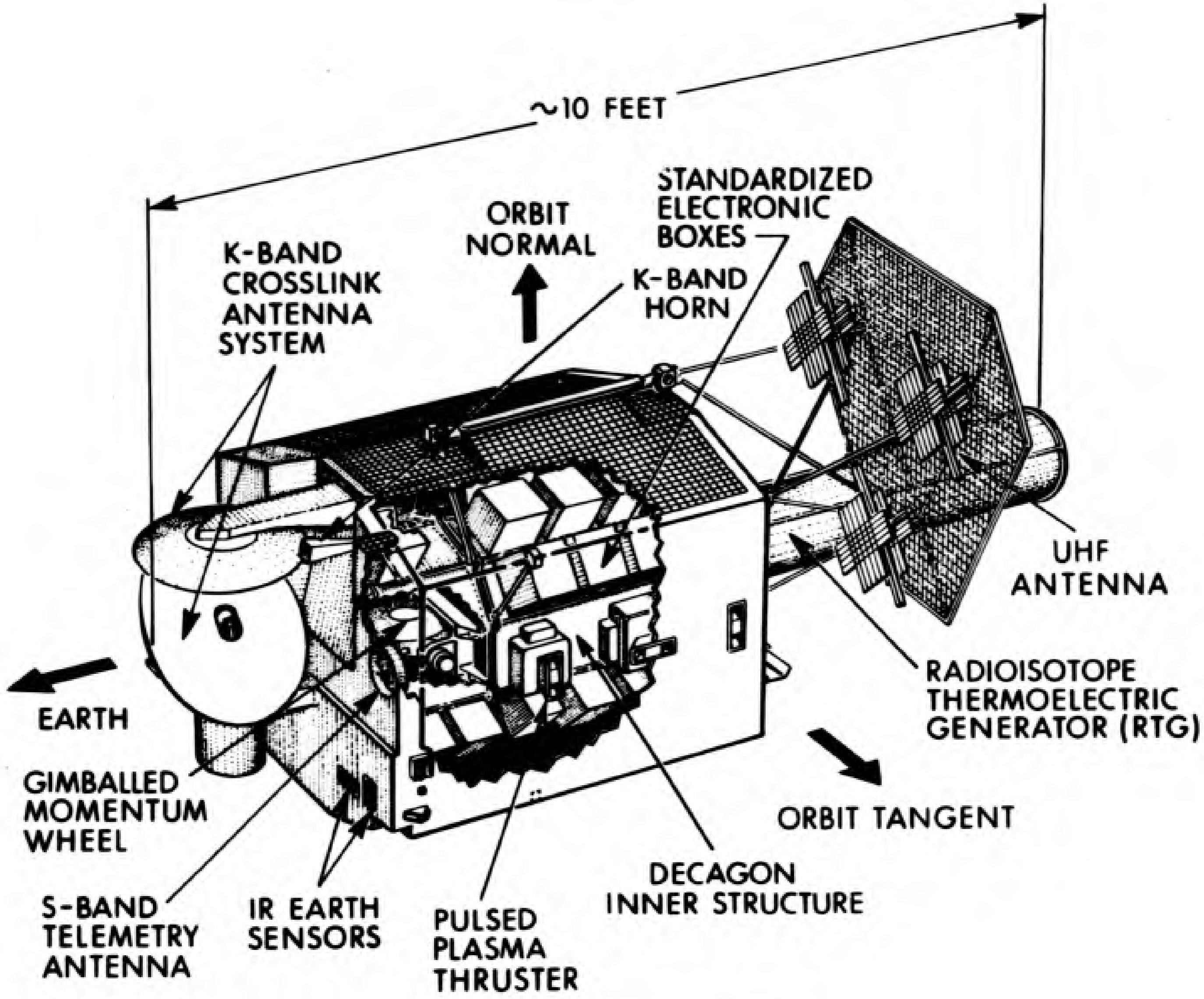

FIGURE 6. CUTAWAY OF LES 9

2.5 MHW-RTGs

The electrical power requirements of the LES 8/9 would be met by four Multi-Hundred Watt RTGs (MHW-RTGs), two per satellite. Each MHW-RTG (Figure 7) is designed to provide a minimum of 125 watts (electrical) throughout a period of at least five years. The MHW-RTG is a newly developed system designed both to provide aerospace radioisotope power in the 100-watt range (the largest previous RTG system supplied about 60 electrical watts) and to have an improved safety capability compared with preceding systems. The LES 8/9 would represent the first use of the MHW-RTGs; they are also scheduled for use in NASA's Mariner Jupiter/Saturn 1977 Program.

2.5.1 Converter

The purpose of the converter (Figure 7) is to convert the thermal energy provided by the heat source into the electrical energy required by the LES 8/9. This is accomplished by the use of thermoelectrics (silicon-germanium thermocouples) mounted in an insulated case of beryllium metal. Beryllium was selected as the structural material because of its light weight and strength. The amount of beryllium used in each generator is 4.88 kilograms (10.73 lb). Further details of the converter design may be found in Reference 4.

2.5.2 Heat Source

The purpose of the heat source (Figure 8) is to provide the thermal energy for the thermoelectrics. This heat is primarily produced by the energy of the alpha particles emitted by plutonium-238, which decays with a half-life of 86 years. The plutonium, which is produced with an initial isotopic composition detailed in Table 1, is used in the chemical form PuO_2 (plutonium dioxide) and is manufactured

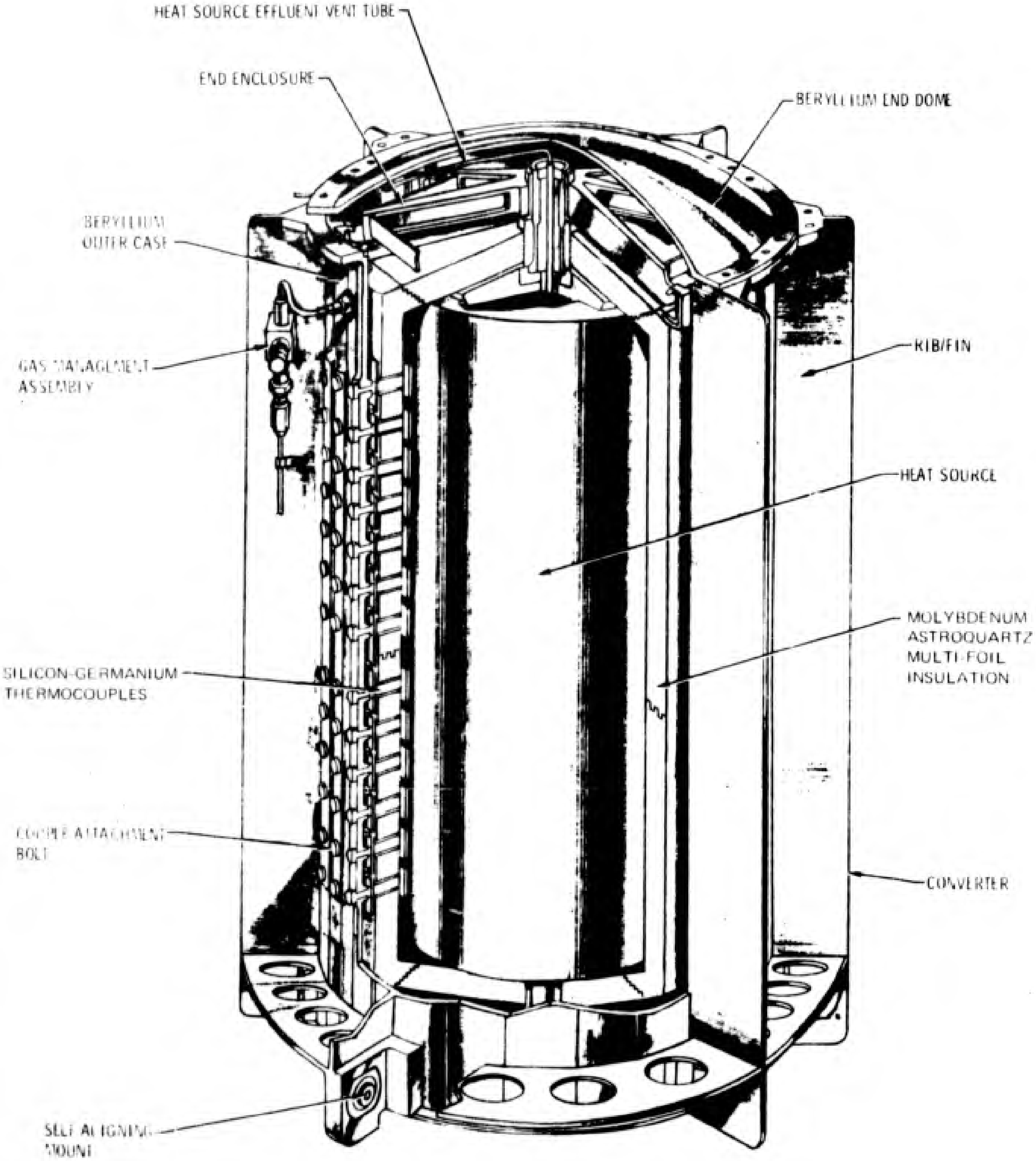

FIGURE 7. CONFIGURATION OF THE MHW RTG

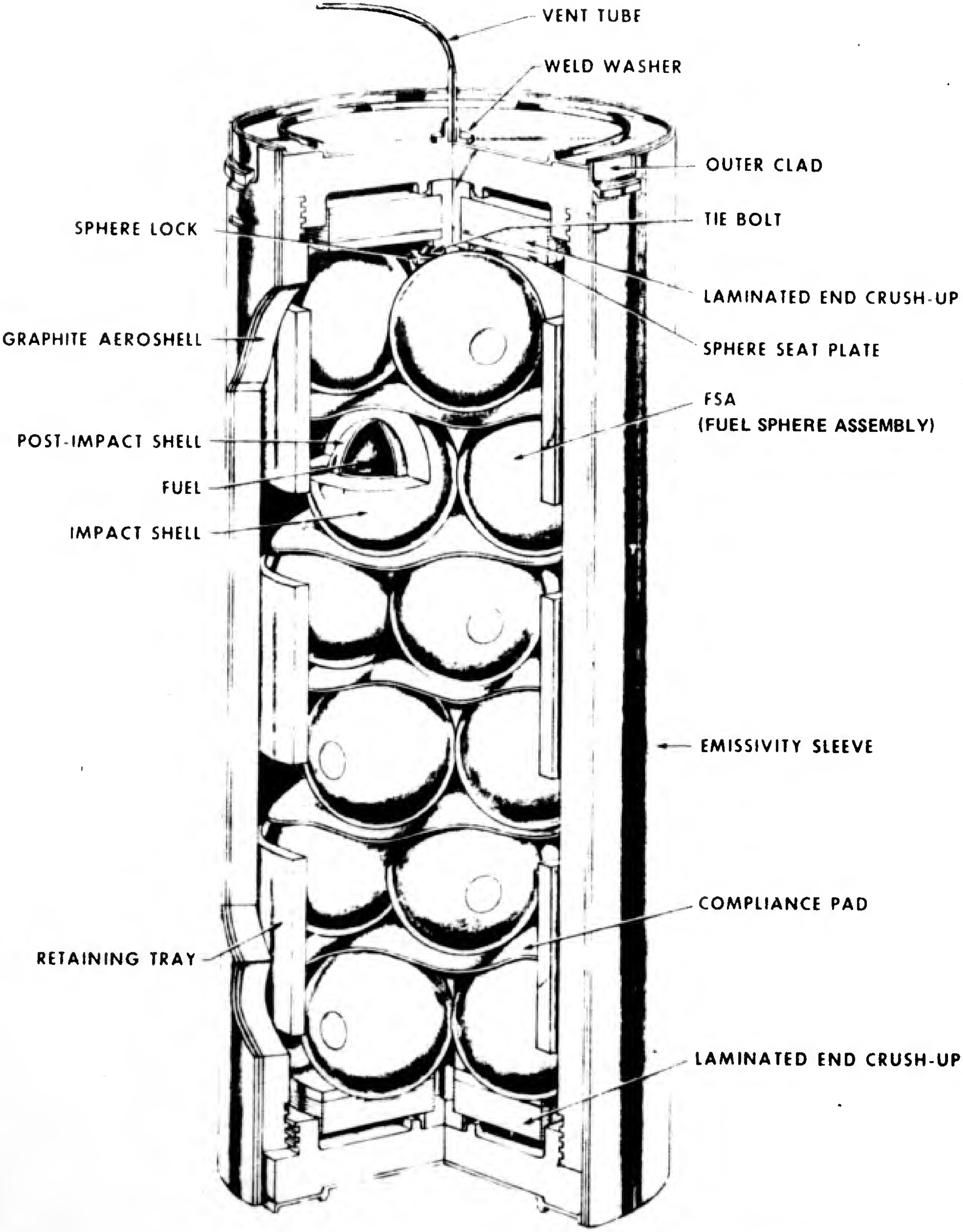

FIGURE 8. CONFIGURATION OF THE MHW RTG HEAT SOURCE

TABLE 1. ISOTOPIC COMPOSITION OF PRODUCTION GRADE $^{238}_{94}$PU

Plutonium Isotope	Weight Percent	Half-Life Years	Radioactivity Curies/gram PuO_2	Mass in Grams Per			Radioactivity in Curies Per		
				RTG	Satellite	Payload	RTG	Satellite	Payload
236	0.00012	2.8	476	.0072	.014	.029	3.4	6.7	13.8
238	81.0	86.4	15.4	4860	9720	19440	74,800	149,600	299,200
239	15.2	24,000	.054	900	1800	3600	49	97	194
240	2.9	6,600	.195	174	348	696	34	68	136
241	0.8	13.0	100.4	48	96	192	4,820	9,640	19,280
242	0.1	370,000	.0034	6	12	24	.02	.04	.08
Total				5988	11976	23952	79,700	159,400	318,800

in solid ceramic spheres about 3.8 cm (1.5 inches) in diameter. (This fuel form is also sometimes called "pressed plutonium oxide," or PPO, even though its chemical composition is that of a dioxide). Each sphere consists of about 250 grams (0.55 pounds) of PuO_2, which represents about 3230 curies of radioactivity. F-3

Each PuO_2 sphere is placed within an 0.508 mm (0.020 in) thick iridium Post-Impact Containment Shell (PICS) which, in turn, is placed within an 11.684 mm (0.460 in) thick Graphite Impact Shell (GIS). This assembly is called a Fuel Sphere Assembly (FSA) and represents the primary plutonium containment structure in the unlikely event of an abort or accident. The iridium shell provides structural integrity and exceptional resistance to high-temperature degradation or oxidation, while the graphite shell protects the PICS during impact and thermal accident environments. The PICS is vented to provide for release of the helium gas generated in the fuel decay process, but the venting is so designed as to prevent a direct path for particulates to travel between the fuel and the vent hole.

The heat source contains 24 FSAs, which are arranged in six planes of four FSAs each and are held in place in groups of eight by segmented graphite retaining trays. Woven graphite cloth pads are positioned between each plane of FSAs to achieve a tight fit. The FSA assemblies are placed within a graphite reentry aeroshell cylinder, which has an outer iridium cladding. Thus, each heat source contains about 6 kg (13.2 lbs) of PuO_2. Within both ends of the aeroshell, graphite crush-up material is provided for additional impact protection. The aeroshell represents a secondary plutonium containment structure which further protects the FSAs from possible accident environments, including all atmospheric reentry environments. Further details of the heat source design may also be found in Reference 4.

2.6 MANUFACTURING, ASSEMBLY, AND TRANSPORTATION

The primary manufacturers associated with the P74-1 Project are listed in Table 2, together with the responsible Federal agency. Overall responsibility for the mission belongs to the Air Force. Reference 1 contains a listing of the manufacturers associated with the Titan III-C program.

As illustrated by Figure 9, five heat sources (four flight and one back-up) for the LES 8/9 program will be manufactured and assembled at Mound Laboratory and will be shipped, no more than two at a time, by ERDA Special Nuclear Materials Vehicles to General Electric. These special trucks are designed to provide safe secure transportation at all times. At General Electric, the heat sources will be inserted into the converters, thus becoming RTGs. The five RTGs will then be subjected to several tests to insure their performance. Next, two of the five RTGs will be shipped by the same mode of transportation to Lincoln Laboratory, while the remaining three RTGs will be returned to Mound Laboratory. At Lincoln Laboratory, the two RTGs will be temporarily installed on the LES 8/9 and more tests conducted to insure proper performance. These two RTGs will then be separated from the LES 8/9 and also returned to Mound Laboratory.

From Mound Laboratory, four of the five RTGs will be shipped to CCAFS. This shipment will be timed to minimize storage time at CCAFS because of limited storage space available at that facility. At CCAFS, the four RTGs will again be installed on the satellites and subjected to more proof tests. The satellites will then be moved to the launch complex, installed on the Titan III-C, and receive final check-out tests before launch.

Throughout the assembly, transportation, and storage processes described above, the RTGs (or heat sources) will be in the continuous custody and control of ERDA personnel, in accordance with ERDA Manual, Chapter 2405, to physically protect the plutonium from theft, diversion, sabotage, or vandalism. For the operations to be conducted at Lincoln K-1

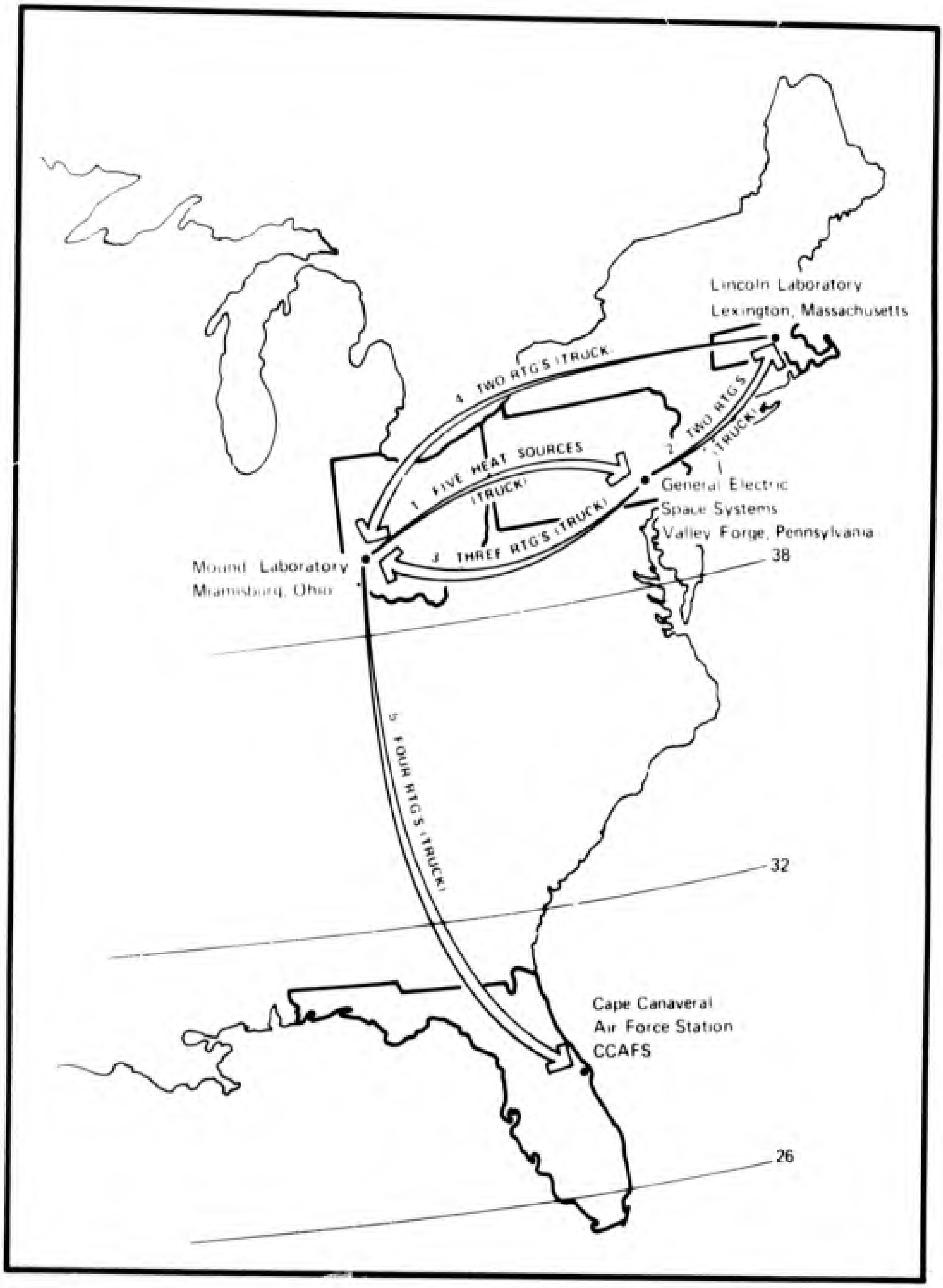

FIGURE 9. TRANSPORTATION OF MHW HEAT SOURCES AND RTGs

Laboratory and CCAFS, special security plans have been formulated (References 5 and 6).

Whenever the RTGs are in storage at Lincoln Laboratory or CCAFS, they will be maintained in controlled-access areas with continuous airborne radioactivity monitoring. Health physics personnel will insure that all personnel performing any operations within these areas wear appropriate radiation monitoring equipment and that their radiation exposures (from the small amounts of gamma radiation emitted by the RTGs) be kept as low as possible. Periodic contamination surveys within these areas will be conducted to insure that no plutonium has escaped the RTGs. In addition, whenever the RTGs are being moved within these facilities, or whenever any other type of operation is being performed on the RTGs themselves, health physics personnel will be present continuously to monitor radioactivity and radiation levels. Specific procedures for the functions to be performed by these personnel are described in Reference 7. K-2

TABLE 2. MANUFACTURERS OF AND FEDERAL AGENCIES RESPONSIBLE FOR P74-1 PROJECT COMPONENTS

System	Manufacturer	Federal Agency
LES 8/9	Lincoln Laboratory	Air Force
....MHW-RTGs	General Electric	ERDA
....Heat Sources*	Mound Laboratory	ERDA
SOLRAD 11A/11B	Naval Research Laboratory	Navy
Payload Integration System	TRW, Inc.	Air Force
Payload Fairing	McDonnell Douglas	Air Force

*Designed by General Electric

2.7 EMERGENCY RESPONSE PROCEDURES

In the unlikely event of an accident during the launch or ascent phases of the P74-1 mission, specially trained and equipped teams would be standing by to recover the MHW RTGs if they impacted on land or in shallow water. Should an accident occur in the launch pad area, the search and recovery process would be conducted by the Air Force Eastern Test Range Impact Convoy (Reference 7), which would be deployed for immediate response during the launch. Search and recovery operations in other parts of the world are the responsibility of the ERDA Space Nuclear Systems Response Team (Reference 8); such operations would be conducted in conjunction with the U.S. Department of State should impact occur within a foreign country. In the even more unlikely event that the MHW-RTGs would release plutonium in such an accident, these teams either have or can quickly call upon all resources needed for any containment and decontamination operations.

2.8 OPERATIONAL SYSTEM

If the LES 8/9 are successful, the demonstrated concepts and technologies are expected to be incorporated into a new, advanced military communications system. Very few details of this potential operational system have yet been formulated. However, its satellites might be powered by nuclear power systems of yet unspecified design.

3.0 EXISTING SITE CHARACTERISTICS AND THE RELATIONSHIP OF THE P74-1 PROJECT TO LAND USE PLANS AND POLICIES

Neither significant environmental nor land use effects would be associated with successful implementation of the P74-1 Project and its associated satellite programs. However, such effects are possible results of certain aborts or accidents which could happen during the launch, ascent, and orbital maneuvering phases of the mission. The probabilities of such effects occurring would not be significantly localized around any particular site. Rather, these very unlikely, accidental effects could conceivably occur almost anywhere on the Earth.

No land use effects would be expected since all facilities utilized existed before the P74-1 Project and would continue their existing operations substantially unchanged if the P74-1 Project were not implemented. The only possible land use effect identified would be associated with the very unlikely creation of radioactive ground contamination from an accident or abort. In such a situation, a relatively small area of land might be precluded from its normal use during a relatively short decontamination period.

As discussed in Section 4.0, the only significant environmental effects possible from the launch of the P74-1 payload would be associated with accidental dispersals of some of the plutonium or beryllium incorporated into the LES 8/9 RTGs or with human injury from accidently reentering payload components. Since these effects could occur almost anywhere on the Earth, the following description of the environment existing prior to the proposed launch is limited to providing background data on the uses, environmental availability, biological effects, and exposure standards relative to plutonium and beryllium.

3.1 BERYLLIUM

3.1.1 Uses of Beryllium

The industrial production of beryllium metal and beryllium chemicals is a comparatively recent development. Most of the beryllium produced is used as an alloying agent, particularly for copper, in low concentrations. The use of pure or nearly pure beryllium metal is largely restricted to military and space applications, and even in those fields its use is restricted to specialized applications by the price of the metal and difficulties in fabricating satisfactory beryllium components.

Beryllium is also used, either as the metal or the oxide, in some nuclear applications where its nuclear properties are favorable. Beryllium oxide refractories have excellent properties, but consumption is small and for highly specialized applications. Before beryllium was recognized as an extremely toxic material, in the mid-1940's, beryllium was used as a component of the phosphors in fluorescent lamps. This use was terminated.

3.1.2 Environmental Beryllium

Beryllium has an estimated abundance in the Earth's crust of about six parts per million (ppm) (Reference 9), based on analyses of M-9 representative shales (Reference 10). Its concentration in coal has been estimated at three ppm (Reference 11) and in stoney meteorites as 0.7-2.0 ppm (Reference 10). Beryllium is a widely distributed element, but concentrations (ore bodies) are relatively rare. The concentration of beryllium in sea water has been reported as 6×10^{-7} ppm (Reference 12), an extremely low value, less than the concentration of gold.

The natural background concentration of beryllium in the atmosphere has been reported as 0.0002 $\mu g/m^3$ (Reference 13). If the reported abundance of beryllium in the Earth's crust is applied to airborne dust concentrations (Reference 14), the calculated air concentration at low altitudes in "clean" locations is about 0.00036 μg/m³. An estimate of the release of beryllium to the atmosphere through the burning of coal and oil yielded a total of 4.1×10^5 kg per year (Reference 11). A similar estimate of the quantity weathered from rocks and eventually deposited in sediments was 5.6×10^6 kg per year.

3.1.3 Biological Effects

Various animal studies undertaken to investigate the toxicity of beryllium oxide have strongly suggested that the toxicity is dependent on the physical state of the oxide. Beryllium oxide which has been subjected to a high temperature calcination displays little toxicity, while uncalcined material, or that calcined at low temperatures, is toxic.

The toxic effects of beryllium compounds are usually classified as acute berylliosis, chronic berylliosis, and beryllium dermatitis, although it is not clear that these classifications reflect differing toxic actions. (Implantation of beryllium salts in or beneath the skin causes persistent ulcers which resist healing until the beryllium is removed.) Acute berylliosis and beryllium dermatitis are problems of the beryllium industry, typically caused by heavy exposure to soluble beryllium compounds. Acute berylliosis onset is rapid, and recovery or death occurs within a few weeks. Some concern exists that apparent recovery from acute berylliosis may be followed after a considerable lapse of time by the development of chronic berylliosis (Reference 15).

Chronic berylliosis is primarily an involvement of the lungs (although other organs may be involved) and is usually associated with the inhalation of beryllium oxide. Symptoms may not be observed for as many as 15 years after exposure. There is typically little correlation between the extent of exposure and the severity or even the development of the disease. Similarly, the existence or absence of beryllium in the urine is not correlated with the existence or absence of the disease. It is suspected that the susceptibility to berylliosis varies over a large range within the population (Reference 13). The development of chronic berylliosis in persons with no industrial exposure to beryllium and living as much as 3/4 mile from a beryllium plant suggests that the disease may be induced by continuous exposure to beryllium concentrations of greater than 0.01 but less than 0.1 micrograms per cubic meter ($\mu g/m^3$). However, the "neighborhood" cases present many puzzling aspects, and it generally cannot be proven that exposure to higher levels of beryllium did not occur, particularly in view of the long latent period.

3.1.4 Exposure Standards

No standards for the control of beryllium existed prior to 1951. In that year, the AEC set as standards for its internal operations and contractors an eight-hour exposure for industrial workers of 2 $\mu g/m^3$ for neighborhoods. These standards have persisted. Medical examinations are routine for workers potentially exposed to beryllium compounds, and efforts are made to screen prospective workers for unusual sensitivity to beryllium. An exposure criteria of 75 $\mu g.minutes/m^3$, not more frequently than every two weeks, has been established by the EPA (Reference 16, 17, 18) to evaluate beryllium hazards to the public from rocket firings, and an outplant concentration of 0.01 $\mu g/m^3$ (Reference 16, 17, 18) combined with an emission limit of 10 g/day is used for industrial facilities.

3.2 PLUTONIUM

Virtually all of the plutonium in the world is man-made, a product of the atomic age. Plutonium exists in the environment primarily as a result of atmospheric weapons tests, with a secondary source being the accidental, high-altitude dispersal of the contents of a plutonium-fueled RTG in 1964.

3.2.1 Uses of Plutonium

There are two isotopes of plutonium which are of primary interest: plutonium-239 and plutonium-238. Plutonium-239 is readily fissionable and has been extensively used in the manufacture of nuclear weapons. This isotope has also been proposed for rapidly increasing utilization in the commercial nuclear power industry. Plutonium-238 is not sufficiently fissionable to support a chain reaction. However, its radioactive half-life is considerably shorter than that of plutonium-239 (88 years as compared with 24,000 years) and, since the energy resulting from its short-ranged alpha radiations can be contained in a small volume, plutonium-238 finds applications in many situations where a small, intense source of reliable thermal energy is required. Such applications have included RTGs, such as the MHW-RTGs, and smaller heater and battery units. Potential future applications include widespread use in heart-pacemaker batteries and artificial heart power supplies.

3.2.2 Environmental Plutonium

Both plutonium-239 and plutonium-238 exist in the fallout from nuclear weapon detonations. Primarily as a result of atmospheric tests conducted by the United States and the Soviet Union before the atmospheric test ban instituted in 1963, about 320,000 curies of plutonium-239 and 7,700 curies of plutonium-238 have been injected into the stratosphere and dispersed into the environment worldwide (Reference 19). Most of this plutonium has now settled from the atmosphere and deposited on the Earth's surface. However, ongoing, smaller test series conducted by France, India and China continue to introduce additional amounts of both plutonium isotopes into the environment.

An additional source of plutonium-238 contamination occurred in 1964, when a navigational satellite with a SNAP-9A RTG failed to achieve orbital velocity and reentered the Earth's atmosphere from about 45,000 meters (150,000 feet). The SNAP-9A heat source, which contained about 17,000 curies of plutonium-238, was designed to vaporize and, thus, release its contents at high altitudes in such an accident situation. Post-accident investigations determined that the heat source performed as designed and released all the plutonium high in the atmosphere. Four months after the accident, the first traces of the SNAP-9A plutonium were detected at 33,000 meters (108,000 feet) (Reference 20).

The subsequent distribution of this SNAP-9A plutonium-238 was measured and analyzed by the AEC's Health and Safety Laboratory (HASL) as a separate source until 1972, when atmospheric levels had decreased sufficiently so that it was no longer practical to distinguish the SNAP-9A plutonium-238 from the plutonium-238 produced in weapons tests.

The latest reported inventories of plutonium still distributed throughout the stratosphere worldwide are summarized in Table 3.

TABLE 3. STRATOSPHERIC INVENTORIES OF PLUTONIUM (CURIES) AS OF JANUARY 21, 1973 (Ref. 21)

	Pu-239	Pu-238
Northern Hemisphere	820	110
Southern Hemisphere	720	120
Total	1540	230

The radiation doses to man resulting from inhalation of the plutonium-239 fallout contamination have recently been investigated and reported (Reference 22). Using plutonium-239 surface air concentrations for New York City measured since 1965 (and deduced from strontium-90 concentrations measured between 1954 and 1965), various organ burdens, already experienced doses, and dose commitments (assuming no new plutonium intake) for "standard man" were calculated. The most recent ICRP inhalation and lung and blood clearance models (Reference 23) were used together with the parameters for the most insoluble class (Class Y) of material.

The inhalation intake (directly proportional to surface air concentration) and various organ burdens are depicted in Figure 10, while the corresponding doses and dose commitments are summarized in Table 4. The intake curve approximately reflects the intensity of atmospheric tests, which peaked during 1961-1963. (Fallout settles from the stratosphere with a half-residence time of about 14 months (Reference 20), thus causing a shift in peak intake from peak testing of almost two years.)

TABLE 4. AVERAGE INDIVIDUAL TOTAL ORGAN DOSES (THROUGH 1972) AND DOSE COMMITMENTS THROUGH 2000 FROM FALLOUT PU-239 (mrem) (Ref. 22)

	Lung	Lymph	Liver	Bone
1954-1972	15	500	4	7
1954-2000	16	950	17	34

The predicted organ burdens agree reasonably well (Reference 22) with autopsy tissue analyses conducted in several locations throughout the country (References 24 and 25). Parallel analyses have indicated that other pathways of the plutonium contamination to man are insignificant relative to the inhalation pathway (Reference 22).

3.2.3 Biological Effects

No significant biological effects in man have been attributed to exposure to plutonium. Some evidence of effects at the cellular level in a few cases has been observed (Reference 27). In one case, direct plutonium contamination of a wound was alledged to have caused a cancer K-4

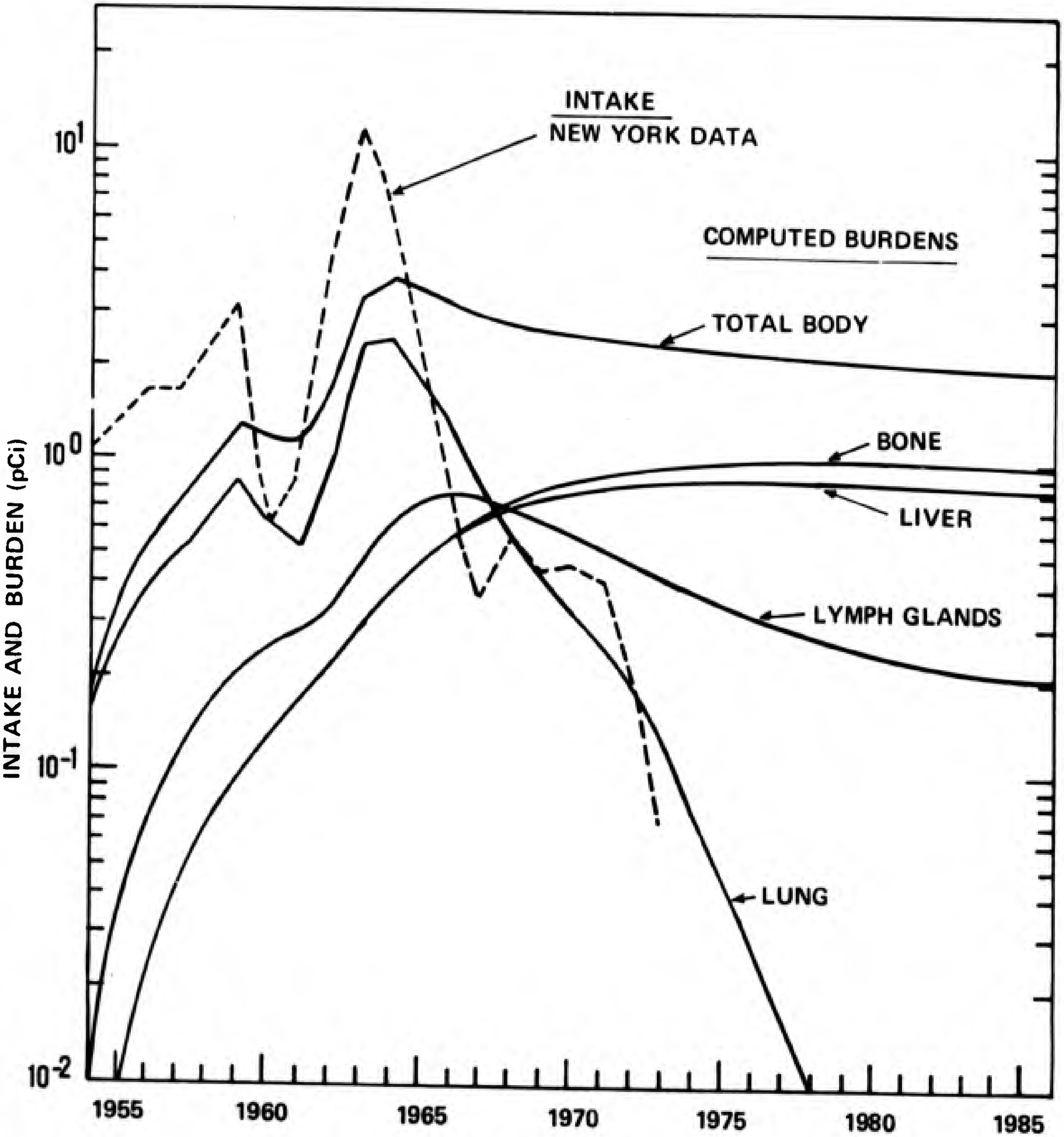

FIGURE 10. INHALATION INTAKE AND BURDEN IN MAN OF FALLOUT ^{239}Pu (Ref. 19)

(Reference 26), but the physicians involved do not support the allegation (see Appendix K). However, the data involving the effects of plutonium in man are very limited, primarily because of the strict controls that have been followed since the days of the Manhattan Project, when plutonium was first produced in significant quantities. Therefore, information on the possible effects of plutonium exposure in man has primarily been inferred from extensive studies that have been and are being conducted with experimental animals.

These studies, which recently have been reviewed in References 27, 28, and 29, suggest that lung and bone cancers are the most important effects of exposure to the lowest levels of plutonium thus far studied. The levels employed in these studies were much higher than those which might be associated with the P74-1 Project accidental events described in Section 4.2.2. In one such experiment, exposure to inhaled, insoluble plutonium (the only situation relevant to the P74-1) was shown to induce lung cancer in dogs at lung burdens of plutonium between 0.2 and 3.3 microcuries (Reference 30); larger lung burdens caused the dogs to die of pulmonary fibrosis within three to four years. Further experiments are now being conducted to investigate the possibility of cancer induction in dogs at lung burdens smaller than 0.2 microcuries.

Some of the limited data involving human exposure to plutonium has been obtained from extensive, continuing examinations that the ERDA has been conducting on a group of 25 men who were occupationally exposed to plutonium in 1945, during some of the first Manhattan Project plutonium operations (Reference 31). These men each accumulated body burdens estimated to be between 0.005 and 0.4 microcuries of plutonium. As of their latest examinations in 1972-1973, all 25 Manhattan Project workers were in generally good health, except for a few ailments that would be expected in a group of men now mostly in their early fifties. None of the 25 men has developed a lung cancer in the almost 30 years since their exposure.

3.2.4 Exposure Standards

The current radiation exposure standards used by the Federal Government are based on the Radiation Protection Guides developed by the Federal Radiation Council (FRC), whose functions have since been transferred to the Environmental Protection Agency (EPA). These standards, in turn, are essentially consistent with those recommended by two non-governmental organizations: the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP). Since the lung is the critical organ for plutonium exposures of the type possible during the P74-1 mission, only the lung dose standards are described. M-4

The various sets of standards are in terms of maximum allowable dose levels for workers occupationally exposed to radiation and for members of the general public. Each organization's occupational limit for lung dose is the same: 15 rem/year. Two different dose limits for members of the general public exist: 500 millirem/year is the lower, while the higher is three times that limit.* If the standard assumption is made that the radiation dose which would be received from inhaled plutonium is averaged throughout the mass of the entire lung, maximum permissible lung burdens can be derived from the above dose limits. These are: 0.016 microcuries for workers occupationally exposed and 0.0005 microcuries for members of the general public.

The adequacy of representing the hazards from plutonium releases by determining the numbers of exposures (if any) which might exceed the above standards is currently the subject of considerable disagreement. Information on the various questions involved in these controversies is

---

*This dose is not explicitly stated in terms of lung burden, but is derived from equations and statements in Reference 45 and is based on the recommendation that the maximum exposure to the general public be a factor of 30 less than the maximum dose for workers occupationally exposed to radiation (15 rem/year). The maximum dose for <u>individual</u> adult members of the general public is recommended to be a factor of 10 less than the maximum dose for radiation workers, i.e., 1.5 rem/year.

TABLE 5. CHARACTERISTICS OF SATELLITES CONTAINING RTG's (36, 37, 38)

S/C	Launch Date	Period, min	Inc., deg	Apogee km	Perigee km	Power Source	Inventory of Pu-238 at Launch (curies)	Expected Orbital Lifetime, years	Disposal Mode
Transit 4A	6/29/61	103.7	66.8	993	881	SNAP-3	1,800	570	Burnup
Transit 4B	11/15/61	105.7	32.4	1103	953	SNAP-3	1,800	1200	Burnup
Transit 5BN1	9/28/63	107.3	89.8	1135	1072	SNAP-9A	17,000	1900	Burnup
Transit 5BN2	12/5/63	107.0	89.9	1119	1067	SNAP-9A	17,000	1800	Burnup
Nimbus III	4/14/69	107.3	99.7	1135	1074	SNAP-19	37,000	3600	Intact Reentry
"Transit" (TRIAD 01-OX)	9/2/72	100.6	90.1	838	742	RTG	24,000	150	Intact Reentry

contained in References 26, 27, 32, and 33, as well as Appendices B and M to this Statement. Appendix B also contains further background information on radiation, radiation effects, the standards-setting organizations, and the exposure standards.

The EPA, in implementing its responsibilities for setting generally applicable environmental radiation standards, is currently reviewing the exposure standards for plutonium and the other transuranic elements. A large body of information collected through the public hearings conducted in this process has recently been published (Reference 34) and will be considered in the establishment of any new standards.

3.3 EXISTING RTG-POWERED SATELLITES

The United States has launched 18 payloads incorporating plutonium-238 fueled RTG systems. Five of these were Apollo Lunar Missions which left their RTGs (SNAP-27s) on the surface of the moon to power various experiments. Two others were NASA's Pioneer 10 and 11 missions to explore Jupiter and Saturn; their SNAP-19 RTGs will eventually leave the solar system. The two most recent launches were those of NASA's Viking spacecraft, now on their way to explore Mars. The eventual destination of their SNAP-19 RTGs is the surface of Mars.

Three launches aborted at various times, resulting in their payloads' RTGs returning to earth. The first was the 1964 incident involving a SNAP-9A powered navigational satellite, which is described in Section 3.2.2 of this Statement. The second involved a NASA meteorological satellite in 1968. This mission's launch vehicle went off course shortly after launch and was destructed; the satellite's SNAP-19 RTGs were recovered from the ocean intact. The third involved the 1970 Apollo 13 mission, which had to be curtailed when an explosion damaged the spacecraft. In conjunction with the safe recovery of the three astronauts, the SNAP-27 was successfully targeted to deposit intact in the Tonga Trench in the South Pacific, where it is effectively isolated from man's environment.

The remaining six launches all involved satellites which are currently in orbit around the Earth. Characteristics of these satellites, their RTG systems, and their orbits are summarized in Table 5. The "Disposal Mode" column indicates the manner in which each RTG was designed to respond to atmospheric reentry. Before 1967, RTGs were designed to burn up at high altitude to enhance the dispersal of their plutonium, as the SNAP-9A abortively launched in 1964 did (see Section 3.2.2). Since then, RTG systems, including the MHW-RTG, have been designed to survive such reentry intact to allow their recovery on Earth and the return of their plutonium inventories to positive control.

4.0 PROBABLE ENVIRONMENTAL IMPACT OF THE P74-1 PROJECT

Implementation of a typical satellite program, which would incorporate solar cell and/or battery power systems, would have only insignificant adverse effects on the Earth's environment. This would be true whether the launch of the payload and completion of the mission were successful or not. (The launch vehicle, as distinct from its payload, might produce minor, localized, and transient adverse effects. These are addressed in a separate Environmental Statement, Reference 1.) These possible, insignificant, adverse effects include:

(1) Pollution of air, water, or soil by typical payload materials or corrosion products.
(2) Reentry debris personnel hazard.
(3) Consumption of natural resources.

These effects are judged insignificant because, for past satellite programs, any such effects have been completely undetected. Analytical estimates of these effects have verified that they would be far smaller than similar effects caused by other common classes of human or natural activity. In fact, for the summation of all but one past satellite programs, the only effects that have been observable are some demographic and land-use effects. (The sole exception to this involved the 1964 incident described in Section 3.2.2 of this Statement, where an abort of a mission powered by an RTG system resulted in detectable plutonium contamination of the atmosphere.)

Against this background, the P74-1 Project and its associated satellite programs are atypical only because of the incorporation of two toxic materials, plutonium and beryllium, in the LES 8/9 RTGs. Thus, while the insignificance of other effects will be briefly discussed as appropriate, the rest of this Statement will deal primarily with potential environmental effects resulting from the proposed use of these two materials.

Any environmental effects connected with the operation of the various government facilities involved with the P74-1 Project are not addressed in this Environmental Statement. These facilities exist independently of the P74-1 Project and its associated programs, and their operation would continue with little change even if the P74-1 Project did not exist. No new facilities have been or will be created for the P74-1 Project.

4.1 NORMAL LAUNCH AND MISSION

Completion of a successful P74-1 launch and the LES 8/9 and SOLRAD missions would cause essentially no environmental effects. Some minor external radiation exposures of occupational personnel would occur during the transportation and handling of the RTGs before launch. However, the doses received would be very minor, would be carefully monitored, and would be well within the criteria established by AEC Manual, Chapter 0524. A normal launch would involve no effects other than those possibly caused by the launch vehicle (see Reference 1). As shown in Figure 2, all payload hardware would be placed in very high orbits from which no material would reenter the Earth's atmosphere for time periods many orders of magnitude greater than the mission lifetimes, if such material were to reenter at all.

4.2 ABORTS AND ACCIDENTS

Significant environmental effects are conceivable as a result of accidental occurrences during the proposed P74-1 Project, primarily related to the possibility of releasing plutonium to the environment during the launch and ascent mission phases. Consequently, extensive safety analysis programs have been conducted to analyze and quantify any such hazards resulting from accidental occurrences.

For events where hazards were predicted, the resulting environmental effects were associated with a predicted probability of occurrence. This process of associating accidental environmental effects with their occurrence probabilities is called a "risk assessment", and the summation of all such accidental effects is the total "risk" associated with the P74-1 Project.

This section has two purposes. The first is to review background information useful when evaluating risk assessments. The second is to present the predicted risks associated with the proposed P74-1 Project. Detailed synopses of the nuclear safety analyses and safety test programs conducted for the MHW-RTGs are contained in Appendices C and D.

4.2.1 Risk

With the increased recognition in recent years of the importance of considering the potential environmental effects of human activities, considerable effort has been expended on collecting and interpreting background data for use in considering risk-benefit questions. The AEC's recent Reactor Safety Study (Reference 39) has summarized most of the previous work on accidental risks and has expanded upon it for the purpose of comparing accidental risks from the commercial nuclear power industry with other types of accidental risks.

The study addressed accidental risks to society and individuals in terms of human fatalities, property damage, and serious human injuries. The most comprehensive data were presented for the societal (summed) risk in terms of human fatalities. This is typical of such studies, since fatality data are the most available and are usually felt to be the most meaningful to the average person.

Figures 11 and 12 synopsize these results from Reference 39). The figures present the frequency in events per year of various man-caused and natural occurrences which cause at least N fatalities per event. Historical data were used whenever available in conjunction with analytical extrapolations and theoretical analyses.

The probabilities associated with these fatality data are useful for providing perspective on the small probabilities of accidental events associated with the proposed P74-1 mission, which are presented in Section 4.2.2. However, in making such comparisons, there is no intent to imply that any fatalities are necessarily associated with the various possible events of interest. In fact, only the accident involving a person or persons being struck by accidentally reentering payload components would be at all likely to involve human fatalities, were that unlikely accident (a probability of 10^{-4} or 0.01 per cent) to occur.

4.2.2 Potential Accidental Environmental Effects

The possible accidental environmental effects associated with the P74-1 Project fall into the following broad categories:

(1) Air or water pollution by vaporized or corroded payload materials. The plutonium and beryllium of the LES 8/9 RTGs are of special interest because of their toxic properties.

(2) Hazards associated with accidental reentry impact of payload components.

The remainder of this section will investigate the risks from each of these categories.

4.2.2.1 Potential Beryllium-Related Effects

Because of the toxicity of beryllium oxide dusts (see Section 3.1), possible exposures to beryllium oxidized from the LES 8/9 RTGs

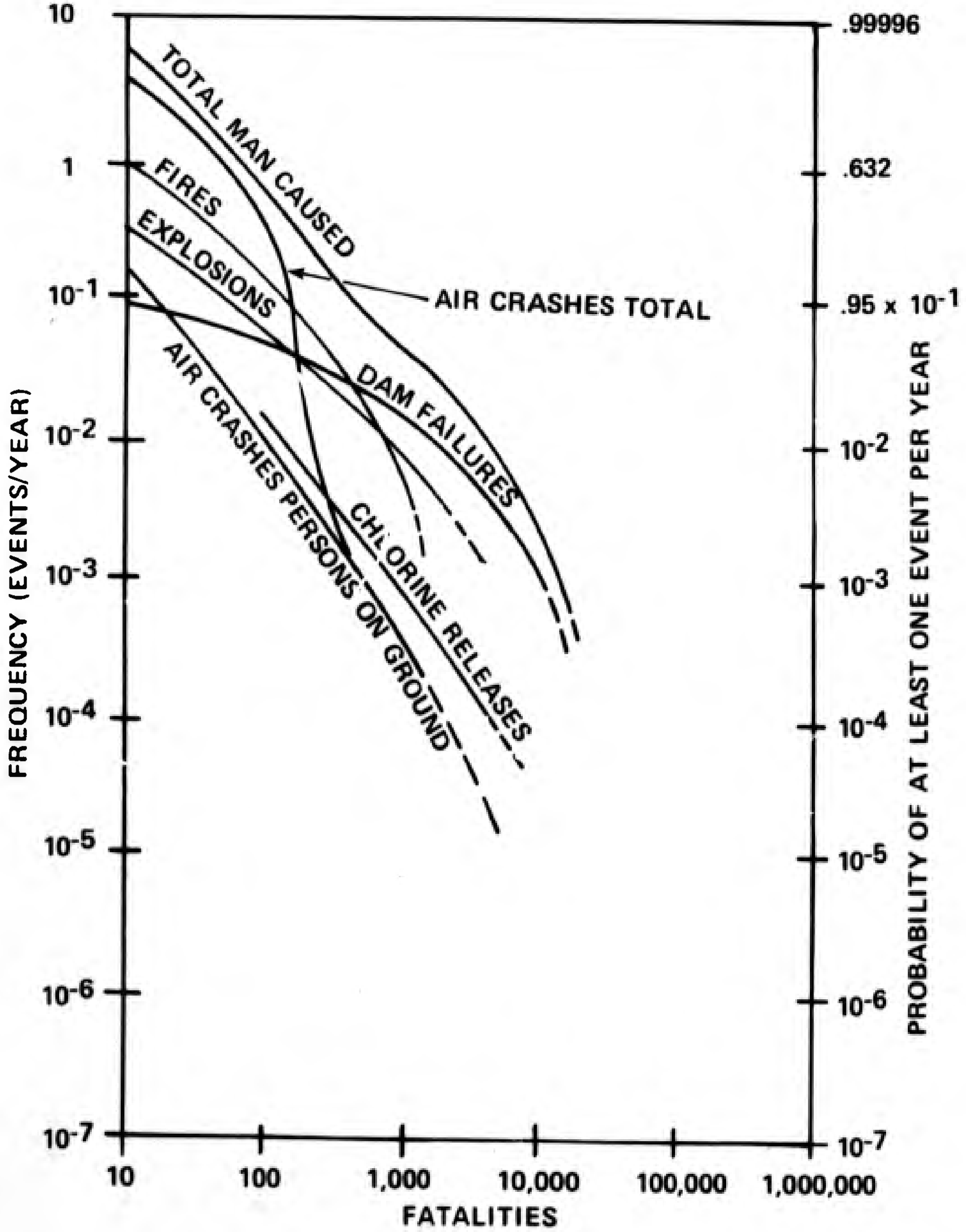

FIGURE 11. FREQUENCY OF FATALITIES DUE TO MAN-CAUSED EVENTS (Ref. 39)

Note: The left-hand vertical scale indicates the expected frequency per year for events which cause at least the number of fatalities indicated by the corresponding coordinate on the horizontal scale. The right-hand scale indicates the expected probability of at least one event per year occurring which causes at least the number of fatalities indicated by the corresponding coordinate on the horizontal scale.

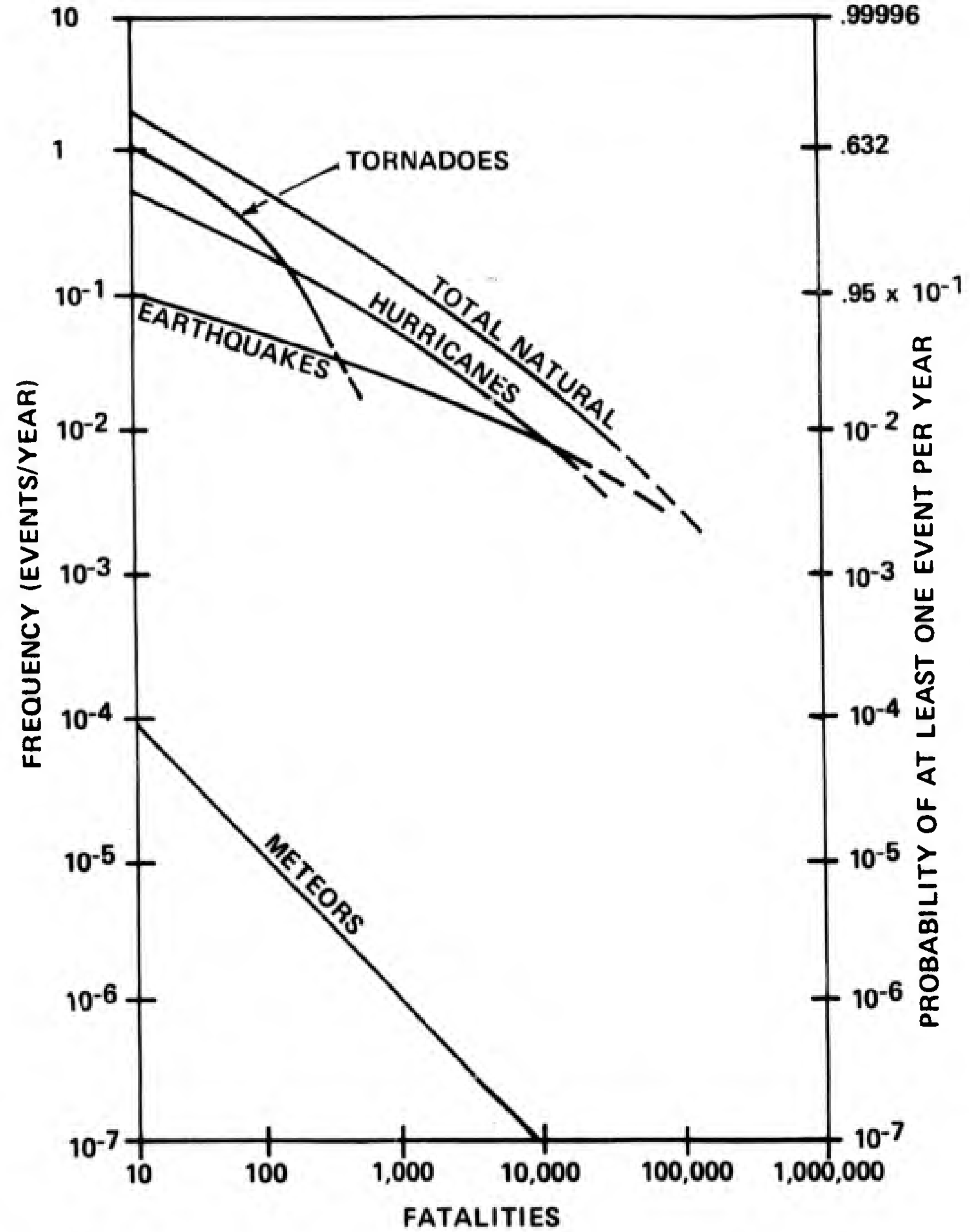

FIGURE 12. FREQUENCY OF FATALITIES DUE TO NATURAL EVENTS (Ref. 39)

Note: The left-hand vertical scale indicates the expected frequency per year for events which cause at least the number of fatalities indicated by the corresponding coordinate on the horizontal scale. The right-hand scale indicates the expected probability of at least one event per year occurring which causes at least the number of fatalities indicated by the corresponding coordinate on the horizontal scale.

are of particular concern. Because any such exposures would be of short duration, the standard of 75 μg.minutes/m^3 has been selected as the representation of hazardous levels. The only situations in which such concentrations could be reached would involve aborts in the launch pad area. (In accidental reentry situations, beryllium from all of the RTGs would be oxidized and dispersed high in the stratosphere and would be so diluted when it reached the surface that it would not present any hazard.)

Consequently, an analysis of the beryllium's response to launch abort thermal environments has been conducted (Reference 40). It was determined that exposure of the RTGs to fireballs and liquid residual fires cannot oxidize enough of the payload's 42 pounds of beryllium to exceed the 75 μg.minutes/m^3 standard. (The atmospheric dispersion analyses were performed using release heights appropriate to the type of fire under consideration.)

The only situation in which it is considered possible for enough beryllium to be oxidized to exceed the 75 μg.minutes/m^3 standard involves exposing the RTGs to solid propellant residual fires. There is some uncertainty about the behavior of beryllium in the chemical environments produced by such a fire. The amount of beryllium expected to oxidize in the fire is about 0.91 kg (2 pounds) which is not sufficient to exceed the 75 μg.minutes/m^3 standard. However, to allow for the uncertainty, the effects from a release of beryllium oxide greater than expected (arbitrarily selected as 10 times the expected amount, or 9.1 kg (20 pounds) were analyzed. In this situation, with "worst-case" meteorology and wind direction, it is possible to subject up to about 1000 persons to integrated beryllium oxide exposures greater than 75 μg.minutes/m^3.

The probability of having an accident in the launch pad area would be about 0.01 (Reference 2). Given such an accident, the probability of exposing the RTGs to a solid propellant residual fire would be about 0.1 (Reference 3). Thus, the probability of beryllium being involved in a solid propellant residual fire would be about 10^{-3}.

The probability of exposing 1000 people also includes the probability of necessary meteorology (for example, more than half of the time the wind is blowing out to sea from CCAFS or towards unpopulated areas, thus preventing any human exposures (Reference 41)) and would be closer to 10^{-4}.

Even this probability is very probably an overestimate considering the conservative assumptions made regarding the solid propellant fire chemical environments. However, comparing this risk number with those presented in Section 4.2.1 shows that the risk of exposing people to greater than the $75\mu g \cdot minutes/m^3$ short-term exposure standards would be orders of magnitude smaller than the accidental risks of fatalities from many other natural and man-caused accidental events.

4.2.2.2 Potential Plutonium-Related Effects

Because of the toxic properties and large amounts of plutonium used in the RTGs, a set of comprehensive nuclear safety analyses and a wide variety of safety test programs have been conducted to study the possibility of releasing plutonium to the environment. These analyses and tests investigated the nuclear power system's responses to all normal and accidental environments to which they might be exposed. Detailed synopses of the results of these programs are presented in Appendices C and D of this Statement.

Since there is more plutonium (24.2 kg of PuO_2) contained in the entire P74-1 payload than the 8.6 kg necessary to form a critical mass under ideal conditions, the possibility of an accidental criticality event has also been investigated (Reference 42). (The plutonium in the RTGs, as opposed to pure plutonium-238, could support a chain reaction under proper conditions because of the 16 percent plutonium-239). However, no conceivable series of accidental events has been identified which could assemble the plutonium into a critical mass. Nuclear criticality is not possible for any configuration or grouping of the fuel spheres, with or without the graphite impact shells present, and regardless of whether or not the configuration is essentially bare or reflected (Reference 42). In order for nuclear criticality to occur, the fuel spheres would have to be melted, at least 8.6 kg of the PuO_2 fuel would have to be separated from the melt, and, finally collected into a spherical mass. Even then, nuclear criticality would not be possible unless the mass were totally reflected by material such as silica (sand or rock), steel, water or concrete.

Similarly, no accidents have been identified which could release plutonium to the environment during ground transportation, primarily because the RTG systems have been designed to survive the more severe accident environments of the launch and ascent mission phases. However, there are conceivable (although highly improbable) accidents during launch and ascent to the final orbits which could release plutonium to the environment. Thus, considerable analytical and experimental effort has been spent on quantifying the amounts and probability of such releases.

For reasons discussed in Appendix C, the only environmental pathway of significance is direct inhalation of airborne plutonium dioxide by man. Therefore, the releases of interest are those involving vaporized plutonium dioxide or particulates small enough to be inhaled (considered to be particulates less than 4 microns in diameter).

Table 6 summarizes the results of the INSRP's SER (Reference 2) I-1
regarding releases of airborne inhalable plutonium dioxide. The total
probability of these releases would be about 2 x 10^{-4}, with releases of M-2
30 millicuries or less accounting for the bulk of this probability. The
total probability for releasing more than one curie of respirable
plutonium would be about 2 x 10^{-5}. Further discussion of these results,
including identification of the specific accidents which lead to each
predicted source term, is contained in Appendix C.

Comparing these probabilities with those presented in Section 4.2.1 shows that the risk of releasing plutonium would be much smaller than the risks of fatalities from many other natural and man-caused accidental events. Further, because of the small sizes of the predicted

TABLE 6. SUMMARY OF NUCLEAR SAFETY ANALYSIS RESULTS

Accident Type	Mission Phase	Impact Location	Probability Of Release	Source Term (millicuries)	Source Term Type
1	Launch	Launch area	4×10^{-6}	1300	Particulate
1	Launch	Launch area	1×10^{-8}	5200	Vapor
2	Ascent	Launch area	1×10^{-5}	1300	Particulate
3	Orbital	Worldwide	1×10^{-4}	30	Particulate
4	Orbital	Worldwide	4×10^{-5}	10	Particulate
5	Orbital	Worldwide	6×10^{-6}	250	Particulate

(Note: For descriptions of the various accident types and details of the results summarized in this Table, see Appendix C.)

source terms, the probabilities of a person accumulating either a 0.016 or a 0.0005 microcurie lung burden would be far smaller than the probabilities for plutonium release.

Relative to plutonium-related site impacts, the INSRP examined the worst possible ground contamination problem at CCAFS and determined that decontamination operations would not have to be conducted off-site. Such decontamination procedures would be conducted through the procedures described in Section 2.7. J-6

4.2.2.3 Potential Effects From Other Payload Materials

Besides the plutonium and beryllium of the LES 8/9 RTGs, the P74-1 payload materials include the small solid propellant motors of the SOLRADs, typical spacecraft structural materials (primarily aluminum, with some steel involved) and typical electronics components. None of these latter materials are particularly toxic nor are they present in sufficient quantities to cause any significant effects on air or water quality in any accident situation. For example:

(1) Any effects from the 112 kg (247 pounds) of solid propellant aboard the SOLRADs would be insignificant compared to similar effects possible from the 395,000 kg (870,000 pounds) of similar solid propellant in the Titan III-C launch vehicle. In turn, the possible effects associated with the Titan III-C solid propellant were shown to be very minor in Reference 1.

(2) Any effects from oxidation/vaporization or corrosion of the payload materials other than beryllium or plutonium would be undetectable and insignificant relative to other common, man-caused and natural, utilizations of similar materials. Far more aluminum oxide (classified only as a nuisance dust, see Reference 1) is produced as a normal combustion product from the Titan III-C solid propellant than could ever result from an accident involving the payload. Iron oxides could be produced only in smaller amounts and are also relatively innocuous pollutants. Any effects associated with the electronic components aboard would be insignificant because of the small amounts

of these materials present and the lack of any such material having particularly toxic properties.

4.2.3.4 Potential Hazards From Accidental Reentry Impacts

Hazards associated with reentering missile and payload hardware were the subject of a recent, comprehensive review of NASA space operations (Reference 43), the results of which are directly applicable to accidental reentry of P74-1 payload components. The general findings of this study were that:

(1) Hazards from reentering components (planned and accidental) from all past space activities of the United States and the Soviet Union (approximately 1300 launches) on an annual basis are on the order of, and probably less than, the similar hazard from natural impacts of meteorites on the Earth's surface. (It is estimated that between 25,000 and 150,000 kilograms of meteorites greater than one kilogram each impact the Earth's surface each year.)

(2) In all of recorded history, there have been no verified human fatalities caused by meteorite impacts. There have been two verified cases of human injuries from meteorite impacts (one in 1847 and one in 1954). There have been about a dozen incidents of possible, but not certain, human fatalities or injuries by meteorite impact. There have been no such incidents of any kind involving man-made space debris.

(3) The various analytical models used for calculating reentry impact hazards were used to calculate the hazards from meteorites and compared with the existing meteorite data. The most accurate models identified after this exercise predict the following risks from a typical set (one launch) of payload and/or vehicle components known to be reentering: a probability on the order of 10^{-4} to 10^{-5} of causing a human fatality and a probability of 10^{-3} to 10^{-4} of causing a human injury.

Reference 2 has indicated that the possibility of any accidental reentry of P74-1 payload components would be on the order of 10^{-1}. Thus, the probability of a human fatality from reentry impacts of P74-1 payload components would be on the order of 10^{-5} to 10^{-6} and the probability of a human injury would be on the order of 10^{-4} to 10^{-5}. Comparison with the accidental risk numbers discussed in Section 4.2.1 indicates how insignificant this risk is when compared to other natural and human activities.

4.3 ULTIMATE REENTRY

The P74-1 payload components would remain in orbit around the Earth long after their useful lifetimes are finished. For reasons discussed in Section 4.2, the possible ultimate reentry of all but one of the component materials represent essentially insignificant environmental hazards. The exception is the radioactive plutonium of the LES 8/9 RTGs. Thus, the purpose of this section is to discuss the long-term considerations involved in placing this plutonium in orbit around the Earth.

4.3.1 Radioactive Decay Characteristics

Each of the four RTGs would be launched with an inventory of about 77,500 curies of plutonium with the isotopic composition shown in Table 1 (Section 2.5.2). As the plutonium-238 decays (producing heat to power the RTGs), the size of this inventory decreases, essentially with the half-life (88 years) of plutonium-238. As shown in Figure 13, this process continues for about 1000 years, by which time the total inventory has decreased to a little more than 0.001 of its original value.

At that time, however, the presence of two long-lived isotopic impurities of plutonium (plutonium-239 and plutonium-240), the long-lived daughter (americium-241) of the short-lived plutonium-241 isotopic impurity, and the daughter products of plutonium-238 itself (uranium-234, for example) would combine to keep the total radioactivity level

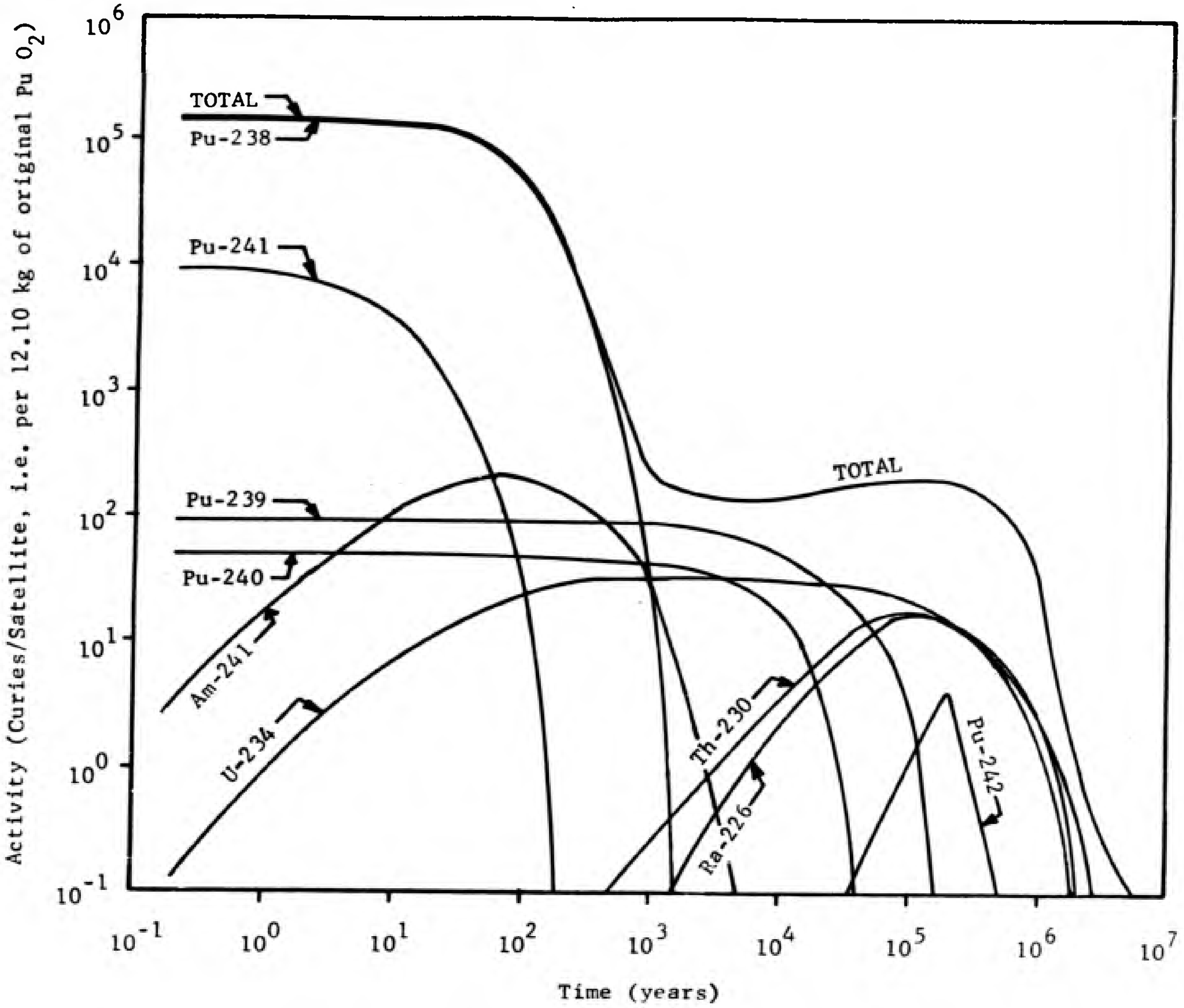

FIGURE 13. RESIDUAL RADIOACTIVITY OF A LES SATELLITE

relatively constant out to almost 1,000,000 years. Thus, each satellite (two RTGs each) would retain on the order of 200 curies of radioactivity (virtually all alpha radioactivity) until almost 1,000,000 years after launch.

4.3.2 Orbital Lifetimes

Because of this long-term radioactivity, the expected orbital lifetimes of the LES 8/9 are of considerable interest. In particular, the questions of whether the LES 8/9 would reenter before 1000 and 1,000,000 years, respectively, are important.

Several studies have addressed the question of remaining in orbit for more than 1000 years, and all indicate a considerable margin of confidence that such a lifetime would be obtained. One study investigated what perigee, given a 35,900 km (22,300 mile) apogee, would be necessary to insure a 1000 year orbit. The result was that a perigee of only 925 km (575 miles) would suffice. Another study used the orbital lifetime chart in Reference 44 at the highest altitude considered (1600 km or 995 miles) for a circular orbit with a satellite ballistic coefficient of 10 (approximately that of the LES 8 or 9). This yielded a predicted lifetime for that orbit of 5000-6000 years. For the orbital ranges and inclinations involved, the much higher orbit of 35,900 km (22,300 miles) circular would have a much longer lifetime than those with lower perigees considered above. Thus, it is clear that the LES 8/9 should have an orbital lifetime well in excess of 1000 years.

Such confidence cannot be shown for the other important lifetime of 1,000,000 years, however. Neither orbital lifetimes of this order nor reentry from synchronous orbit have previously been of interest. Thus, no set of well-studied analytical techniques for investigating orbital lifetimes of this magnitude exist. Because of the growing interest in using nuclear-powered satellites at such altitudes, studies are now being initiated in an attempt to rectify this deficiency. However, their results will not be available for this Statement.

A qualitative examination of the forces on satellites in synchronous orbit, however, does indicate that lifetimes should be extremely long and possibly approaching infinity. At these altitudes, atmospheric drag no longer exists. The effects of variations in Earth, moon, and sun gravitational forces on such orbits is one aspect of the problem which has been studied in some detail (Reference 45). The conclusion was that, for the orbital inclinations of the LES 8/9, the orbit would move about somewhat, but with no overall, long-term decrease in perigee (no energy is removed from the orbit by such variations). Since these variations do not begin to approach the range in which atmospheric drag would be of significance, there is no indication that these perturbations would cause reentry.

Solar radiation pressure has been observed to have significant effects on satellite orbits, most notably on NASA's ECHO balloon satellites, which combined very large areas with relatively little mass. For the more typically designed LES 8/9, however, solar radiation pressure has been investigated and appears to have the same kind of effects as variations in gravitational potentials: small shifts in orbital position, but no long-term effects on perigee altitude.

The only remaining mechanism which could cause the LES 8/9 to reenter involves the possibility of impact with meteorites or other space debris of sufficient size and velocity to remove sufficient energy or severely perturb the orbit. This problem has not yet been completely investigated, but preliminary indications are that the probability of such an event would be extremely small.

In summary, there is currently no obvious reason that the LES 8/9 could not be expected to remain in their planned orbits past 1,000,000 years. However, analytical techniques are not now available to justify expectations of such long lifetimes. Therefore, the next section will briefly explore the effects which might be associated with reentry of the RTGs between 1000 and 1,000,000 years.

4.3.3 Potential Environmental Effects of Ultimate Reentry

Attempting to predict the environmental effects of RTG reentry during the period approaching 1,000,000 years after launch is almost a totally speculative process. The physical state of the RTGs, and even the environmental and ecological states of the Earth at such long times cannot be addressed with any confidence. (It is expected that the Earth will still be here, however. Destruction of the Earth by an expanding ("red giant") sun is not predicted until about 6,000,000,000 years from now, see Reference 46.)

Three possibilities can be briefly explored, however. The first is that the RTGs would remain essentially unchanged and would behave as predicted for accidental reentry as described in Section 4.2. This is unlikely, however, since such long exposures at the RTG operating temperatures are likely to compromise the containment integrity of the iridium PICS.

The second is that the physical state of the entire RTG would be so deteriorated (it might even be just a cloud of dust) that all of the radioactivity would be dispersed in the upper atmosphere upon reentry. Such a release of about 400 curies (four RTGs) of alpha radioactivity (assuming that reentry occurred between 1000 and 1,000,000 years) would not be a completely trivial incident, but would be orders of magnitude less severe than similar events in recent years (see Section 3.2).

The third, and most disturbing, possibility, is that the RTG heat sources would retain their reentry capability throughout the period, but not their containment capability. In this situation, a heat source could impact land intact and produce a localized release of a large portion of its approximately 100 curies of radioactivity. Although no meaningful effects analysis of such an event can be performed, it is conceivable that such an occurrence could represent a very significant hazard. Large numbers of persons could receive doses above current standards, with the possibility of significant numbers of long-term health effects.

4.3.4 Potential Recovery of the LES 8/9

The possible environmental effects discussed in Section 4.3.3 above can be considered an avoidable risk, however. The United States is currently engaged in developing a Space Transportation System (STS) (References 47 and 48) which will be capable of retrieving satellites from orbit, including synchronous orbit. The STS will be operational in the 1980's. Consequently, should further information indicate its necessity, the LES 8/9 could be recovered and returned to Earth sometime after the 1980's. Such further information could include a better understanding of predicted health effects from plutonium inhalation, more complete predictions of the expected orbital lifetimes of the LES 8/9, and future data on the expected condition (reentry behavior) of the RTGs in orbit.

It is not now believed that recovery of the LES 8/9 would be necessary as a hazard prevention procedure, and recovery of the satellites would be an expensive operation. However, the existence of the STS means that the nation would not have made an irrecoverable commitment in launching these satellites. In the event, judged to be of small probability, that some future information or policy indicates that recovery of these satellites would be desirable, the capability will be available. Further information concerning the possibility of recovery with the STS is contained in Section 6.5 of this Statement.

4.4 SOCIO-ECONOMIC EFFECTS

Minimal social and economic effects would be associated with implementation of the P74-1 Project and its associated satellite programs. No more than a few hundred employees are involved with the P74-1 Project at the widespread locations indicated in Table 3. The majority of these jobs would exist regardless of the P74-1 Project, since they would be diverted to other priority projects.

4.5 OPERATIONAL SYSTEM

As previously indicated, the LES 8/9 experiment would be directed at the implementation of an operational system. A later Environmental Statement will be prepared to explore possible effects associated with that system. However, current plans indicate that such a system would have accidental risks no more severe than those associated with the LES 8/9.

The hazards involved with the possible ultimate reentry of the operational system may be more severe than those associated with the LES 8/9 (see Section 4.3.3), and will be studied extensively. There are insufficient data for any further conclusion at this time.

5.0 ADVERSE ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED IN THE PERFORMANCE OF THE P74-1 PROJECT

Any possible adverse environmental effects associated with the LES 8/9 or any other components of the P74-1 Project can be separated into three categories:

(1) Unavoidable effects that can be expected to occur.

(2) Effects which might occur if certain, highly improbable, accidental sequences of events take place; these are termed unavoidable risks.

(3) Possible long-term effects which might occur, but which could be avoided if necessary through utilization of currently developing technology.

5.1 UNAVOIDABLE AND EXPECTED EFFECTS

There are no significant environmental effects associated with the P74-1 Project which would be expected to occur. There are some minor, transient effects associated with the Titan III-C launch vehicle which could occur. These are addressed in Reference 1.

5.2 UNAVOIDABLE RISKS

Certain highly improbable accidental events during the launch and ascent of the P74-1 payload might cause adverse environmental effects. Such effects have been analyzed and associated with their probability of occurrence to define predicted environmental risks which would be associated with performance of the P74-1 Project. These risks include:

(1) A probability on the order of 10^{-4} of exposing up to 1000 people to an integrated air concentration of beryllium oxide greater than the short-term exposure standard.

(2) A probability on the order of 10^{-4} of releasing plutonium to the environment, with a much smaller probability of causing persons to accumulate more than recommended maximum levels of plutonium.

(3) A probability on the order of 10^{-5} to 10^{-6} of causing a human fatality from physical impact of accidentally reentering payload components, with a probability on the order of 10^{-4} to 10^{-5} of causing a human injury through the same mechanism.

5.3 AVOIDABLE LONG-TERM EFFECTS

Relatively large releases of radioactive material might occur if the LES 8/9 RTGs were to reenter the Earth's atmosphere between 1000 and 1,000,000 years after the launch. Although such reentry would not be expected, analytical techniques are not sufficiently developed to discount this possibility. Any adverse environmental effects from such a release can be considered avoidable; however, since the United States is currently developing the capability, through the Space Transportation System program to recover or otherwise dispose of orbital payloads.

6.0 ALTERNATIVES

The following concepts represent alternatives to the plans for the P74-1 Project and the LES 8/9 mission which could have different levels of environmental impact in comparison with the proposed program. Only the LES 8/9 mission, as opposed to the other parts of the P74-1 Project, is addressed in this section, since virtually all of the environmental effects discussed in Sections 4.0 and 5.0 relate to the LES 8/9 mission (except for hazards from physical impact of payload component(s) after an accidental reentry, a risk present for all launches.)

- The alternative of not performing the mission
- The use of a ground-based communications system rather than satellites
- The possibility of performing the mission with only one satellite
- Changes in the nominal parameters of the LES 8/9 mission
- The use of the space shuttle for ultimate recovery or disposal
- The use of other power sources
- The use of other existing RTG designs.

6.1 ALTERNATIVE OF NO MISSION

Not performing the LES 8/9 mission would eliminate the possibility of any direct environmental impact from this project. But there would still be a need for some new system of military communications. Current communication systems employed for force element command and control are relatively vulnerable to attack. The LES 8/9 experiment would represent a significant advance in secure communications capability and survivability. If the experiment is not performed, the DoD may be in a highly vulnerable communications position before the end of this decade. Thus, there would still be a future need for a secure communications system which might involve an alternative system such as described in the next section and which would carry with it the environmental impacts described. The impacts of the alternative system may well be greater than the system of which the LES 8/9 are the forerunners. Selection of an alternative system might also delay the date when an advanced military communications capability would be available.

Thus, the consideration of not attempting the LES 8/9 experiment would be to foreclose on a survivable communications option that DoD might need in the event of an all out attack. The LES 8/9 program would provide the proving ground for the technology necessary to advance our defense communications in a significant way, thus enhancing our deterrent posture around the globe.

6.2 GROUND-BASED COMMUNICATION SYSTEMS

The use of a ground-based communications system would eliminate all of the possible environmental impacts discussed in this statement. But such a land-based system would have its own impact, quite different in kind and, therefore, difficult to compare with environmental impacts which might result from performance of the LES 8/9 mission. In the implementation of a ground-based system, there would appear to be a number of significant features which could lead to measurable environmental impacts. For example, large land areas may be required for implementation of some of these systems. Humans would have to be excluded from these areas. The electromagnetic radiation might have effects on animals, plants, and wildlife.

Other factors which would have significance would be the large uses of materials and energy; also, a large number of personnel would be required for operating such a facility. Construction of a ground-based communications system would require large amounts of steel, copper, and/or aluminum. There might also be significant needs for construction equipment. Operation of the facility would probably require the production and consumption of large amounts of electricity with its associated impacts. Manpower would probably be significant in numbers for construction, for operation, for maintenance, and to provide security.

Further, ground-based communications systems do not appear to be able to provide comparable performance to satellite systems such as the LES 8/9. There are only a limited number of electromagnetic propagation effects useful for world-wide communication. (Effects other than electromagnetic might be used, for example, seismic waves, but all such known effects are extremely limited in their information-carrying capacity and have other undesirable features). The possible effects are as follows:

- -- Wire connected systems
- -- Very low frequency radio (waveguide or surface wave mode)
- -- High frequency radio (ionospheric reflection).

Other modes of radio communication, for example, forward scatter and line-of-sight, would require numerous relay or repeater stations and would be difficult to implement in transoceanic links.

Difficulties shared by all of the above communication schemes are that they are easily monitored covertly, easily jammed, relatively easily sabotaged and, for those modes dependent on the ionosphere, susceptible to high altitude nuclear weapons effects. The very low frequency radio systems also suffer from a low information-handling capacity (a result of the low frequency).

In contrast, the satellite system, which the LES 8/9 are intended to demonstrate, is relatively difficult to monitor or jam and is quite difficult to sabotage. Thus, for the military communications system required, the use of a satellite system is preferable to any known ground-based system.

6.3 USE OF ONE SATELLITE

As a technology demonstration, consideration could be given to launching a single LES, rather than two, in an attempt to reduce the potential for environmental impact. The reduction in potential for environmental impact would result primarily from decreasing the amount of plutonium which would be used by one half. Thus, the kinds of potential impacts would be the same but the levels would be lower. Using a single LES, however, would preclude testing one important part of the potential operational system, the satellite-to-satellite communication link.

6.4 CHANGES IN THE NOMINAL PARAMETERS OF THE MISSION

Because the LES 8/9 mission would be predominantly a demonstration of the technology required for a secure, survivable, worldwide communications system, rather than an operational system as such, alteration of the nominal parameters of the mission might be considered. Such alternatives might be different orbital inclinations and altitudes with or without alterations in the design of the satellites. However, such changes would have at best minor effects on the environmental consequences of the mission. For example, it is possible that higher altitudes would provide greater confidence of longer times in orbit. This might allow longer times for radioactive decay to reduce the amounts of radioactivity available for release. However, it is not clear, as previously discussed in Section 4.3, that higher orbit altitudes would provide a benefit in terms of longer orbital lifetimes (since no technique for estimating such lifetimes is available) or that longer lifetimes would cause significant reductions in the amounts of radioactivity. It is clear that such a modification would add to the complexity of the planned communications experiments.

Also, a maneuvering of the launch vehicle to avoid instantaneous impact point traces crossing land masses would cause a small decrease in the potential for environmental impact but would require greater complexity in the launch operation and probably a more than off-setting decrease in reliability.

6.5 ALTERNATE DISPOSAL TECHNIQUE

An alternative to leaving the LES 8/9 in orbit at the end of their mission would be to utilize the capabilities of the Space Transportation System (STS) or some successor system. The spent satellites might be recovered and returned intact to the Earth by the STS for disposal or reprocessing of the remaining radioactivity values. Such a procedure would lessen the potential for environmental impact in comparison to allowing the spent satellites to reenter without control, should that occur.

A related possible alternative would be to use an STS-type system to carry up additional propulsion and guidance for attachment to each LES. This propulsion and guidance capability would be designed to propel the LES 8/9 beyond the Earth's influence into the sun or into a solar orbit. Successful implementation of such an alternative would preclude any eventual return to Earth and eliminate any potential for environmental impact.

These alternatives will be studied for possible implementation
as characteristics of the STS become better defined and as more informa- G-2
tion is obtained relative to the uncertainties described in Section
4.3.4. The best information available at this time (Reference 48) J-3
indicates that such a recovery mission would involve from three to K-3
six days of space operations. The Space Shuttle, carrying a reusable,
propulsive upper stage (called the Space Tug), would achieve a low-
level orbit. A typical altitude might be 280 km (175 miles). Then
the Shuttle would deploy the Space Tug, which would make the trip to
synchronous orbit altitude, recover the satellite, and return to a
low-altitude orbit. The Shuttle would next recover the Tug, with the
recovered satellite, and return to Earth. A rough, preliminary estimate
of the cost of such an operation is $11 million. All of this would not
necessarily be chargeable to the recovery operation, however, since
deployment of some other payload would almost certainly be accomplished
during the same mission.

6.6 ALTERNATE POWER SOURCES

As pointed out previously, the environmentally significant feature of the LES 8/9 spacecraft is the use of RTGs for electrical power generation. RTGs were chosen for these spacecraft as the only technically feasible way of supplying the necessary quantities of electrical power for the necessary duration while still meeting the proposed mission requirements.

All conceivable alternatives to the RTGs including solar cells, fuel cells, batteries, and chemical dynamic systems have been explored in great detail to determine if objectives can be met. Solar cells could supply the necessary power for a useful period. However, a solar cell system could not satisfy all of the specific survivability requirements of the proposed mission. Batteries with a demonstrated energy capacity of 100 to perhaps 150 watt-hours per pound would exceed the weight of the entire current spacecraft for a mission duration of a few weeks. Fuel cells, with energy capacities of perhaps 400-600 watt-hours per pound, would at most make the usable life of the satellites a few months, and chemical dynamic systems might have similar characteristics.

G-1

M-8

Although potential environmental impacts would be less for each of these alternative systems, they are not equivalent and cannot meet all of the proposed mission requirements.

6.7 ALTERNATE RTG SYSTEMS

For the reasons discussed, RTGs have been proposed to power the LES 8/9 spacecraft. The specific power level chosen for the RTGs is dictated by the requirements of the Earth-based portions of the communications. This is because relatively small, and in some cases mobile, terminals require substantial transmitted power from the satellites.

At the present time, the MHW-RTG is the only available RTG system, in a sufficiently high state of development, which will provide the large power requirements of the LES 8/9 mission. Use of this new power source rather than an existing one such as the SNAP 19 was based on weight, size, and complexity considerations. Many multiples of the SNAP 19 generator, which has a nominal rating of 30 watts, would be needed to replace the two MHW-RTGs on each LES 8/9 spacecraft.

7.0 RELATIONSHIP BETWEEN LOCAL SHORT-TERM USE OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

In performing the LES 8/9 program, the only portion of the P74-1 Project with the potential for significant long-term environmental effects, the Air Force would be attempting to develop a new military communications system. Possible benefits to long-term productivity from such a system are difficult to quantify, other than to identify the general contribution to an enhanced capability for national defense; this capability, in turn, is designed to deter possibilities of widespread military conflicts. The possible adverse environmental effects have been quantitatively assessed, however, and have been shown to be very minor or avoidable.

As discussed in Section 4.2, the possible short-term effects on man's environment involve several very small risks related to the launch and ascent of the P74-1 payload. These risks consist of very small probabilities (0.0001 and less) of causing human injuries or fatalities from accidentally reentering payload components, or of causing small numbers of persons to receive excessive exposures to toxic compounds of beryllium or radioactive plutonium. These short-term effects are far too small to have any significant deleterious effect on long-term productivity.

As discussed in Section 4.3, if reentry of the RTGs occurs before 1,000,000 years (a possibility that cannot be dismissed), there would be a potential for radioactive contamination of localized areas of the environment. The effects of such an occurrence on long-term productivity are impossible to assess. However, such effects can be considered avoidable because the United States is currently developing the capability, through the Space Transportation System program, to recover orbital payloads. This capability could be used to alleviate any such potential hazards if future information indicates the desirability of such an action.

8.0 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

For the P74-1 mission, the materials incorporated in the payload are essentially irretrievable once the final orbit has been achieved except as future use may be made of potential Space Transportation System-type retrieval systems. For most of the materials used, replacement is relatively easy and, in general, they are replaceable from domestic resources with relatively insignificant expenditure of manpower, energy, or capital. Two items of possible significance, iridium and plutonium-238, of the LES 8/9 RTGs, are considered in detail below, since considerable quantities of both materials are used relative to available supply.

Although the operational system at which the LES 8/9 experiment is directed is not directly the subject of this Environmental Statement, some consideration will be given to this possible eventuality. Maximum amounts of use can be predicted for both iridium and plutonium-238 based on present designs for the MHW-RTG units being contemplated. However, as technology development continues, new nuclear power system designs will be considered and the replacement of iridium and plutonium-238 by other materials should not be unexpected.

As mentioned, it is conceivable that the components of the LES 8/9 system (and those of any operational system, as well) could be retrieved at some future time through a manned space mission. This action could accomplish two functions: eliminate potential future environmental hazards from the plutonium content (and radioactive decay products), and retrieve valuable resources (iridium). Although this action is not being planned for the present, future consideration may be given to this possibility.

8.1 IRIDIUM

The amount of iridium contained in the MHW-RTG is approximately 4.58 kg (about 150 troy ounces). Since four RTGs are proposed to be launched, a total of 18.32 kg (about 600 troy ounces) of iridium may not be recoverable. The individual weights of the RTG iridium components are given in Table 7 (Reference 49).

It is estimated that an additional 5.3 kg (170 troy ounces) of iridium may be lost through normal operations, refining, testing, etc. The basis for this estimate is given in Table 8 (Reference 49).

Thus, approximately 23.62 kg (770 troy ounces) of iridium may not be recoverable as a result of the LES 8/9 launch. Based on 1970 data and projections of cost to the year 2000, it is expected that the dollar value of iridium will be approximately $200 per troy ounce ($6,540 per kg) (Reference 50). Based on these figures, approximately $154,000 worth of iridium would be irreversibly committed to this program. Due to the widely fluctuating market in the platinum metals, the "value" associated with iridium may vary widely. For example, in 1972, the range was from $145 to $525 per troy ounce (dealer prices) (Reference 51).

Indicated world reserves of platinum-group metals are estimated conservatively as 424 million troy ounces (1.32×10^7 kg) (Reference 50) of which approximately 2 percent or 8.5 million troy ounces (2.6×10^5 kg) would be iridium. The majority of this reserve is located in the U.S.S.R. and the Republic of South Africa. The amount of iridium which would be lost in the LES 8/9 mission is thus 0.000091 percent of the indicated world reserves, which does not include undiscovered new sources of the platinum metals. In addition, essentially all platinum metals are recycled in domestic use and the percentage of loss is very small. This means that the total supply available does not appreciably decrease with time as is the case for less precious materials which are not reclaimed. The United States maintains a strategic stockpile of the platinum-group metals and as of 1972 had an inventory of 17 thousand troy ounces (5.3×10^2 kg) of iridium available (Reference 52). The amount of iridium lost in the LES 8/9 mission would represent 0.045 percent of the stockpile and this amount could easily be replaced from the world supply through current sources.

TABLE 7. MHW RTG IRIDIUM COMPONENT WEIGHTS (Reference 49)

Post Impact Containment Shell (PICS)			
2 Hemishells @ 34.000 g each	=	68.000 g	
2 Frit Vents @ 0.746 g each	=	1.492 g	
2 Retainers @ 0.227 g each	=	0.454 g	
1 Weld Band @ 2.390 g	=	2.390 g	
Total		72.336 g	
24 x 72.336 g	=		1736.064 g
Outer Clad Cylinder	=		1945.911 g
Bottom Lid	=		421.841 g
Top Lid	=		427.738 g
Pressure Relief Device and Tubing	=		52.618 g
Total	=		4584.172 g
	=		147.4 troy ounces

TABLE 8. IRIDIUM LOST THROUGH NORMAL OPERATIONS (Reference 49)

Process	Iridium, troy ounces	Estimated Loss, percent	Loss troy ounces
Manufacturing, testing	7000	2	140
Refining	1000	2	20
Decontamination	300	3	9
Total			169

8.2 PLUTONIUM-238

The amount of plutonium-238 oxide contained in the MHW RTG is 6.05 kg (13.3 lb) (Reference 4). Since four RTGs are proposed to be launched, a total of 24.2 kg (53.2 lb) of plutonium oxide may not be recoverable. The individual weights of the RTG plutonium components are given in Table 9 (Reference 4).

The element plutonium is essentially synthetic and plutonium-238 is produced by the neutron irradiation of neptunium-237, which in turn is produced by successive neutron captures in the chain starting with uranium-235 and/or uranium-238. Thus, plutonium-238 can be produced in practically any quantity desired by neutron irradiation in power or research reactors. Neptunium-237 can be obtained from the waste streams of the fuel reprocessing plants and is a by-product from normal reactor operations. Thus, although the launching of a large inventory of plutonium-238 represents a commitment of resources in the sense that the material may never be recovered, additional plutonium-238 can be manufactured from reactor waste products to replace the lost material. This process can be repeated as long as there is nuclear fuel available for the reactors and, with the advent of breeder reactors, is essentially unlimited as long as the need for the material exists.

8.3 OTHER MATERIALS

The total quantity of other materials in the payload which would be irreversibly and irretrievably committed to the LES 8/9 program are relatively minor and consist primarily of beryllium, steel, aluminum, titanium, iron, molybdenum, plastics, glasses, nickel, chromium, lead, zinc, copper, etc., as well as small quantities of silver, mercury, gold, and platinum. The quantity of materials of various kinds which are utilized are insignificant in comparison with those used in one year of production (10,000,000) of automobiles,

TABLE 9. WEIGHTS OF RTG PLUTONIUM COMPONENTS (Reference 4)

Component	Material	No. Units per RTG	Unit Weight kg (lb)	Total Weight per RTG, kg (lb)	No. of RTG's	Total Weight of PuO_2 for Mission, kg (lb)
RTG Fuel	PuO_2	24	0.252 (0.563)	6.05 (13.3)	4	24.2 (53.2)

for example. The total mass of payload hardware employed in the LES 8/9 program is equivalent to about one automobile.

8.4 OPERATIONAL SYSTEM

The operational system at which the LES 8/9 experiment is directed would have commitments of amounts of resources corresponding to the numbers of satellites which ultimately are used in the operational system.

Future estimates of commitments of resources will depend on modified configurations of components and the satellites themselves as research and development programs lead to improved designs. It is conceivable, for example, that future designs may not utilize iridium and/or plutonium-238 since alternative materials may be developed or found to exist. Thus, it should be expected that future estimates of commitments of resources to the operational system will be lower as design improvements are achieved.

9.0 CONSIDERATIONS THAT OFFSET THE ADVERSE ENVIRONMENTAL EFFECTS

Most of the adverse environmental effects conceivable from implementation of the P74-1 Project and its associated satellite programs would involve the LES 8/9. The potential benefits from the LES 8/9 program derive from its investigations of techniques and concepts which could be utilized to give the United States a military communications system considerably more secure and survivable than current systems. Development of such a communications system would enhance this country's capability to deter widespread military conflicts. As discussed in section 6.0, no alternatives to the LES 8/9 program have been identified which have a greater potential for providing such benefits, and several of these alternatives would probably involve significantly greater adverse environmental effects.

Adverse environmental effects even more minor and improbable would be associated with the SOLRAD program. The potential benefits from this program involve a better capability to predict and understand the performance of space systems dependent upon solar radiation environments. No alternatives have been identified which could provide these benefits with less potential for adverse environmental effects.

10.0 DETAILS OF UNRESOLVED CONTROVERSIES

The purpose of this section is to summarize aspects of this Environmental Statement which might relate to either existing or potential controversies. The details of such aspects are discussed in other sections, as appropriate.

10.1 HEALTH EFFECTS OF PLUTONIUM

Several techniques for relating human health effects, such as long-term induction of lung cancer, to plutonium exposure have recently been advanced. All such techniques rely heavily on considerable extrapolation of animal exposure data and human exposures to other forms of radiation and other radionuclides at much higher doses; plutonium itself has not existed long enough, nor have enough humans been exposed to have developed a more applicable data base. In view of the uncertainties involved and the very small risks associated with the P74-1 Project in any case, the older technique of evaluating plutonium exposures by comparisons to reference lung burdens derived from recommended dose standards has been retained in this Environmental Statement. Further details associated with this question are contained in Section 3.2.4. and Appendix B. J-8

10.2 GROUND TRANSPORTATION OF RTG's AND HEAT SOURCES

As discussed in Section 2.6, the plutonium-fueled RTG's or their heat sources will be transported by special truck on public highways several times before their launch into space. Such transportation may cause some public concern. However, as explained in Appendixes C and D, safety analyses of this ground transportation have verified that the RTGs and their heat sources, which are designed to withstand the very severe accident environments associated with launch and ascent, would easily prevent plutonium release during any ground transportation accidents. In addition, all such ground transportation will be performed by specially monitored and controlled ERDA couriers and equipment.

REFERENCES

(1) Draft Environmental Statement, U.S. Air Force Space Launch Vehicles, August, 1973.

(2) LES 8/9 Nuclear Safety Evaluation Report (June 1975)

(3) General Electric Space Division, Final Safety Analysis Report (FSAR), GEMS-419 (March 1975)

(4) General Electric Preliminary Safety Analysis Report (PSAR) Document No. GESP-7075 GEMS-407, July, 1972.

(5) Security Operating Plan for Protection of Special Nuclear Material at Massachusetts Institute of Technology, Lincoln Laboratory, Lexington, Massachusetts (January 8, 1975)

(6) Security Plan for the Handling, Storage, and Launch of MHW Radioisotope Thermoelectric Generators at the AFETR, Florida for the LES 8/9 (February 7, 1975)

(7) Air Force Eastern Test Range Safety Operating Plans, Ionizing Radiation and Nuclear and Toxic Material, November, 1974.

(8) U.S. AEC Manual Chapter 0526, Albuquerque Operations Office, Appendix, Annex A, August 25, 1971.

(9) Handbook of Chemistry and Physics, 42nd Ed., 1960-61.

(10) Goldschmidt, V. M., Geochemistry, Oxford Univ. Press, 1954.

(11) Bertine, K. K., and Goldberg, E. D., "Fossil Fuel Combustion and the Major Sedimentary Cycle", Science 173 (July 16, 1971).

(12) Hill, M. N. (Ed.), The Sea, Vol. 2, Interscience Publishers, 1963.

(13) Cholak, J., "The Analysis of Traces of Beryllium," Archives of Industrial Health, 19, 205-210 (1959)

(14) Federal Register, 36, No. 84, 8186-8201, April 30, 1971.

(15) Anon., "Occupational Exposure to Beryllium", U.S. Dept. of Health, Education, and Welfare, National Institute for Occupational Safety and Health, HSM 72-10268 (1972).

(16) Federal Register, 36, No. 105, 10505, May 29, 1971.

(17) Federal Register, 36, No. 234, 23243-23244, Dec. 7, 1971.

(18) Federal Register, 38, No. 66, 8820-8850, Apr 6, 1973.

(19) Hardy, E. P., et al., Nature, Vol. 241, No. 5390, Feb. 16, 1973.

(20) HASL-250, "Global Inventory and Distribution of Pu-238 from SNAP 9A", Hardy, E. P., Krey, P. W., and Volchok, H. L., March 1, 1972, USAEC, Washington, D.C.

(21) HASL-281, "Fallout Program Quarterly Summary Report", December 1973-March 1974, USAEC (April 1974).

(22) HASL-278, "Fallout Program Quarterly Summary Report", September-December 1973, USAEC (January 1974).

(23) ICRP Task Group on Lung Dynamics, "Deposition and Retention Models for Internal Dosimetry of the Human Respiratory Tract", Health Physics 12, 173 (1966).

(24) LA-4875, "Plutonium in Autopsy Tissues", Campbell, E. E., et al., USAEC (1973).

(25) Magno, P. J., et al., Health Physics 13, 1325 (1967).

(26) Tamplin, A. R., and Cochran, T. B., A Report on the Inadequacy of Existing Radiation Protection Standards Related to Internal Exposure of Man to Insoluble Particulates of Plutonium and Other Alpha-Emitting Hot Particles, National Resources Defense Council (February 1974).

(27) U.S. Atomic Energy Commission, Proposed Final Environment Statement Liquid Metal Fast Breeder Reactor Program, WASH-1535 (December 1974).

(28) Bair, W. J., "Toxicology of Plutonium" in Advances in Radiation Biology, Vol. 4, Lett, J. J., et al, Editors, Academic Press, 1974.

(29) Bair, W. J., et al., "A Radiobiological Assessment of the Spatial Distribution of Radiation Dose from Inhaled Plutonium", USAEC Report WASH-1320, September 1974.

(30) Bair, W. J., and R. C. Thompson, "Plutonium: Biomedical Research", Science 183, 715-722 (1974).

(31) Hempelmann, L. H., et al., "A Twenty-Seven Year Study of Selected Los Alamos Plutonium Workers", USAEC Report LA-5148-MS, January 1973.

(32) National Academy of Sciences--National Research Council, The Effects on Populations of Exposure to Low Levels of Ionizing Radiation (BEIR Report) (November 1972).

(33) NCRP Report No. 43, Review of the Current State of Radiation Protection Philosophy, National Council on Radiation Protection and Measurement (NCRP) (January 15, 1975)

(34) U.S. Environmental Protection Agency, Proceedings of Public Hearings: Plutonium and the Other Transuranium Elements, Vols I-III.

(35) ICRP Publication 2. Report of Committee II on Permissible Dose for Internal Radiation, Pergamon Press, 1959.

(36) "Satellite Situation Report", Vol. 13, No. 11, Office of Public Affairs, GSFC (November 30, 1973).

(37) "TRW Space Log", Vol. 10 (1971).

(38) "TRW Space Log", Vol. 11 (1972).

(39) U.S. Atomic Energy Commission, DRAFT-Reactor Safety Study--An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants, WASH-1400 (August 1974).

(40) Conway, T. W., Potential Beryllium Release Consequences of LES 8/9 Launch Aborts, NUS Corporation, NUS-1257 (August 1974).

(41) Parsont, M. A., et al., Environmental and Demographic Data Summary for the Cape Kennedy, Florida Vicinity, NUS Corporation, NUS-793 (June 1971).

(42) General Electric Space Division, Bi-Monthly Progress Report, MHW RTG Program (March 1, 1973 to April 30, 1973).

(43) Drago, V. J., and Edgecombe, D. S., A Review of NASA Orbital Decay Reentry Debris Hazard, Battelle Columbus Laboratories, BMI-NLVP-TM-74-1 (March 1974).

(44) Perini, L. L., Orbital Lifetime Estimates, Johns Hopkins University--Applied Physics Laboratory, ANSP-M-8 (February 1974).

(45) Ash, M. E., Doubly Averaged Effect of the Moon and the Sun on a High Altitude Earth Satellite Orbit, Lincoln Laboratory, Technical Note 1974-5 (March 1974).

(46) Haymes, R. C., Introduction to Space Science (Addison-Wesley, 1971).

(47) Yardley, J., "Testimony Before House Subcommittee on Space Science and Applications, Committee on Science and Technology," (February 1975)

(48) Space Shuttle, System Summary, Rockwell International, SSV74-32(R) (May 1975)

(49) Information supplied by the United States Atomic Energy Commission, Heat Source Branch.

(50) U.S. Dept. of the Interior, Bureau of Mines, Mineral Facts and Problems, Platinum Group Metals, 1970 edition, Bulletin 650, Washington, D.C.

(51) U.S. Dept. of the Interior, Bureau of Mines, Mineral Industry Surveys, Platinum-Group Metals in 1972, Dec. 27, 1972, Washington, D.C.

(52) U.S. Dept. of the Interior, Bureau of Mines, Commodity Data Summaries, January, 1973, Washington, D.C.

(53) USAEC, "Management of Commercial High Level and Transuranium-Contaminated Radioactive Waste", WASH-1539 (September 1974).

(54) Petition to Amend Radiation Protection Standards As They Apply to Hot Particles, National Resources Defense Council, February 14, 1974.

(55) Safety Analysis Report For Packaging (SARP); Multi-Hundred Watt Isotope Heat Source Shipping Container (MHW IHS SC), Mound Laboratory, Report No. MLM 074 (June, 1974).

(56) Safety Analysis Report for Packaging (SARP); Multi-Hundred Watt Radioisotope Thermoelectric Generator (MHW RTG) Shipping Container, General Electric, GEMS-408, Rev. B (February, 1975).

(57) U.S. Atomic Energy Commission, Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants, WASH-1238 (December 1972)

(58) Selby, J. M., et al., Considerations In the Assessment of the Consequences of Effluents From Mixed Oxide Fuel Fabrication Plants, Battelle Pacific Northwest Laboratories, BNWL-1697 (June 1973).

(59) Recommendations of the International Commission on Radiological Protection (Adopted September 17, 1965), ICRP Publication 9.

(60) MCR-72-260, "Titan III-C Failure Modes and Effects Analysis", Martin-Marietta (October 1972).

(61) De Buisson, J. C. and Willard, W., Transtage Orbital Anomaly Probabilities Report, Martin-Marietta Corporation, MCR-73-192, Revision 2.

(62) General Electric Co., Space Division, Safety Test No. S-1, Explosion, GEMS-410, (April 20, 1973) Final Report.

(63) General Electric Co., Space Division, Safety Test No. S-2, Liquid Propellant Fire Thermochemical Effects, GEMS-413, (July, 1973) Final Report.

(64) General Electric Co., Space Division, Safety Test No. S-3, Solid Propellant Fire, GEMS-414, (July, 1973) Final Report.

(65) Snow, E. C., Safety Test No. S-6, Launch Pad Abort Sequential Test, Phase I: Low Velocity HSA Impact, LASL, Report LA-5705-MS, Los Alamos Scientific Laboratory, New Mexico (August, 1974).

(66) Snow, E. C., and Frantz, C. E., Safety Test No. S-6, Launch Pad Abort Sequential Test Phase III: FSA Impacts, LASL, Report LA-5855-MS, Los Alamos Scientific Laboratory, New Mexico (January, 1975).

(67) Knight, D. D., Subsonic Ablation, General Electric Company, GE/PIR No. 4326, Final Test Report (March 29, 1973).

(68) General Electric Company, MHW Heat Source Ablation Test Report, Document No. GESP-7083 (December 7, 1972).

APPENDIX A

GLOSSARY OF TERMS AND ACRONYMS

A.0 APPENDIX A

GLOSSARY OF TERMS AND ACRONYMS

Absorbed dose	When ionizing radiation passes through matter, some of its energy is imparted to the matter. The amount absorbed per unit mass of irradiated material is called the absorbed dose, and is measured in rems and rads.
Absorber	Any material that absorbs or diminishes the intensity of ionizing radiation, e.g. a thin sheet of paper or metal will absorb or attenuate alpha particles and all except the most energetic beta particles.
ACS	Attitude Control System. A set of small thrusters or rocket motors used to control the attitude of and make small changes in the velocity of a rocket vehicle.
AEC	The U. S. Atomic Energy Commission (now ERDA).
AKM	Apogee Kick Motor. A (usually) solid propellant rocket motor fired at the apogee of an orbit to establish a new orbit with a different (usually higher) perigee.
Alpha particle	A positively charged particle emitted by certain radioactive materials, e.g. plutonium 238. It is made up of two neutrons and two protons bound together and is identical with the nucleus of a helium atom. It is the least penetrating of the three common types of radiation (alpha, beta, gamma) emitted by radioactive material, being stopped by a sheet of paper. It is not dangerous to plants, animals or man unless the alpha-emitting substance has entered the body.
Apogee	The point in the orbit of a satellite of the earth at the greatest distance from the center of the earth.

Background radiation	The radiation in man's natural environment, including cosmic rays and radiation from the naturally radioactive elements, both outside and inside the bodies of men and animals. It is also called natural radiation.
Beta particle	An elementary particle emitted from a nucleus during radioactive decay, with a single electrical charge and a mass equal to 1/1837 that of a proton. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron. Beta radiation may cause skin burns, and beta-emitters are harmful if they enter the body. Beta particles are easily stopped by a thin sheet of metal.
Biological dose	The radiation dose absorbed in biological material. Measured in rems.
Biological half-life	The time required for a biological system, such as a man or animal, to eliminate, by natural processes, half the amount of a substance (such as a radioactive material) that has entered it.
Biological shield	A mass of absorbing material placed around a reactor or radioactive source to reduce the radiation to a level that is safe for human beings.
Body burden	The amount of radioactive material present in the body of a man or an animal.
CCAFS	Cape Canaveral Air Force Station
Circularize	The process of changing the trajectory of a body from an elliptical orbit to a circular orbit.
CSDS	Command Shutdown and Destruct System
Curie	The basic unit to describe the intensity of radioactivity in a sample of material. The curie is equal to 37 billion disintegrations per second, which is approximately the rate of decay of 1 gram of radium. A curie is also a quantity of any nuclide having 1 curie of radioactivity. Named for Marie and Pierre Curie, who discovered radium in 1898.
Daughter product	A nuclide formed by the radioactive decay of another nuclide, which in this context is called the parent.

Decay chain	A radioactive series.
Decay heat	The heat produced by the decay of radioactive nuclides.
Decay, radioactive	The spontaneous transformation of one nuclide into a different nuclide or into a different energy state of the same nuclide. The process results in a decrease, with time, of the number of the original radioactive atoms in a sample. It involves the emission from the nucleus of alpha particles, beta particles (or electrons), or gamma rays; or the nuclear capture or ejection of orbital electrons; or fission. Also called radioactive disintegration.
Decontamination	The removal of radioactive contaminants from surfaces.
DoD	U. S. Department of Defense
Dose	See absorbed dose, biological dose, maximum permissible dose, threshold dose.
Dose equivalent product	A term used to express the amount of effective radiation when modifying factors have been considered. The produce of absorbed dose multiplied by a quality factor multiplied by a distribution factor. It is expressed numerically in rems.
Dose rate	The radiation dose delivered per unit time and measured, for instance, in rems per hour.
Ecliptic plane	The plane defined by the Earth's orbit about the Sun.
Equatorial plane	The plane defined by the Earth's equator.
ERDA	Energy Research and Development Administration (formerly AEC).
Fallout	Airborne particles containing radioactive material which fall to the ground following a nuclear event. "Local fallout" falls to the earth's surface within 24 hours. "Tropospheric fallout" consists of material injected into the troposphere but not into the higher altitudes of the stratosphere. It does not fall out locally, but usually is deposited in relatively narrow bands around the earth at about the latitude of injection. "Stratospheric fallout" or worldwide fallout is that which is injected into

	the stratosphere and which then falls out relatively slowly over much of the earth's surface.	
Food chain	The pathways by which any material (such as radioactive materials from fallout) passes from the first absorbing organism through plants and animals to man.	
fps	Feet per Second.	
FRC	Federal Radiation Council.	
FSA	Fuel Sphere Assembly.	
Geostationary	Stationary with respect to a point on the earth's surface. Generally applied to synchronous equatorial circular orbits.	
GIS	Graphite Impact Shell	J-7
Half-life	The time in which half the atoms of a particular radioactive substance disintegrate to another nuclear form. Measured half-lives vary from millionths of a second to billions of years.	
Half-life, biological	See biological half-life.	
Half-life, effective	The time required for a radionuclide contained in a biological system, such as a man or an animal, to reduce its activity by half as a combined result of radioactive decay and biological elimination.	
HASL	Health and Safety Laboratory (ERDA)	
HSA	Heat Source Assembly	J-7
ICRP	International Commission on Radiological Protection.	
IIP	Instantaneous Impact Point.	
INSRP	Interagency Nuclear Safety Review Panel	
Instantaneous impact point	The point on the earth's surface where a rocket vehicle would impact if all thrust were terminated and the vehicle subsequently followed a ballistic trajectory. Because the impact point changes continuously with time during powered flight, each	

	instant of time has its own impact point. The locus of all the impact points is called the trace of the IIP
Intensity	The energy or the number of photons or particles of any radiation incident upon a unit area or flowing through a unit of solid material per unit of time. In connection with radioactivity, the number of atoms disintegrating per unit of time.
Ion	An atom or molecule that has lost or gained one or more electrons. By this ionization it becomes electrically charged. Examples: an alpha particle, which is a helium atom minus two electrons.
Ionizing radiation	Any radiation displacing electrons from atoms or molecules, thereby producing ions.
Irradiation	Exposure to radiation
ISDS	Inadvertent Separation and Destruct System
Isotope	One of two or more atoms with the same atomic number (the same chemical element) but with different atomic weights. Thus plutonium 238 and plutonium 239 are isotopes of the element plutonium with the 238 and 239 denoting the differing mass numbers or approximate atomic weight. Isotopes usually have very nearly the same chemical properties, but somewhat different physical properties.
K-Band	As defined by the Joint Chiefs of Staff in 1971, that band of radio frequencies between 20×10^9 Hz and 40×10^9 Hz.
Kg	Kilogram = 2.2 pounds.
LES	Lincoln Experimental Satellite
Lethal dose	A dose of ionizing radiation sufficient to cause death. Median lethal dose (MLD or LD-50) is the dose required to kill within a specified period of time (usually 30 days) half of the individuals in a large group of organisms similarly exposed. The LD-50/30 for man is about 400-450 roentgens.

Maximum permissible concentration, MPC	The amount of radioactive material in air, water, or food which might be expected to result in a maximum permissible dose to persons consuming them at a standard rate of intake. An obsolescent term.
Maximum permissible dose, MPD	That dose of ionizing radiation established by competent authorities as an amount below which there is no reasonable expectation of risk to human health, and which at the same time is somewhat below the lowest level at which a definite hazard is believed to exist. An obsolescent term.
MHW	Multi-hundred watt
MRC	British Medical Research Council
NASA	National Aeronautics and Space Administration
NCRP	National Council on Radiation Protection and Measurement
NSC	National Security Council
Parent	A radionuclide that upon radioactive decay or disintegration yields a specific nuclide (the daughter) either directly or as a later member of a radioactive series.
Payload	The equipment placed in orbit or on a trajectory which serves a useful purpose, excluding launch vehicle parts, shrouds, adapters, etc., having no further mission function. Generally synonymous with spacecraft.
PICS	Post-Impact Containment Shell
PPO	Pressed Plutonium Oxide
Perigee	The point in the orbit of a satellite of the earth that is nearest to the center of the earth.
PKM	Perigee Kick Motor. A (usually) solid propellant rocket motor fired at the perigee of an orbit to establish a new orbit with a different (usually higher) apogee.
psi	Pounds per square inch

Quality factor	The factor by which absorbed dose is to be multiplied to obtain a quantity that expresses on a common scale, for all ionizing radiations, the irradiation incurred by exposed persons.
Rad	(Acronym for Radiation Absorbed Dose). The basic unit of absorbed dose of ionizing radiation. A dose of one rad means the absorption of 100 ergs of radiation energy per gram of absorbing material.
Radiation protection guide	The officially determined radiation doses which should not be exceeded without careful consideration of the reasons for doing so. These standards, established by the Federal Radiation Council (FRC), are equivalent to what was formerly called the maximum permissible dose or maximum permissible exposure.
Radiation source	Usually a man-made, sealed source of radioactivity. A radioisotopic thermoelectric generator (RTG) may be considered a source.
Radiation standards	Exposure standards, permissible concentrations, rules for safe handling, regulations for transportation, regulations for industrial control of radiation, and control of radiation exposure by legislative means.
Radioactive series	A succession of nuclides, each of which transforms by radioactive disintegration into the next until a stable nuclide results. The first member is called the parent, the intermediate members are called daughters, and the final stable member is called the end product.
Radioisotopic generator	A small power generator that converts the heat released during radioactive decay directly into electricity. These generators can produce only a few watts up to several hundred watts (MHW) of electricity and use thermoelectric or thermionic converters.

Rem	(Acronym for Roentgen Equivalent Man.) The unit of dose of any ionizing radiation which produces the same biological effect as a unit of absorbed dose of ordinary X-rays. The Relative Biological Effectiveness (RBE) dose (in rems) = RBE x absorbed dose (in rads).
Relative biological effectiveness, RBE	A factor used to compare the biological effectiveness of different types of ionizing radiation. It is the inverse ratio of the amount of absorbed radiation, required to produce a given effect, to a standard (or reference) radiation required to produce the same effect.
Roentgen	A unit of exposure to ionizing radiation. It is that amount of gamma or X-rays required to produce ions carrying 1 electrostatic unit of electrical charge (either positive or negative) in 1 cubic centimeter of dry air under standard conditions. Named after Wilhelm Roentgen who discovered X-rays in 1895.
RTG	Radioisotopic Thermoelectric Generator
SAR	Safety Analysis Report
SER	Safety Evaluation Report
SNAP	(Acronym for Systems for Nuclear Auxiliary Power.) An AEC program to develop small auxiliary nuclear power sources for specialized space, land, and sea uses. One approach used heat from radioisotope decay to produce electricity directly by thermoelectric methods.
SOLRAD	Navy satellites for monitoring of solar electromagnetic and particulate radiation emissions.
SRM	Solid Rocket Motor. A rocket motor consisting of a chamber (case) containing a solid propellant and an attached nozzle. Distinguished from liquid (propellant) rocket motors or hybrid (propellant) rocket motors.

Sub-vehicle Point	The point on the earth's surface vertically below the instantaneous position of a rocket vehicle.
Synchronous Altitude	The altitude of a circular synchronous orbit, about 22,300 miles.
Synchronous orbit	An orbit with a period equal to the earth's rotational period, 24 hrs, such that a body in synchronous orbit returns to a fixed relationship with a point on earth one or more times each 24 hrs.
Thermocouple	A device consisting essentially of two conductors made of different metals, joined at both ends, producing a loop in which an electric current will flow when there is a difference in temperature between the two junctions.
Thermoelectric conversion	The conversion of heat into electricity by the use of thermocouples.
Threshold dose, threshold limit value (TLV)	The minimum dose of radiation that will produce a detectable biological effect.
Transfer orbit	An orbit, generally elliptical, connecting two other orbits and representing the trajectory by which a body can be transferred from one orbit to the other.
Trajectory	The path followed by a body moving in space.
UHF	Ultra High Frequency. That band of radio frequencies between 3×10^8 Hz and 3×10^9 Hz.

NUMERICAL ABBREVIATIONS

Numerical abbreviations used in nuclear science are likely to be composed of two elements: first, an abbreviation of a numerical prefix expressing some multiple or fraction of unity, and second, an abbreviation of a unit which measures some basic property. Examples of both elements are:

Prefixes

Prefix	Meaning
pico	divide by 1 trillion (10^{-12})
nano	divide by 1 billion (10^{-9})
micro	divide by 1 million (10^{-6})
milli	divide by 1 thousand (10^{-3})
kilo	multiply by 1 thousand (10^{3})
mega	multiply by 1 million (10^{6})
giga	multiply by 1 billion (10^{9})

Units

Unit	Abbreviation	Measured Property
curie	Ci	radioactivity
gram	g	mass
meter	m	length
rad	rad	radiation absorbed dose
roentgen	r	radiation dose
rem	rem	radiation dose
second	sec or s	time
watt	w	power

CONVERSION FACTORS

Multiply	by	To Get
centimeters	0.3937	inches
centimeters	0.01	meters
centimeters	10	millimeters
feet	30.48	centimeters
feet	12	inches
feet	0.3048	meters
feet	1.645×10^{-4}	nautical miles
feet per second	30.48	centimeters per second
feet per second	1.097	kilometers per hour
feet per second	0.6818	miles per hour
grams	10^{-3}	kilograms
grams	0.03527	ounces (av)
grams	0.03215	ounces (troy)
grams	2.2046×10^{-3}	pounds
inches	2.54	centimeters
kilograms	10^{3}	grams
kilograms	2.2046	pounds
kilometers	10^{3}	meters
kilometers	3281	feet
kilometers	0.6214	miles
meters	100	centimeters
meters	3.2808	feet
meters	10^{-3}	kilometers
meters	5.396×10^{-6}	nautical miles
meters per second	3.2808	feet per second
meters per second	2.237	miles per hour
miles	1.609×10^{5}	centimeters
miles	5280	feet
miles	1.609	kilometers
miles (nautical)	1853.2	kilometers
miles (nautical)	1.1516	miles (statute)
miles per hour	1.609	kilometers per hour
ounces (av)	28.35	grams
ounces (av)	0.0625	pounds
ounces (av)	0.9115	ounces (troy)
ounces (troy)	31.10	grams
ounces (troy)	0.0833	pounds (troy)

APPENDIX B

PLUTONIUM EXPOSURE STANDARDS AND BIOLOGICAL EFFECTS MODELS

B.0 APPENDIX B

PLUTONIUM EXPOSURE STANDARDS AND BIOLOGICAL EFFECTS MODELS

Over the last several years, controversies have developed relating to the adequacy of representing the hazards from plutonium inhalation by comparing such exposures to the standards discussed in Section 3.2.4 of this Statement. The two main themes of these controversies have involved: (1) the possibility that very small radiation doses, smaller than those corresponding to existing standards, may cause increased incidences of long-term health effects and (2) the possibility that small particles of alpha-emitting radionuclides (such as those that might accidentally be released as a result of the P74-1 mission) present a uniquely severe hazard not properly allowed for by existing standards. The purpose of this Appendix is to present, primarily by extracting from relevant publications, some of the background information relevant to these issues.

B.1 The Need for Radiation Standards

The following information has been extracted from Reference 53:

"Most substances can be divided chemically into more fundamental substances called elements. The smallest particle into which any substance can be divided physically, without changing its chemical properties, is called a molecule. The smallest particle into which an element can be divided physically is an atom. A common example of these terms is ordinary water, which is made up of molecules each consisting of two atoms of the element hydrogen and one atom of the element oxygen.

"Certain atoms (some natural, some man-made) are unstable and become stable by ejecting subatomic particles and energy from their centers, or nuclei. This phenomenon is called radioactive decay, and the atoms which exhibit it are radioactive. Radionuclide is a collective term for all the radioactive atoms which have exactly the same original composition of subatomic particles in their nuclei; there are several hundred different radionuclides, although many are so rare as to be essentially laboratory curiosities.

"The subatomic particles and rays of energy which are ejected from decaying radionuclides usually have the property, directly or indirectly, of turning atoms in their paths into electrically charged particles called ions. This phenomenon is called ionization and the types of radiation which can produce it are called ionizing radiation.

> "The fact that ionizing radiations from radioactive materials and from X-ray machines could be biologically hazardous was recognized very shortly after the first scientific identification of these two radiation sources in the 1890s. By the time the Manhattan Project, U. S. Army Corps of Engineers, was organized in the early 1940s to produce nuclear weapons, there were already well-established primary standards for occupational radiation exposure. Thus, the need of the Manhattan Project was not to develop new radiation standards so much as to apply the existing standards to new activities involving a much greater scale of effort. The needs for new applications of the standards have continued to the present with the growth of peaceful applications of nuclear energy."

B.2 Standards-Generating Organizations

M-4

B.2.1 International Commission on Radiological Protection

The basic responsibility for providing guidance in matters of radiation safety has been assumed by the International Commission on Radiological Protection (ICRP). This organization was established in 1928 by the Second International Congress of Radiology as the International X-ray and Radium Protection Commission. At that time and for many years afterward, its main concern was with the safety aspects of medical radiology. Its interests in radiation protection expanded with the widespread use of radiation outside the sphere of medicine, and in 1950 its name was changed to the ICRP in order to more accurately describe its areas of interest. In describing its operating philosophy, the ICRP says that "The policy adopted by the Commission in preparing recommendations is to deal with the basic principles of radiation protection and to leave to the various national protection committees the responsibility of introducing the detailed technical regulations, recommendations, or codes of practice best suited to the needs of their individual countries."

B.2.2 National Committee of Radiation Protection and Measurements

In accordance with the policy laid down by the ICRP, its recommendations are adapted to the needs and conditions in the various countries by national bodies. In the United States, there have been two such bodies. The older one is called the National Committee on Radiation Protection and Measurements (NCRP). This committee, which was originally known as the Advisory Committee on X-ray and Radium Protection (founded in 1929), consists of a group of technical experts who are specialists in radiation protection and scientists who are experts in the disciplines which form the basis for radiation protection. The concern of the NCRP is only with the scientific and technical aspects of radiation protection. It should be emphasized that the NCRP is not an official government agency, despite the fact that its recommendations are published by the U. S. Government. However, its recommendations are very often adopted by Federal, state, and local government agencies that are concerned with the regulation of radiation hazards.

B.2.3 Federal Radiation Council

The second national body that has dealt with radiation protection guides was the Federal Radiation Council, the functions of which were transferred to the Environmental Protection Agency in 1970. An official United States government agency, it was formed in 1959 to guide the government in the formulation of Federal policy on human radiation exposure. One of its major functions was to "advise the President with respect to radiation matters directly or indirectly affecting health, including guidance for all Federal agencies in the formation of radiation standards and in the establishment and execution of programs of cooperation with the states". The FRC relied heavily on the technical recommendations of the NCRP. However, the FRC weighed non-scientific aspects of radiation exposure, such as political, military, economic, and social considerations as well as the strictly technical and scientific considerations in making risk versus benefit evaluations.

B.2.4 Environmental Protection Agency

The Environmental Protection Agency (EPA) was vested with the responsibility for establishing environmental radiation standards through the transfer of authorities to the EPA from the Atomic Energy Commission and the former Federal Radiation Council by the President's Reorganization Plan No. 3 of 1970. The EPA's role, for example, is complementary to the responsibilities recently transferred from the AEC to the Nuclear Regulatory Commission, which are focused on the detailed regulation of individual facilities within the standards established by EPA, whereas EPA must address public health and environmental concerns taken as a whole.

B.3 Basic Radiation Safety Standards

The following information has been extracted from Reference 53:

"The basic radiation safety standards of the ICRP, NCRP, FRC, and the International Atomic Energy Agency (IAEA) are all very similar. To avoid duplication, only one will be summarized here. Excerpts from the IAEA model regulatory code pertinent to radiation exposure received by members of the public are shown below; AEC explanatory comments are in brackets.

"'Dose Limits for Individual Members of the Public

"'In any organ or tissue, the total dose shall comprise doses contributed by external sources and doses resulting from the intake of radioactive material.

"'The annual dose limits for individual members of the public are listed below:

> "["Dose" as used here is by extension of its medical sense of a measured quantity of something received by the body. The common dictionary sense that the measured quantity is of something beneficial is not intended. When considering future dose which is considered unavoidable, for example, from material already deposited within the body, the related term "dose commitment" is now used.]

"'Organ	Limit per year (rem)
Whole body, gonads, red bone marrow	0.5
Any single organ, excluding the red bone marrow, gonads, bone, thyroid and skin	1.5
Bone, thyroid[a], skin of the whole body (excluding the skin of the hands, forearms, feet and ankles)	3.0
Hands, forearms, feet and ankles	7.5

[a] The exposure of the thyroid of children below the age of 16 shall be limited to 1.5 rem/year

> "[A rem (an acronym for "roetgen-equivalent-man") is the amount of any type of radiation which has the same biological effect as one roentgen (the traditional basic unit) of x-ray radiation. The annual natural background radiation exposure in different parts of the United States varies from about 0.1 rem to about 0.25 rem.]

"'<u>Dose Limits for the Whole Population</u>

"'The genetic dose to the whole population over a period of 30 years shall be kept to the minimum amount consistent with the necessity and shall not exceed 5 rem. Any allocation of the genetic dose, from whatever source, among the various sections of the population will depend on circumstances which may vary from country to country and should, therefore, be decided upon by the competent national authorities.

"'<u>Individual Members of the Public</u>

"'The maximum permissible doses for workers given in Section 3 [in general, 10 times those for individual members of the public] are regarded as upper limits and the doses may have to be individually controlled to ensure that the maximum permissible doses are not exceeded. The dose limitation for members of the public is a more theoretical concept, intended to provide standards for the design and operation of radiation sources so that it is unlikely that individuals among the public will receive more than a specified dose. The effectiveness of this is checked not by observing individuals, but by assessments through sampling procedures in the environment and statistical calculations, and by a control of the sources from which the exposure is expected to arise. For these reasons it is seldom meaningful to speak of maximum permissible doses for individual members of the public, instead the term dose limits should be used.

"'The basis for the limitation of exposures of members of the public is the dose to the various body organs and not the derived criteria by which the dose is controlled. The actual doses received by individuals will vary depending on factors such as differences in their age, size, metabolism, and customs, as well as variations in their environment. The variation resulting from these sources makes it impossible to determine the maximum doses that might be received individually. In practice, it is feasible to take account of these sources of variability by the selection of appropriate critical groups within the population, provided the critical group is small enough to be homogeneous with respect to age, diet,

> and those aspects of behavior that affect the doses received. Such a group should be representative of those individuals in the population expected to receive the highest dose, and the Agency believes that it will be reasonable to apply the appropriate dose limit for members of the public to the mean dose of this group. Because of the innate variability within an apparently homogeneous group, some members of the critical group will receive doses somewhat higher than the dose limit; however, at the very low levels of risk implied, it is likely to be of minor consequence to their health if the dose limit is marginally or even substantially exceeded.'"

B.4 Secondary and Tertiary Standards

The following information has also been extracted from Reference 53:

> "As described above, the primary standards for radiation exposure to people are in units or rems, quantities of radiation (energy) which should not be exceeded. For guidance in cases where the source of the radiation is radioactive material deposited within the body, calculations or estimations have been made for the quantity of each different radioactive material which will result in the permissible exposure to the entire body or to a specific organ of interest. For each radionuclide, this particular quantity is called the "Maximum permissible body burden" (MPBB).
>
> "The MPBB values are useful for planning the protection of workers who must handle, or work near, various inventories of radioactive materials. This usefulness of the MPBB unit is because it may be applied to hazards analyses involving all of the routes of potential deposition within the body -- inhalation, ingestion, absorption through the skin, and injection via contaminated injuries. The last two routes, however, pertain almost entirely to workers and have little or no significance in environmental situations. For consideration in environmental analyses, the secondary standards of MPBB values have been used to calculate still a third (tertiary) standard known as the "maximum permissible concentration" (MPC) or "radioactivity concentration guide" (RCG). The MPC is the concentration of radioactive material in air or water which, if the air or water is consumed continuously, will eventually result in the deposition of exactly one MPBB quantity of radioactive material within the body when biological equilibrium is reached or after 50 years (whichever comes sooner)."

B.5 The Linear Theory of Radiation Effects

At the very low dose levels which might occur from P74-1 Project accidental events, there are no data for either animals or man which can be confidently applied to derive dose-effect relationships. The health effects (e.g., cancers) which might occur would probably be indistinguishable from non-radiation related effects, and their incidence would be so low as to be essentially undetectable against the normal numbers of similar effects. Therefore, although no data exist that such low doses have any effect, the possibility that they might cause some incidence of effects cannot be ruled out either.

Recently, an advisory committee to the National Academy of Sciences, in the report commonly known as the BEIR Report (Reference 32) has derived estimates of increased incidence of various health effects to be expected per man-rem of radiation dose. These were based upon the development of a linear dose-effect relationship based upon human data resulting from relatively high exposures (on the order of 200-500 rem in the case of the lung, due either to external radiation or to the internal deposition of radionuclides other than plutonium) and upon two assumptions: that the dose-effect relationship can be linearly extrapolated to much lower doses and that it intersects the "zero-dose, zero-effect" point.

There is a sharp divergence of opinion on the appropriate use (if any) of such health effects estimations at these very low dose levels. The EPA has stated one position on this question in its comments on this Statement (see Appendix M), from which the following has been extracted: K-5

> "It is the present policy of the Environmental Protection Agency to assume a linear, nonthreshold relationship between the magnitude of the radiation dose received at environmental levels of exposure and ill health produced as a means to estimate the potential health impact of actions it takes in developing radiation protection as expressed in criteria, guides, or standards. This policy is adopted in conformity with the generally accepted assumption that there is some potential ill health attributable to any exposure to ionizing radiation and that the magnitude of this potential ill health is directly proportional to the magnitude of the dose received."

The position recently formulated by the NCRP in Reference 33 is in contrast to the EPA position. The following are two excerpts from Reference 33:

> "The NCRP, after reviewing recent developments relating to radiation standards for the public, particularly in regard

> to extrapolated estimates of cancer risk at low doses and low dose rates, takes the position that no change is required at this time in the conclusions set out in NCRP Report No. 39, issued in 1971. (Consistent with the IAEA guidelines cited above)
>
> "The NCRP position is centered on the principle that the 'lowest practicable' radiation level is the fundamental basis for establishing radiation standards, and on the assumption that the most important radiation health effects do not have a dose threshold. On this basis, the setting of radiation protection standards requires consideration of compensatory trade-offs between currently assumed hazards and benefits.
>
> "At such low radiation levels as are involved in the radiation protection standards, identification and quantification of both risks and benefits are so highly uncertain and imprecise at this time that the practice of balancing risks and benefits numerically is not useful to pursue without far more thorough and penetrating exploration."

B.6 "Hot" Particle Effects

As discussed in Section 3.2.4 of this Statement, maximum allowable lung burden standards are derived from maximum allowable lung dose standards by assuming that the dose received from deposited radionuclides is averaged over the entire mass of the lung. This approach is consistent with procedures established by the various standards-generating organizations such as the ICRP and NCRP. However, the assumption that the dose is distributed throughout the lung has always been recognized as a gross approximation made in the lack of data indicating a more appropriate or meaningful method.

In particular, the radiation dose received from alpha-emitting particulates (or "hot particles") is concentrated in a very small amount of tissue around the radioactive material because of the very short range of alpha particles in tissue. Thus, the dose to these small amounts of tissue alone is much higher than that calculated if the dose is averaged over the entire lung mass.

In a proposal to drastically reduce certain plutonium standards, the National Resources Defense Council (NRDC) has asserted its belief that such exposure conditions can represent a carcinogenic risk orders of magnitude greater than would be presented by the same total dose distributed throughout the lung (Reference 26). This contention is primarily based upon:

a. data derived from experiments which investigated skin cancer induction in rats from localized and diffuse doses.

b. a single human puncture wound exposure situation.

c. a hypothesis relating these data to lung cancer induction.

From these data, the NRDC derived a numerical risk of 1 cancer per 2000 "hot particles" deposited in lung parenchyma, a "hot particle" containing at least a specified amount of alpha-emitting radioactivity. For comparison, the risk of lung cancer induction was derived for the existing standards based on the linear dose-effect relationship discussed in Section B.5 above. Then, invoking the principle that the standards for "hot particle" and uniform dose exposures should reflect approximately equal risks, the NRDC petitioned the EPA and the regulatory arm of the AEC (now the NRC) to reduce plutonium standards by a factor of 115,000 where particles containing an activity equal to or greater than 0.07 picocuries per particle are involved. More recently, the NRDC has revised this value to 0.14 picocuries per particle.

As the P74-1 (LES 8/9) Environmental Statement was being prepared, no official action had been taken on the NRDC petition. However, the AEC has released a study (Reference 29) which surveyed data and theoretical considerations relevant to the "hot particle" problem. The conclusion of this report was ". . . that the nonuniform dose distribution of plutonium particles in the lung is not more hazardous and may well be less hazardous than if the plutonium were uniformly distributed and that the mean dose lung model is a radiobiologically sound basis for establishment of plutonium standards." (Reference 29).

This issue has also been studied by other organizations: the Los Alamos Scientific Laboratory, the National Council on Radiation Protection and Measurements, the National Radiological Protection Board of the United Kingdom, the Medical Research Council of the United Kingdom, and a subgroup of the Biophysical Society. Each of these professional organizations rejects the "hot particle" hypothesis tendered by the NRDC. The National Academy of Sciences is also addressing this issue at the request of the EPA and ERDA, but it will be some time before their report is completed.

APPENDIX C

NUCLEAR SAFETY ANALYSIS SUMMARY

C.0 APPENDIX C

NUCLEAR SAFETY ANALYSIS SUMMARY

Because of the toxic properties and large amounts of plutonium used in the MHW-RTGs, a set of three comprehensive nuclear safety analyses and a wide variety of safety tests were conducted to study the possibility of releasing plutonium to the environment. These analyses and tests investigated the nuclear power systems' responses to all normal and accidental environments to which they might be exposed. The purpose of this Appendix is to briefly describe the methodology used in these safety analyses and to summarize their results. The results of the safety tests are summarized in Appendix D.

C.1 GROUND TRANSPORTATION SAFETY ANALYSES

Two of the three safety analyses addressed the ground transportation of the plutonium. The first was concerned with the transit of the MHW heat sources from Mound Laboratory to General Electric (Reference 55). The second addressed the ground transportation of the MHW-RTGs (Reference 56).

For both modes of transportation, special shipping containers have been designed to safely reject the heat produced by the plutonium and to protect the systems from damage in transportation and handling accidents. In addition to this protection, the heat source or RTG remains the primary plutonium containment structure during ground transportation.

In both safety analyses, the approach taken was similar. ERDA Manual Chapter 0529 specifies a series of four hypothetical accident environments that such packages are to survive. These four environments are:

(1) Impact (simulated by a free drop from 9.15 m (30 feet) onto a flat, unyielding surface).

(2) Puncture (simulated by a free drop from 1.0 m (40 inches) onto a vertical steel bar at least 19.3 cm (8 inches) high and no more than 15.2 cm (6 inches) in diameter).

(3) Fire (simulated by a thermal environment of at least 800 C (1475 F) for at least 30 minutes).

(4) Water immersion (under at least 91.4 cm (3 feet) of water for a period of not less than 8 hours).

The effects of each environment on the package (the shipping container plus the heat source or RTG) are either tested or analyzed.

process described in Section 1.3 of this Statement. The results of these analyses have been documented in References 3 and 4, respectively. After reviewing the Final SAR, the INSRP added some of its own independent assessments in preparing the SER (Reference 2). The various sections below outline the procedures followed in this safety analysis and summarize the results of the Final SAR, as modified by the SER.

C.2.1 Environmental Pathway Analysis

Studies which include evaluations of the behavior of radionuclides released to the environment normally must address a wide variety of environmental pathways to man to insure that no hazards are being overlooked. However, for insoluble forms of plutonium such as the plutonium dioxide fuel of the MHW-RTGs, several studies have clearly demonstrated that the direct inhalation of airborne plutonium dioxide by man is the predominant pathway of interest (References 27, 58). This is caused by the general chemical inactivity and immobility of plutonium dioxide in ecosystems.

Figure 14 illustrates this point. Each pathway in the figure indicates the fraction of plutonium passed on to the next step in the chain. For equal amounts of plutonium, it can readily be seen that direct inhalation of airborne plutonium (the bottom pathway in the picture) is many orders of magnitude more effective than any other pathway in transferring the plutonium to man.

Because of the much greater amounts of the RTGs' plutonium which conceivably could be introduced to water systems than to the atmosphere, this pathway has been investigated. However, experiments on the dissolution rate of the MHW-RTGs' PPO fuel have revealed that, even if all of the available plutonium surface area of all four RTGs was exposed to sea water, the total dissolution rate would be about one curie per year. J-5

Using a set of very conservative assumptions on aquatic diffusion, plutonium uptake by fish (fish concentration ten times water concentration), and human eating habits (30 grams of plutonium-contaminated fish eaten per day, all of the fish caught from the area of localized plutonium contamination), the radiation dose to the critical organ of a man (bone for ingested plutonium) would be only 33×10^{-5} rem/year. This dose is more than a factor of 10^4 less than the general bone dose limit recommended by the ICRP (Reference 59).

Thus, the only environmental pathway considered in the nuclear safety analyses is direct inhalation of plutonium dioxide by man. For such inhalation of insoluble plutonium, the lung is considered the critical organ. Therefore, the standards of interest are the lung burdens described in Section 3.2 of this Statement.

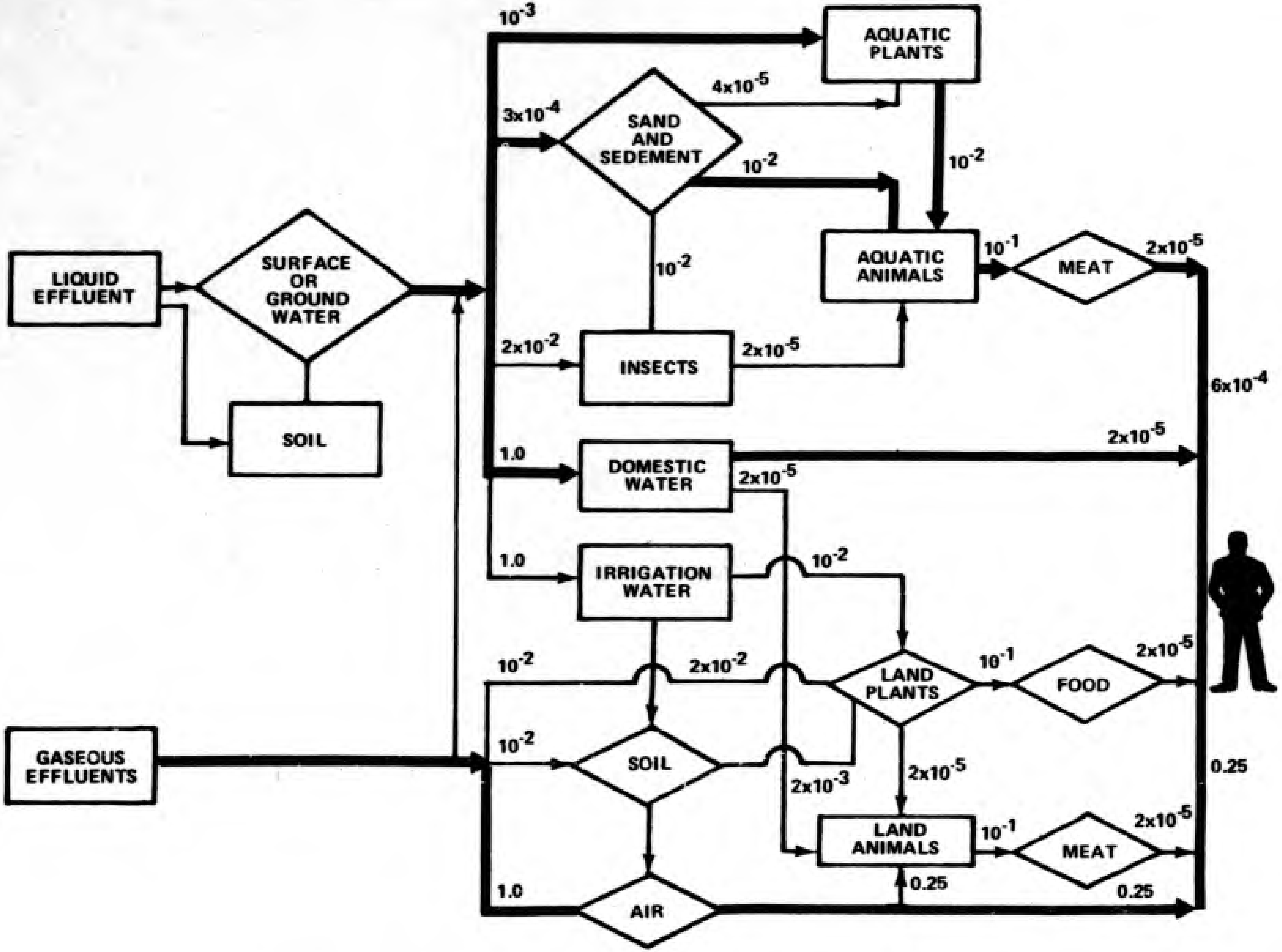

FIGURE 14. TRANSFER FACTORS FOR PLUTONIUM IN THE BIOSPHERE(Ref. 58)

C.2.2 Launch Vehicle Failure Modes and Effect

The first step in the safety analysis was the identification of an exhaustive set of possible launch vehicle malfunctions. Historical component failure rate data and analytical studies were used to associate probabilities with each malfunction. Further, the effect of each malfunction on the launch vehicle was evaluated to determine the resultant sequence of accident environments to which the RTGs might be exposed.

Similar sequences of accident environments were grouped and their probabilities added to arrive at a set of accident environment sequences and probabilities to be used in the later analyses. For the P74-1 Project, this work is documented in References 60 and 61.

Because of the predominance of the inhalation environmental pathway, this identification of accident environments breaks down into two phases: (1) launch-area accidents, where a variety of environments may be produced by the launch vehicle and (2) accidental orbital reentry, where the only environments of interest are atmospheric reentry heating and reentry impact on land. Although accidents can occur after the missile leaves the launch area and before orbital velocity is obtained, virtually all of them would result in the RTGs impacting in the ocean, with insignificant environmental effects.

Table 10 depicts a summary of the range of malfunctions, accident environments, and occurrence probabilities which resulted from this analysis. As described above, the probabilities shown are primarily analytically-derived and would, when summed, yield a total failure probability (2.2. x 10^{-2}) somewhat less than that observed historically. Consequently, the INSRP, in preparing the SER increased these probabilities to reflect a total launch vehicle failure probability of 0.1. I-3

C.2.3 RTG System Responses

After the identification of the accident environment sequences to be addressed, the responses of the MHW-RTG systems to these sequences were investigated. Maximum possible use was made of data generated in the safety tests (see Appendix D). Where test data could not be obtained, theoretical extrapolations and analyses were performed.

The typical environmental sequence considered in the launch-area phase is: overpressure and fireball (from explosion of the Titan), ground impact, and liquid and/or solid propellant residual fires. In some, very improbable, launch-area accident scenarios the sequence becomes: ground impact (of the entire launch vehicle), overpressure and fireball (from the resultant explosion of the Titan), and liquid and/or solid propellant residual fires. The environment sequence considered for accidental orbital reentry is always the same: atmospheric reentry heating and reentry impact on the ground.

TABLE 10. PROBABILITIES OF FAILURE MODES AND FAILURE MODE EFFECTS DURING THE VARIOUS P74-1 MISSION PHASES (Refs. 60, 61)

FAILURE MODE		FAILURE MODE EFFECTS	
TYPE	PROBABILITY	TYPE	PROBABILITY
PRELAUNCH PHASE			
Structural	2.2×10^{-5}	Explosion/Fireball	2.2×10^{-5}
LAUNCH PHASE			
Structural	1.3×10^{-4}	Explosion/Fireball	1.8×10^{-4}
Guidance	1.1×10^{-5}		
Control	4.3×10^{-5}		
ISDS Inadvertant	3.3×10^{-8}		
CSDS Inadvertant	5.0×10^{-9}		
Propulsion	3.2×10^{-5}	Tipover on Pad	3.2×10^{-5}
ASCENT PHASE			
Structural	1.2×10^{-3}	Structural	
Guidance	4.4×10^{-3}	Explosion/Fireball	2.2×10^{-4}
Control	1.1×10^{-3}	L.V. Breakup	8.9×10^{-4}
Electrical	1.1×10^{-5}	Trajectory Error	1.1×10^{-3}
ISDS Inadvertant	7.2×10^{-7}	Tumbling Vehicle	9.2×10^{-3}
CSDS Inadvertant	3.4×10^{-7}	Stage II Short Burn	1.2×10^{-3}
Propulsion	5.9×10^{-3}		
Target Reference	4.5×10^{-4}	Target Error	4.5×10^{-4}
PARKING ORBIT PHASE			
Failure to Fire Transtage Engines	2.7×10^{-3}	Reentry	2.7×10^{-3}
TRANSFER ORBIT PHASE			
Heading and Position Errors	3.4×10^{-4}	Reentry Escape	3.3×10^{-4} 7.0×10^{-6}
TRANSFER ORBIT COAST PHASE			
Failure to Fire Transtage Engines	4.3×10^{-3}	Reentry	4.3×10^{-3}
ORBITAL ACQUISITION PHASE			
Heading and Position Errors	1.7×10^{-3}	Reentry Very Long Orbit	1.7×10^{-3} 1.1×10^{-5}

Because the RTGs are designed to withstand such environments, the analyses of the system responses to these sequences indicate that plutonium release would be expected only in a few situations where some individual environments are particularly severe. In these situations, the probability of the particular sequence occurring was multiplied by the probability of that sequence causing plutonium release. This probability was then associated with the predicted plutonium source term to form the basis for the risk assessment.

The source term was then characterized to determine its behavior in the environment and its importance to the safety analysis. Since only inhalable plutonium is of immediate environmental significance, the source terms primarily addressed are plutonium particles less than four microns in diameter (larger particles are not considered significantly inhalable) and any vaporized plutonium.

C.2.4 LES 8/9 Safety Analysis Results

I-1

The final results of the launch and ascent phase safety analyses indicate that there are only five accidents which would be expected to release inhalable plutonium to the environment. The characteristics of these accidents are briefly described below:

C.2.4.1 Accident 1

This accident would be initiated by an explosion of the launch vehicle after it has been ignited and lifted off the pad, but before it starts to head downrange (at about 11 seconds after lift-off). If the launch vehicle had attained sufficient altitude before the explosion, the RTGs (assumed to be separated from the spacecraft by the explosion) could attain a fall velocity of over 60 meters/second (200 feet/second. If the RTGs were then to impact on the concrete pad, some of their FSAs were assumed to fail, thus releasing plutonium dioxide particulates. (The plutonium particulates would be created by the effects of vibration, overpressure, and impact forces on the otherwise solid PPO sphere.) The total respirable source term released was determined to be 1300 millicuries with a probability of 4×10^{-6}.

A further possible event in this accident is that an FSA or FSAs might impact and fail in close proximity to a piece of burning solid propellant. Were this to occur, some of the otherwise non-respirable particulates released were assumed to be vaporized by this fire. The total respirable source term released in this situation was calculated to be 5200 millicuries of vapor in addition to the 1300 millicuries of respirable particulates. The probability associated with this source term was 1.4×10^{-8}.

C.2.4.2 Accident 2

The other fuel-releasing accident considered in the launch pad area involved downrange accidents. This could involve downrange land impact of the entire launch vehicle or trans-stage, which could occur if the vehicle destruct system failed to operate (a double malfunction). Alternatively, it could involve a destruct action in the air, with subsequent RTG impact on the limited concrete or rock surfaces downrange from the launch pad. The INSRP grouped these two scenarios together and determined that the source term which might occur to be 1300 millicuries of respirable particulates with a probability of 1.1×10^{-5}. Exposure to solid propellant fires was not considered credible during this phase, since either scenario would result in dispersion of the solid propellant well away from the projected impact area of the RTGs.

C.2.4.3 Accidents 3 and 4

Accident 3 and 4 both involve accidental reentry of the P74-1 payload from failure to achieve the proper orbit. Most of these situations would involve insertion into a relatively short-lived orbit, with subsequent orbital decay and reentry. In these situations, the heat source aeroshell would not fail from reentry heating. However, as discussed in Appendix D, impact on a hard surface such as concrete or granite could cause breaching of some PICSs and breaking of some GISs.

The INSRP determined that each such hard surface impact would cause release of particulate plutonium to the environment. (The Final SAR assumed release in only part of the cases, thus contributing to the lower probability shown in the Draft Environmental Statement.) Two source terms were derived. Accident 3 was assumed to involve an orbit short enough to preclude significant radioisotope decay and shows a 30 millicurie release with a probability of 1.3×10^{-4}. Accident 4 was assumed to involve an orbit long enough to allow some radioisotope decay and shows a 10 millicurie release with a probability of 3.6×10^{-5}.

C.2.4.4 Accident 5

This accident would involve an accidental reentry resulting from a misoriented burn during one of the orbital maneuvers necessary to obtain the final LES 8/9 orbits desired. Were this reentry to occur at a sufficiently steep angle, the INSRP determined that the aeroshell would fail due to thermal stress forces (not ablation) and would release the FSAs to the atmosphere. The FSAs would not be expected to fail from reentry heating; however, their subsequent impact response capability would be degraded. Thus, although they would still not fail upon soil impact, the amount of plutonium released upon rock impact was determined to be 250 millicuries larger than the amount for Accident 3. The probability of this source term occurring was assessed as 6×10^{-6}.

C.2.4.5 Other Accidents

Many other accident scenarios were considered in detail in the safety analysis and were not predicted to release plutonium. In almost all cases, this conclusion was reached as a result of safety test data that indicated failure would not occur. Further details on the other accidents considered may be found in Reference 3.

One accident which was not considered was any launch area accident culminating in a double proximity solid propellant fire exposure (which the safety tests showed would breach an FSA). This accident was neglected because it has consistently been considered an incredible event. However, an analysis has been performed that indicates that the plutonium vapor source term which would result from such an accident would be about 8000 millicuries. Thus, the consequences of such a situation would be of the same magnitude as the vapor source terms from Accident 1, were double proximity exposure considered a credible event.

APPENDIX D

SAFETY TEST PROGRAM

D.0 APPENDIX D

SAFETY TEST PROGRAM

MHW heat source components have been exposed to several series of tests which have investigated the survivability of the Heat Source Assembly (HSA) and/or its components in the event of a catastrophic accident. The accident environments simulated in this test program included those conceivable during the prelaunch, launch, ascent, and orbital maneuvering phases of the proposed P74-1 Project.

An underlying philosophy of the test program was to expose the FSAs to environments which the HSA and/or the converter in part or in entirety would experience. This procedure, in general, produced overtests of the FSAs, since all protection afforded by the HSA and the converter was neglected. Therefore, if the FSA survived the test environments, it could be considered to have an inherent margin of safety with regard to the planned use.

The purpose of this appendix is to summarize the results of this safety test program. In most of the FSA tests described below, a very slightly radioactive thorium dioxide was used in place of the plutonium, usually necessitating heating of these "simulant FSAs" to reproduce the normal MHW-RTG operating temperatures. One exception to the above involved some of the FSA impact tests, which were conducted with normal plutonium fuel in a special facility at the Los Alamos Scientific Laboratory.

D.1 LAUNCH PAD ABORT ENVIRONMENT TESTS

D.1.1 Blast Environment (S-1) Safety Test

The S-1 safety test was performed to determine the survivability of the FSAs in the blast environments created by an explosion in the Titan Transtage propellant tanks. (A Transtage explosion would be the closest center of explosion to the RTGs). Such an explosion was simulated for this test by placing an "eight pack" of FSAs in a shock tube. (An "eight pack" is a subassembly of an HSA, with two planes of FSAs in their retaining tray). The following parameters summarize the test environment:

(1) Five percent TNT equivalent yield (more than ten times the yield expected in the vast majority of Titan aborts)

(2) Peak static overpressure of 57 psi.

(3) Peak stagnation overpressure of 133 psi.

(4) Static impulse of 1.31 psi-sec.

(5) Stagnation impulse of 3.2 psi-sec.

In the tests, the FSAs were accelerated to velocities of approximately 49 meters/second (160 feet/second) and impacted up to 180 meters (200 yards) away from the end of the shock tube. Details of the test equipment and procedures are described in Reference 62.

The PICS suffered no breaches and very little damage as a result of the blast. One GIS showed some gouges where that FSA hit a wooden crate, but no substantial damage was sustained by any of the GISs Figure 15 shows one of the FSAs after the test. The threaded cap of the GIS has been taken off and the Post-Impact Shell Assembly (PISA) removed to indicate the lack of significant damage to either component. (A PISA is an FSA without the GIS or, in other words, a PICS containing either plutonium or simulant).

D.1.2 Liquid Propellant Fire (S-2) Safety Test

The S-2 liquid propellant fire tests exposed two simulant FSAs and two simulant PISAs to the thermochemical equivalent of a liquid propellant residual fire. The four test specimens were preheated to the MHW-RTG operating temperature of 1090° C (2000° F) in an inert atmosphere. The specimens were then dropped into a tub containing a shallow level of Aerozine 50 (the liquid propellent of the Titan), which was ignited and burned for approximately 20 minutes at temperatures ranging from 820° to 930°C (1500° to 1700° F).

The result of the test was slight charring of the FSAs, with minor degradation of the GIS surfaces. The PISAs only had their PICSs discolored by residues from the fire. There was no breaching or apparent damage to any of the PICSs. Figure 16 shows pictures of one FSA and one PISA after the test. Details of the test are discussed in Reference 63.

D.1.3 Solid Propellant Fire (S-3) Safety Tests

The solid propellant fire tests were designed to expose both FSAs and PISAs to some of the most severe fire conditions conceivable. Two situations were studied. The first was a "direct contact" fire in which the FSAs and PISAs were placed on top of a piece of burning propellant. The second was a "double proximity" fire in which the FSAs and

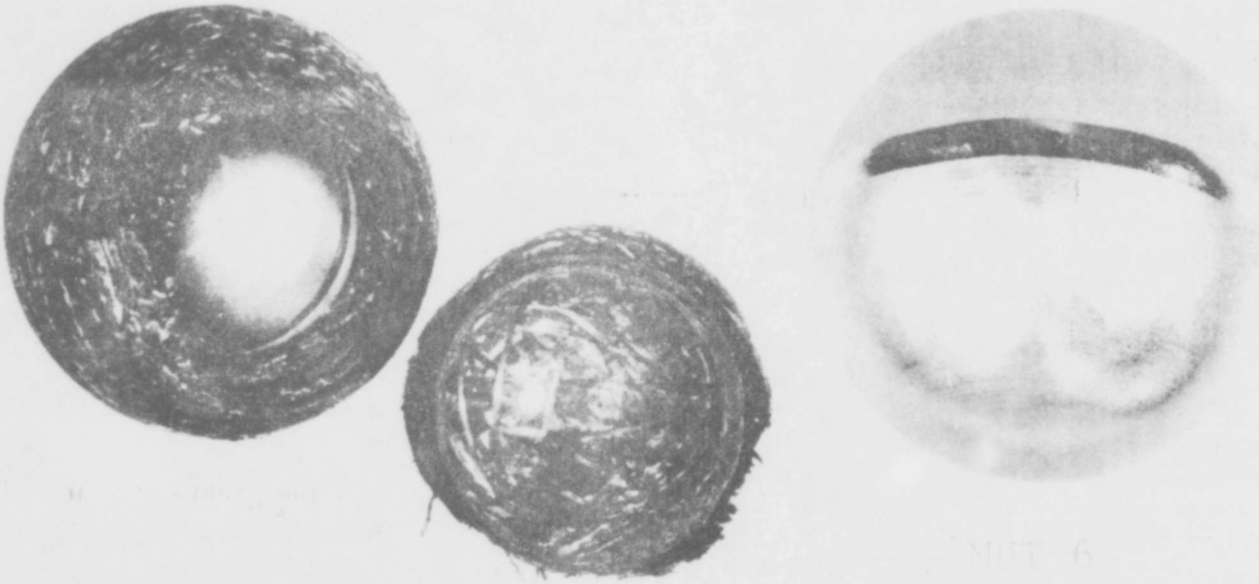

FIGURE 15. A GIS (WITH ITS THREADED CAP REMOVED) AND A PISA AFTER THE S-1 TEST

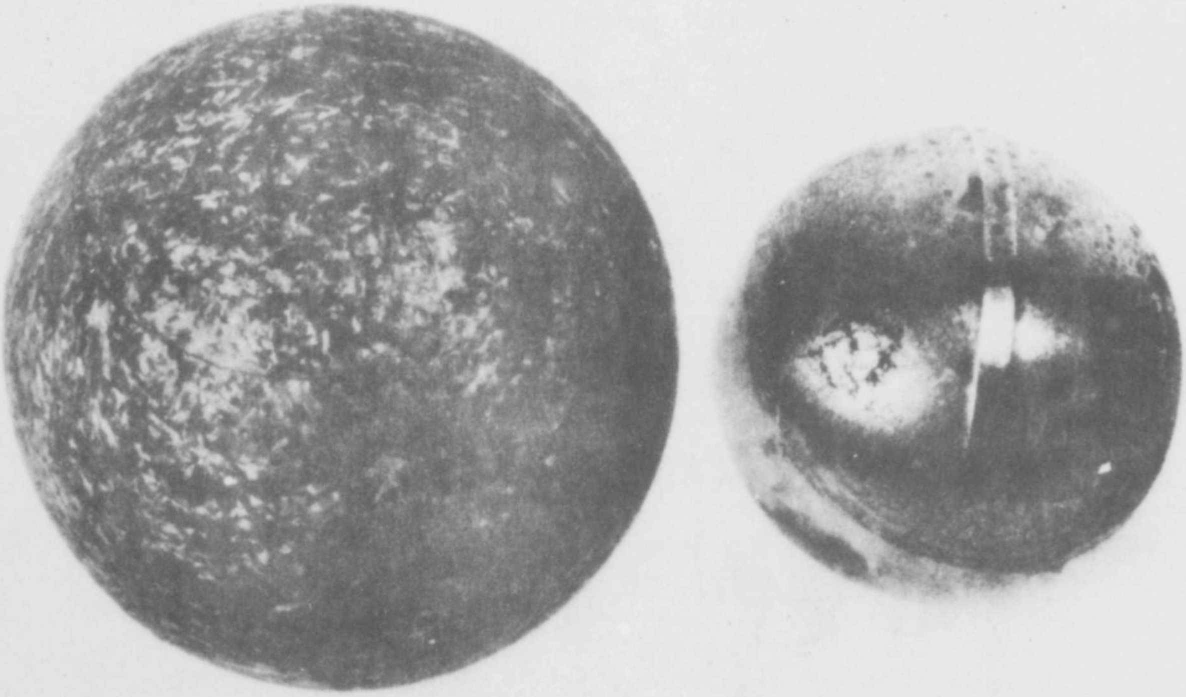

FIGURE 16. A GIS AND A PISA AFTER THE S-2 TEST

PISAs were placed between two pieces of propellant positioned about 30 centimeters (1 foot) apart.

In each situation, the piece(s) of propellant were cubes 91 centimeters (3 feet) on a side to simulate the full thickness of solid propellant in a Titan III-C. Pieces this size burn at temperatures up to 2200 C (4000 F) for times up to 10 minutes. The double proximity test in particular was an over-test, since the INSRP has consistently considered such an exposure situation to have such a low probability that it is considered an incredible occurrence.

In the direct contact test, only the FSAs were actually exposed to the fire. (The PISAs both accidentally rolled off the block of propellant and were not significantly heated). The GISs of the FSAs had flat spots about 1 inch in diameter, but neither the GISs or the PICSs were breached. There was, however, minor, localized melting on the surface on one PICS. Figure 17 shows two views of this specimen.

In the dual proximity test, both PISAs and one of the two FSAs exposed were breached in this severe fire. The remaining FSA showed relatively little damage. In all failures, the breaches were about 1.6 cm^2 (0.25 in^2) in area. Post-test analyses indicated that the failures were due not to simple melting, but to various, complex, high-temperature reactions of the PICSs and GISs with materials such as iron and sand which were in the test environment.

Details of the above tests are documented in Reference 64. Single proximity solid propellant fire tests (with the FSAs, etc., placed beside, not in contact, with the solid propellant) were conducted in the S-6 series of tests described below.

D.1.4 Launch Pad Abort Sequential (S-6) Safety Tests

These tests, were conducted in three phases. Phase I involved a full HSA impact at a velocity typical of a launch pad or early ascent accident. Phase II consisted of additional solid propellant fire exposure tests. Phase III involved a variety of FSA impact tests.

D.1.4.1 S-6 Phase I Test

This test consisted of impacting an HSA at a velocity of 30 meters/second (100 feet/second) on a concrete target. The impact conditions were selected to simulate free fall of an HSA from heights at which an RTG might be blown free from a missile exploding over the concrete launch pad.

During the test, the oven being used to heat the simulant HSA to MHW-RTG operating temperatures partially failed. Thus, the HSA was only partially heated and was impacted at temperatures considerably below those which would exist, should such an accident occur. This reduced temperature resulted in the iridium PICS being at temperatures lower

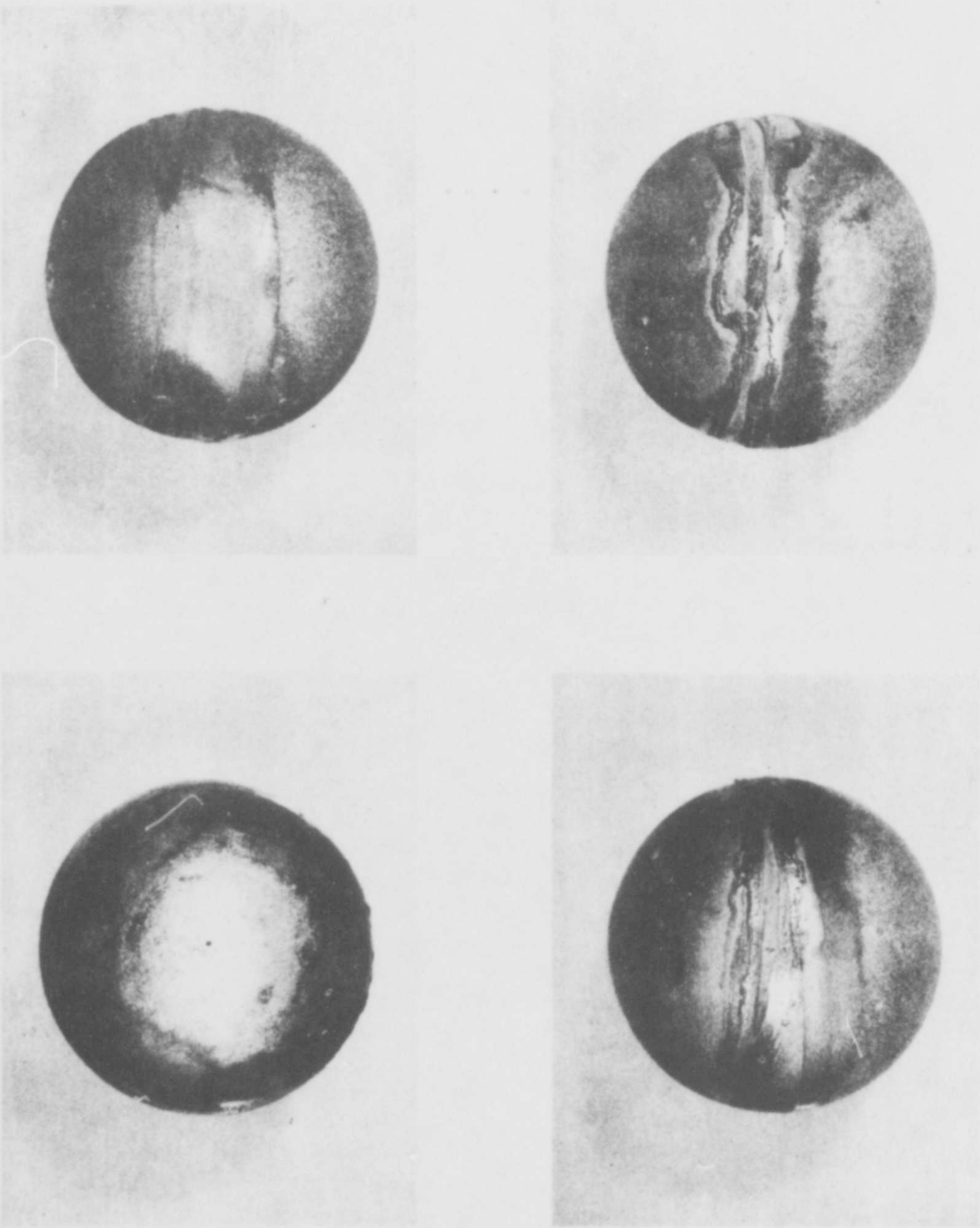

FIGURE 17. A PISA AFTER EXPOSURE AS AN FSA TO THE DIRECT CONTACT FIRE OF THE S-3 TEST

than they were designed for (estimated to be only about 460° C, rather than about 1000°C). At the lower temperature, iridium is known to be quite brittle.

The HSA broke upon impact. However, there was very little scattering of the FSAs, with only two rolling away from the broken HSA by a few feet. None of the GISs were seriously damaged and all continued to contain the PISAs. However, several of the PICSs were cracked. This cracking has since been shown to be due to the artificially low impact temperatures of the PICSs. Detailed results of this test are contained in Reference 65.

D.1.4.2 S-6 Phase II Tests

Phase II was designed to add to the results of the S-3 by investigating single proximity exposures of both single FSAs and an FSA "eight-pack." In both tests, the specimens were placed beside a block of solid propellant similar to that of the S-3 test. Steel plates were placed on top of the propellant blocks to allow for the interactions observed in the double proximity part of the S-3 test.

In the test of single FSAs, two FSAs (one of whose PICS had been cracked in Phase I) were used. The results were similar to those of the S-3 direct contact test, although the GISs were partially penetrated by reactions with molten iron. No significant damage to the PICSs was observed, and the existing cracks in the PICS damaged in Phase I did not become larger.

An iridium can was placed over the "eight-pack" used in the other test to simulate exposure of an HSA. Much of this iridium can was removed by the solid propellant fire, and the FSA retaining ring was significantly eroded. However, damage to the GISs was slight, and none of the eight PICSs suffered significant damage. (Again, the response was similar to that observed in the direct contact part of the S-3 test.)

D.1.4.3 S-6 Phase III Tests

Phase III included five FSA impact tests: three were performed at launch pad impact velocities (30 meters/second or 100 feet second), and two at reentry impact velocities (85 meters/second or 280 feet second). The reentry impact tests are discussed in the next section.

One low velocity impact was on a piece of an angle iron: the GIS remained intact, the PICS was badly deformed, but did not breach (see Figure 18). The other low velocity tests involved double-ball impacts (one FSA impacting on top of another) on concrete at different impact temperatures. One was performed at the expected

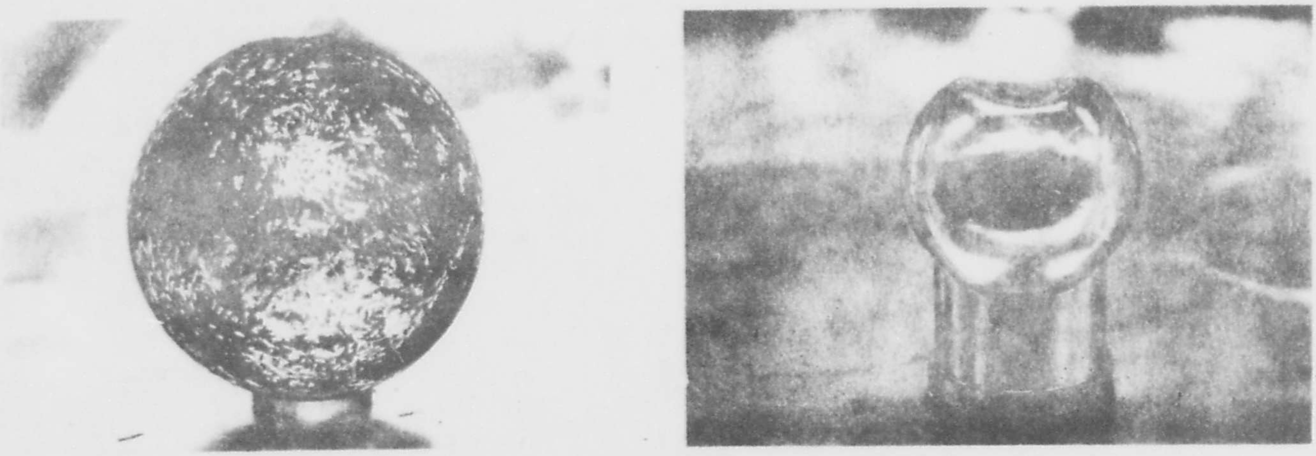

FIGURE 18. THE GIS AND PISA AFTER THE LOW-VELOCITY ANGLE-IRON IMPACT TEST OF THE S-6 PHASE III TESTS

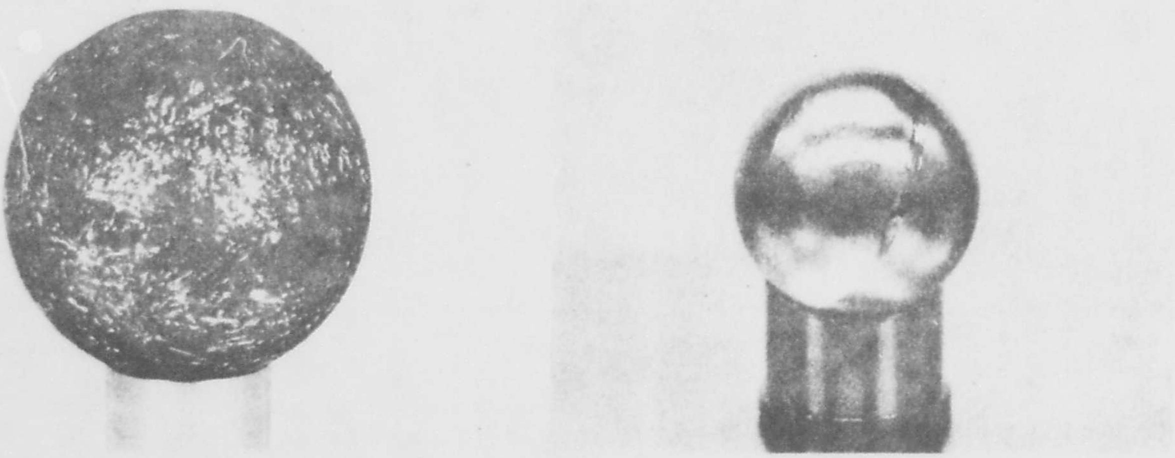

FIGURE 19. THE GIS AND PISA AFTER THE REENTRY-VELOCITY SOIL IMPACT TEST OF THE S-6 PHASE III TESTS

impact temperature (about 1100°C) with results similar to that of the angle iron test. The other was performed at the temperature evidently experienced in the S-6 Phase I test to further check the concept that iridium brittleness at such temperatures accounted for the Phase I cracking. As predicted, these PICS showed similar cracking. Details of these tests are described in Reference 66.

D.2 REENTRY IMPACT TESTS

Many series of reentry impact tests have been performed on the MHW heat source components. These tests were system design and verification tests, with the exception of those reentry impacts associated with Phase III of the S-6 tests. Consequently, many of the earlier impact tests were performed with candidate FSA component materials (different graphite or iridium shells, for example) that were not incorporated into the system design. Such tests have been deleted from the following discussion. Only those tests involving the type of hardware proposed to be used in the P74-1 Project will be described.

D.2.1 S-6 Phase III Tests

The reentry impacts in the S-6 Phase III tests investigated response of an FSA at 85 meters/second (280 feet/second) on soil and concrete. The impact on soil caused little damage to either the GIS or the PICS. (See Figure 19). The impact on concrete shattered the GIS and badly deformed the PICS; however, no breach of the PICS was observed. Reference 66 also documents the results of these impacts.

Subsequent to these tests, however, another FSA impact at the reentry terminal velocity was conducted on concrete (Reference 66). In this test, the PICS was breached in a manner similar to those breaches on granite discussed in the following section.

D.2.2 System Impact Tests

One of the desired objectives for the FSA design was that it represent the first RTG system which would survive reentry impact at the maximum terminal velocity of the HSA (85 meters/second or 280 feet/second) on impact targets of smooth granite. Such conditions essentially represent the most severe reentry impact environment possible.

In general, this design goal has not been met, for a large fraction of the PICSs tested have failed in such tests. However, in an HSA impact run under these conditions, the GISs remained around many of those PISAs which breached, thus preventing dispersal of plutonium released through the PICSs (Figure 20).

The PICSs in these tests were breached by three basic mechanisms. Tensile and hoop stress failures produced the most

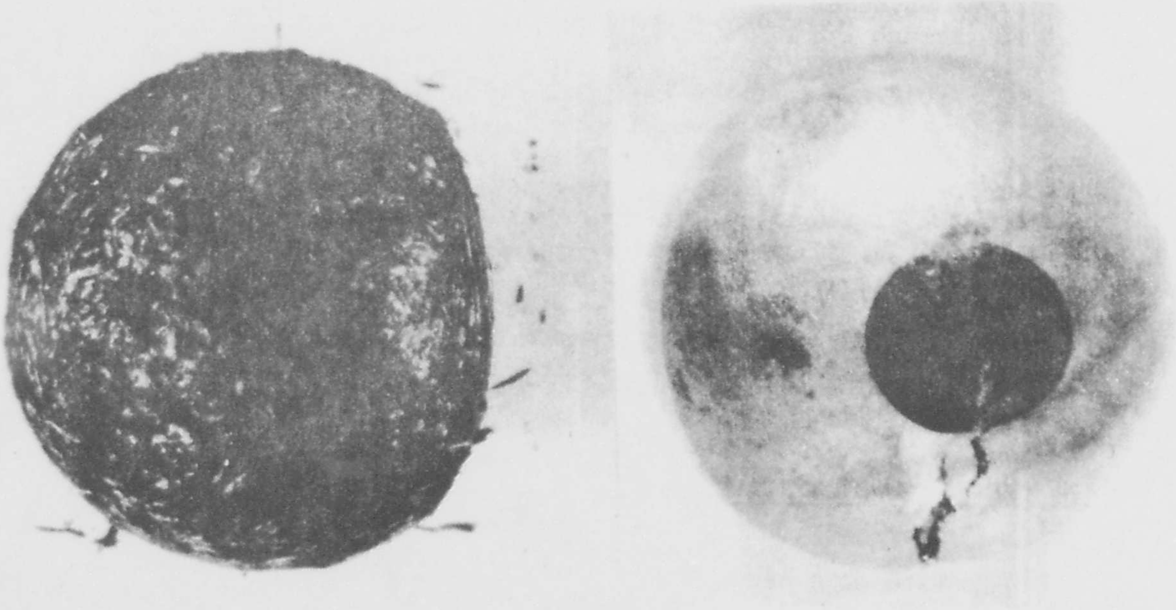

FIGURE 20. A BREACHED PISA AND ITS INTACT GIS AFTER A HSA REENTRY VELOCITY IMPACT TEST ON GRANITE

FIGURE 21. FAILURE MECHANISMS OF BREACHED PISAs FROM REENTRY-IMPACT TESTS ON GRANITE

severe cracks and occurred in conjunction with large PISA deformations and with stretching over pieces of broken fuel within the PICSs (see Figure 21). The third mechanism, fingerprint cracks, was a fairly common but relatively inconsequential failure observed on the PISA impact faces.

In these tests, data were also collected on the amount of plutonium which escaped through these breaches in the PICSs. These results have been reflected in the source terms discussed in Section 4.2.2.2 of this Statement.

D.3 MATERIAL COMPATIBILITY AND BURIAL TESTS

Tests have been run to verify the performance of the FSAs after operation for long periods of time. The FSAs were subsequently examined and checked for material interactions and changes in material properties. No significant material degradation or interactions were observed.

Tests to investigate the behavior of an unrecovered FSA after reentry impact have indicated (Reference 3) that: (1) the PICS will survive indefinitely sitting on top of the ground, (2) the PICS will survive indefinitely buried in sandy soils, and (3) the PICS will oxidize and degrade, releasing plutonium to the soil, if buried in certain soils with unusually low thermal conductivities.

D.4 AERODYNAMIC TESTS

D.4.1 Aeroshell Subsonic Ablation Tests

MHW heat source conditions (aeroshell shape and thickness) at impact are influenced by the aerodynamic forces and ablation throughout the reentry trajectory. This reentry path may include up to 150 seconds of subsonic flight prior to impact. Wind tunnel runs were made to measure mass loss, heat transfer, and graphite oxidation (via gas sampling). The data were used to modify existing ablation models, the details of which are presented in Reference 67.

No aeroshell failures due to either subsonic or hypersonic ablation during reentry are expected as a result of these tests and the tests described in the next paragraph.

D.4.2 Aeroshell Hypersonic Ablation Tests

A series of ablation tests were done to determine the aeroshell ablation when subjected to simulated hypersonic flight conditions. The test data for recession rates matched predicted rates very closely. The aeroshell corners remained sharp with only a slight shape change, i.e., the aeroshell became slightly barrel shaped. The details of the test and analysis are described in Reference 68.

D.4.3 Emissivity Sleeve Hypersonic Ablation Tests

During the final stages of the INSRP review, it was determined that thermal stress failures (not ablation) might cause the aeroshell to fail under certain severe, steep-angle misorientation reentries. Therefore, a series of hypersonic ablation tests were performed on the graphite used for the heat source emissivity sleeve to determine its capability to protect the aeroshell. (Similar graphite is used in the GISs; however, the aeroshell graphite is a different material.)

These tests indicated that the sleeve would probably fail from ablation during such reentries and could not be considered to protect the aeroshell from thermal stress failure. Thus, the FSAs could be released from the aeroshell. However, it was judged that the additional protection from the graphite of the GISs would be sufficient to protect the PICSs from being breached due to the atmospheric reentry heating.

D.5 CONCLUSIONS FROM SAFETY TEST PROGRAM

The following conclusions have been drawn from the above tests:

(1) Breaching of the PICS and subsequent release of inhalable plutonium from the PISA to the environment is not expected as a result of any of the following: blast environments, liquid propellant fires, solid propellant contact or single proximity fires, free FSA or HSA impact in any situation other than reentry terminal velocity impact on granite or concrete, reentry heating, or sustained post-impact exposure to the environment.

(2) Breaching of the PICS can occur in double proximity solid propellant fire exposures (considered to be an incredible event) or upon reentry terminal velocity impact on granite or concrete (although the GIS may prevent plutonium release in many cases in this event).

APPENDIX E

COMMENTS FROM
UNITED STATES DEPARTMENT OF TRANSPORTATION

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

SOUTHERN REGION
P. O. BOX 20636
ATLANTA, GEORGIA 30320

June 17, 1975

Dr. Billy E. Welch, Ph.D.
Special Assistant for Environmental
Quality
Office of the Assistant Secretary
Department of the Air Force
Washington, D. C. 20330

Attention: SAF/ILE

Dear Dr. Welch:

We have reviewed the Draft Environmental Statement describing the proposed launching of Lincoln Experimental Satellites 8 and 9 and Solrad Satellites 11A and 11B by a single Titan III-C launch vehicle, with respect to potential environmental impact for which this agency has expertise.

Our review of the data presented indicates there will be no significant adverse effects to the existing or planned air transportation system as a result of this project.

Sincerely,

for BENNY C. FRAZIER
Chief, Planning and Appraisal Staff

NO RESPONSE REQUIRED

APPENDIX F

COMMENTS FROM NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO ATTN OF: ADA-1

July 18, 1975

Dr. Billy E. Welch
Special Assistant for
Environmental Quality
SAF/ILE
Department of the Air Force
Washington, D.C. 20330

Dear Dr. Welch:

This letter responds to yours of June 2, 1975, addressed to the NASA Comptroller, requesting that NASA review the draft environmental impact statement "Lincoln Experimental Satellites 8 and 9 (LES 8/9) Program."

The draft has been reviewed by appropriate offices within NASA. We have found it a complete and informative description of the possible environmental effects associated with the program. Our comments on specific details are as follows:

1. Retrieval of the LES 8/9 spacecraft by the Space Shuttle is mentioned a number of times in the draft. The context in which such retrieval might take place should be clarified to include the following points:

    F-1 a. The term, Space Shuttle, should be limited to the relatively low orbital systems currently under development; the term Space Transportation System (STS) is used to describe the eventual system having synchronous orbit capability.

F-2 b. Retrieval by the Space Shuttle itself has significance for LES 8/9 abort orbits of low altitude (and relatively short lifetime). The probabilities of such orbits should be considered; they may be found so small that this mode of retrieval has little significance.

F-1 c. Retrieval by the STS should eventually be possible, and therefore of some significance, for synchronous orbit and for long period elliptical orbits. However, when discussing retrieval in the far future, reference should be made to the Space Transportation System "or some successor system," as is done in section 6.5 (p. 61).

F-3 2. Table 1 (page 17) shows that the total radioactivity in curies per payload is 318,800 Ci; from calculations using data from section 2.5.2 (page 18), the total radioactivity per payload is 320,600 Ci; and from calculations using data from section 4.3.1 (page 48), the total radioactivity per payload is 297,600 Ci. The differences should be resolved in the final EIS.

We appreciate the opportunity to comment on this draft environmental statement, and look forward to receiving the final statement containing the data employed in the Safety Evaluation Report.

Sincerely yours,

Nathaniel B Cohen

Nathaniel B. Cohen, Director
Office of Policy Analysis

Comment	Response
F-1	This correction has been made throughout the Statement.
F-2	Aborts resulting in low-altitude orbits have been considered as part of the nuclear safety analysis, with reentry of the RTGs within the appropriate orbital lifetime assumed. No avoidance of possible risks from low-altitude orbits due to Space Shuttle recovery has been assumed. However, should an abort result in a low-altitude orbit with a lifetime long enough to be a candidate for Shuttle recovery (which would not be possible until the 1980's), this course of action would be extensively considered. As implied, the probability of such a low-altitude orbit would be very small.
F-3	Table 1 (page 17), Section 2.5.2 (page 18), and Section 4.3.1 (page 48) have been revised based on data from Reference 3, and the discrepancies have been resolved.

APPENDIX G

COMMENTS FROM
UNITED STATES DEPARTMENT OF COMMERCE

G-1

UNITED STATES DEPARTMENT OF COMMERCE
The Assistant Secretary for Science and Technology
Washington, D.C. 20230

AF/PRE
__Dir ______
__Dep Dir ______
__Assoc ______
__Dep Coordin ______
__[illegible] ______
✓ [illegible] ______
__SUSP ______
__[illegible] ______
__INFO: V______

July 22, 1975

Dr. Billy E. Welch
Special Assistant for
Environmental Quality
SAF/ILE
Department of the Air Force
Washington, D. C. 20330

Dear Dr. Welch:

The draft environmental impact statement for the proposed "Lincoln Experimental Satellites, 8 and 9 (LES 8/9) Program," which accompanied your letter of June 2, 1975, has been received by the Department of Commerce for review and comment.

The environmental statement was reviewed with respect to satellite engineering and operation and general completeness. The areas of launch vehicle failure probabilities, orbital decay rates, radioisotope thermoelectric generator technology, decay rates for plutonium and beryllium atmospheric contamination, and biological effects of contamination are not commented upon as no expertise exists within the Department of Commerce for reviewing these topics.

Our comments are as follows:

G-1 (1) The statement in Section 6.6, that solar power is not adequate as an alternative power source, is thin. Technologically, solar arrays plus chemical storage batteries could provide adequate power for this mission. If they are not acceptable for survivability or other reasons, then that fact should be stated.

(2) Section 6.5 discusses the use of the space shuttle or its successor for recovering the radioactive material from orbit and either returning it to earth or disposing of it in space. G-2 Is a recovery capability for geostationary satellites planned as a part of the shuttle program? If not, then the discussion is largely rhetorical. If such disposal will not be possible

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

G-2

G-3 for some time, then who will continue to carry the responsibility for periodically reviewing the issue of disposal before these generators reenter?

Thank you for giving us an opportunity to provide these comments, which we hope will be of assistance to you. We would appreciate receiving eight copies of the final statement.

Sincerely,

Sidney R. Galler
Deputy Assistant Secretary
for Environmental Affairs

Comment	Response
G-1	Reference revised Section 6.6 (page 62).
G-2	Yes, as indicated by both Reference 48 and the NASA comments on this Statement (Appendix F). Also, reference revised Section 6.5 (page 61).
G-3	Additional data relative to the question of satellite recovery will be developed in conjunction with the Environmental Statement to be prepared for the possible operational system resulting from the LES 8/9 experiments. The need for such a periodic review will be studied as part of that effort.

APPENDIX H

COMMENTS FROM THE STATE OF FLORIDA

STATE OF FLORIDA

Department of Administration

Division of State Planning

660 Apalachee Parkway · IBM Building

TALLAHASSEE

32304

(904) 488-2371

Earl M. Starnes
STATE PLANNING DIRECTOR

Reubin O'D. Askew
GOVERNOR

Lt. Gov. J. H. "Jim" Williams
[redacted]
SECRETARY OF ADMINISTRATION

July 23, 1975

Dr. Billy Welch
SAF/ILE
Washington, D. C. 20330

Dear Dr. Welch:

Functioning as the State planning and development clearinghouse contemplated in U. S. Office of Management and Budget Circular A-95, we have reviewed the following draft environmental impact statement:

Lincoln Experimental Satellites 8 and 9
(LES 8/9) Program - May, 1975 -
SAI: 75-2222E

During our review we referred the environmental impact statement to the following agencies, which we identified as interested: Department of Commerce, Department of Natural Resources, Department of Health and Rehabilitative Services, Department of Pollution Control, Department of Transportation, and the Game and Fresh Water Fish Commission. Agencies were requested to review the statement and comment on possible effects that actions contemplated could have on matters of their concern. Letters stating no adverse comments are enclosed from the Department of Natural Resources, Department of Transportation, and the Game and Fresh Water Fish Commission, while the Department of Pollution Control by telephone reported no comments. Based upon these comments and our review, we have no objections or comments to the Draft Environmental Impact Statement.

In accordance with the Council on Environmental Quality guidelines concerning statements on proposed federal actions affecting the environment, as required by the National Environmental Policy Act of 1969, and U. S. Office of Management and Budget Circular A-95, this letter, with attachments, should be appended to the final environmental impact statement on this project. Comments regarding this statement and project contained herein or attached hereto should be addressed in the statement.

We request that you forward us copies of the final environmental impact statement prepared on this project.

Sincerely,

Ed Maroney

E. E. Maroney, Chief
Bureau of Intergovernmental Relations

EEM/Ccm

Enclosures

cc: Mr. Doug Maddox
Mr. J. Landers
Mr. W. N. Lofroos
Mr. William Partington
Mr. Harmon Shields
Mr. E. J. Trombetta
Dr. Robert Lulofs
Mr. H. E. Wallace
Mr. Robert Williams
Mr. Walter Kolb

H-3

STATE OF FLORIDA

Department of Administration

Division of State Planning

660 Apalachee Parkway · IBM Building

TALLAHASSEE

32304

(904) 488-2371

Earl M. Starnes
STATE PLANNING DIRECTOR

Reubin O'D. Askew

Lt. Gov. J. H. "Jim" Willi
SECRETARY OF ADMINISTRATION

CEIVED
JUL 8 1975
Executive Director
of Natural Resources

Division of State Planning
Intergovernmental Relations
JUL 16 1975
RECEIVED
SAI NO.

DATE: JUN 30 1975

DUE DATE: JUL 1 4 1975

TO: Mr. Harmon Shields, Ex. Dir.
Department of Natural Resources
202 Blount St.
Tallahassee, Florida 32304

FROM: Bureau of Intergovernmental Relations

SUBJECT: SAI: 75-2222E

Please review and comment to us on the above draft environmental impact statement, copy attached. In reviewing the statement, you should consider possible effects that actions contemplated could have on matters of concern to your agency.

If you feel that a conference is needed for discussion of the project or resolution of conflicts, or if you have questions concerning the statement, please call Mr. Walt Kolb at (904) 488-2401. Please check the appropriate box below, attach any comments on your agency's stationery and return to IGR or telephone "no adverse comments" by the above due date.

On that date, we intend to consider all review comments received and develop a state position on the project. In both telephone and written correspondence please refer to the above SAI number.

Sincerely,

Ed Moroney

Chief
Bureau of Intergovernmental Relations

Enclosure

****

TO: Bureau of Intergovernmental Relations

FROM: Department of Natural Resources

SUBJECT: DEIS Review and Comments

☒ No Comments

☐ Comments Attached

Reviewing Agency:

Signature: James G. Smith

Date: 7/15/75

TITLE: Administrative Assistant

Department of Administration

Division of State Planning

660 Apalachee Parkway · IBM Building

TALLAHASSEE

32304

(904) 488-2371

Earl M. Starnes
STATE PLANNING DIRECTOR

Reubin O'D. Askew
GOVERNOR

Lt. Gov. J. H. "Jim" Williams
SECRETARY OF ADMINISTRATION

TO: Mr. H. E. Wallace
Game & Fresh Water Fish Commission
Bryant Building
Tallahassee, Florida 32304

DATE: JUN 30 1975

DUE DATE: JUL 14 1975

FROM: Bureau of Intergovernmental Relations

SUBJECT: SAI: 75-2222 E

Please review and comment to us on the above draft environmental impact statement, copy attached. In reviewing the statement, you should consider possible effects that actions contemplated could have on matters of concern to your agency.

If you feel that a conference is needed for discussion of the project or resolution of conflicts, or if you have questions concerning the statement, please call Mr. Walter Kolb at (904) 488-2401. Please check the appropriate box below, attach any comments on your agency's stationery and return to IGR or telephone "no adverse comments" by the above due date.

On that date, we intend to consider all review comments received and develop a state position on the project. In both telephone and written correspondence please refer to the above SAI number.

Sincerely,

Ed Moroney

Chief
Bureau of Intergovernmental Relations

Enclosure

****

TO: Bureau of Intergovernmental Relations

FROM: Game and Fresh Water Fish Commission

SUBJECT: DEIS Review and Comments

☒ No Comments

☐ Comments Attached

Reviewing Agency:

Signature: R. Daniel [illegible]

Date: July 8, 1975

TITLE: Section Leader, Environmental Protection Section

Florida
REUBIN O'D. ASKEW
GOVERNOR

Department of Transportation
Haydon Burns Building, 605 Suwannee Street, Tallahassee, Florida 32304, Telephone (904) 488-8772
TOM WEBB, JR. [redacted] SECRETARY

July 7, 1975

DIVISION OF STATE PLANNING,
Bureau Of
Intergovernmental Relations
JUL 8 1975
RECEIVED
SAI NO. __________

Mr. E. E. Maroney
Chief, Bureau of Intergovernmental
Relations
Division of State Planning
660 Apalachee Parkway
Tallahassee, Florida 32304

Dear Mr. Maroney:

Subject: Draft Environmental Statement
Lincoln Experimental Satellites
8 and 9 (LES 8/9) Program
Department of the Air Force
SAI:75-2222

We have reviewed the transportation aspects of the Lincoln Experimental Satellites 8 and 9 (LES 8/9) Program and have no adverse comments.

We appreciate the opportunity to comment at this early date.

Very truly yours,

RAY G. L'AMOREAUX, DIRECTOR
DIVISION OF PLANNING AND PROGRAMMING

for

W. N. Lofroos, P. E.
Chief, Bureau of Planning

WNL:RFK:mb

NO RESPONSE REQUIRED

APPENDIX I

COMMENTS FROM DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

MEMORANDUM

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

TO : Colonel Herbert E. Bell
HQ USAF/PREVP
Room 5E425, The Pentagon
Washington, D. C. 20330

DATE: 29 July 1975

FROM : Principal Environmental Officer

SUBJECT: Comment on USAF Draft Environmental Impact Statement - Lincoln Experimental Satellites 8 and 9.

The following comments have been prepared in response to your routing memo of 18 July 1975.

Technical review of the subject document has been provided by the following: Mr. Ernest C. Anderson, Assistant Director for Special Projects, Bureau of Radiological Health, Food and Drug Administration; and, Dr. Phillip J. Walsh, Environmental Biophysics Branch, National Institute of Environmental Health Sciences, National Institutes of Health.

It has not been possible to review the references referred to in the statement within the time frame allowed for review and comment. Accordingly, the important topics discussed in the references have not been fully addressed in our review.

I-1 It is unfortunate that the Safety Evaluation Report of the Interagency Nuclear Safety Review Panel had not been completed at the time the statement was released for review. The conclusions of an independent safety analysis would have been helpful to our reviewers; and will, we suggest, be included in the Final Environmental Impact Statement.

Our reviewers have found some inconsistencies in the presentation of data with respect to the probabilities for accidental release of Pu.

I-2 The probabilities given in Table 6 can be refuted by other information included in the statement. For example, on page 46, under Item 3, the probability of accidental re-entry causing a human fatality is given as 10^{-4} to 10^{-5} while the probability of human injury is 10^{-4}. Also on page 46, last paragraph, it is stated: "Reference 3 has indicated that the possibility of any accidental re-entry of P74-1 payload components would be of the order of 10^{-2}." This probability times the probability that HSA would impact with re-entry velocity on concrete or granite should yield the probability of Pu release. The probability that HSA would impact on concrete or granite may be as great or greater that the probability of human injury. The probabilities in Table 6 therefore appear 3 or 4 orders of magnitude too low. I-3 It should also be noted that on page 33 the actual experience has been 3/16 accidental re-entries, not 10^{-2}.

We appreciate the opportunity of providing Public Health Service comment.

George Deming
George H. Deming
Acting Deputy
Environmental Officer

cc - Director, Office of Environmental Affairs,
DHEW, Room 4740, HEW-N

Comment	Response
I-1	Reference revised Section 4.2.2.2 (page 42) and revised Appendix C (page C-7).
I-2	The probabilities quoted on page 46 under Item 3 are for a set of payload debris assumed to be reentering. The comparable probability used in the safety analysis for rock or concrete impact would be 2 x 10^{-2}. Thus, as the comment suggests is appropriate, the probability of rock or concrete impact is significantly larger than that for striking a person. To derive accidental risks for the P74-1 Project for each of these two situations, the probability of having such an accidental reentry must be included. In the Final SAR, for various reasons, plutonium release was assumed to occur in only a small fraction of the cases predicting reentry impact on rock or concrete, resulting in the release probabilities shown in the Draft Statement. In the SER, rock or concrete reentry impact was assumed to always cause plutonium release, resulting in the much larger numbers shown in the revised Table 6 (page 44).
I-3	Reference Appendix C (page C-5), a launch vehicle failure rate of 0.1 (ten percent), based on overall launch vehicle experience, was used in the SER risk assessment.

APPENDIX J

COMMENTS FROM
UNITED STATES DEPARTMENT OF THE INTERIOR

J-1

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

JUL 31 1975

In Reply Refer To:
PEP ER-75/579

Dear Dr. Welch:

This is in response to your request for the Department of the Interior to review and comment on the draft environmental statement for the proposed Lincoln Experimental Satellites 8 and 9 (LES 8 and 9) Program, Cape Canveral Air Force Station, Florida. Accordingly, we have reviewed the statement and offer the following comments.

J-1 We believe that the chance that the LES 8 or 9, if it ultimately strikes the earth's surface, will strike concrete or other hard surfaces will probably increase with time. Because of the extremely long period during which such an event would pose a significant hazard of exposure of individuals to radioactivity, and because of the large number of RTG systems that may be placed in orbit by various countries, it appears that protracted use of such systems could result in a significant cumulative risk to future populations. The magnitude of the risk would apparently depend in part upon the amount of hard surfaces such as concrete or other hard materials created over the earth's surface in the future, in addition to natural surfaces of hard rock and ice. Because of unforeseeable future developments in technology, this risk cannot be estimated, but the trend toward paving of the earth's surface that is evident over the past few decades, if projected over the next millenium or beyond, suggest that the risk of impacting on a hard surface at the end of the probable orbital lifetime of LES 8/9 is significant. It is noted that the probable orbital lifetime cannot be reliably predicted, as studies of this are only now being initiated (p. 50, par 3).

In spite of the foregoing circumstances, which otherwise appear to constitute a significant risk to future populations, the high probability of being able to recover RTGs from orbit during the 1980's or shortly thereafter would evidently make it possible to remove nearly all risk of reentry by recovering any RTG-equipped satellites whose orbits were observed to be unsatisfactory at any future time. However, it would be advisable to provide additional information on the following subjects: (1) the projected

development of a recovery system by the United States (for
J-2 example, the Space Shuttle system) as compared to similar capability
by the USSR or other countries; (2) the estimated cost
J-3 and risk involved in recovering an RTG-equipped satellite from
orbit by means of the Space Shuttle; and (3) an evaluation of
J-4 risks involved in recovery of a plutonium-fueled RTG intact by
another country, either by recovery from orbit or by recovery
of the satellite after impact on the ground in the other country.

J-5 We find that little consideration is given in the environmental
statement specifically to ground water, except in figure 14,
which portrays transfer factors for plutonium in the biosphere.
Inasmuch as the action under consideration involves only launch,
ascent, and possible reentry prospects, with related possible
accidents, we believe that the general approach used is adequate
for the purpose of the statement and the method of statistical
analysis is appropriate in evaluating impacts on the water
environment. However, we believe that there should also be
J-6 included at least a generalized analysis of site impacts that
might result from the release of plutonium in the case of a
severe accident on the launching pad, including emergency mitigating
measures that would be activated.

The quantity of plutonium alpha activity contained in one launch
payload is similar to the total introduced into the atmosphere by
all nuclear explosions prior to the 1963 test ban (p. 27) and
thus is very large. Acceptability of this program rests largely
upon the degree of assurance that the plutonium can be kept
from the biosphere. However, it is noted that only the effects
of plutonium made available for breathing at the time of an
J-5 accident is considered in the accident analysis. This represents
only a miniscule fraction of the total plutonium launched. The
evaluation of what eventually happens to the bulk of the plutonium
in an accident is cut short by the statement that direct inhalation
of plutonium is many orders of magnitude more effective
than any other pathway to man. However, the quantities remaining
in the ground or in water would be many orders of magnitude
greater than those considered available for breathing. In some
circumstances plutonium would be released to the soil (p. D-9)
and could then be further transported by water. The long term
environmental effects of all the plutonium involved in accidents
should be considered.

Comment	Response
J-1	The potential of a long-term increase in the hard surface fraction of the Earth's surface will be considered in the Environmental Statement addressing a possible follow-on operational system using RTGs.
J-2	No other country is known to be developing a Space-Shuttle-type system. However, the USSR can be considered to have at least a limited low-altitude-orbit recovery capability.
J-3	Reference revised Section 6.5 (page 61) for cost estimate. Risk will be addressed in future studies.
J-4	The costs and technological sophistication necessary for recovery of a satellite from space would appear to be far greater than the resources necessary to manufacture quantities of plutonium-238. The risks from ground recovery are considered to be minimal because of the comprehensive recovery program described in Section 2.7 (page 22).
J-5	Reference Appendix C (page C-3) for an analysis of the seawater-fish-man pathway. Plutonium dixoide shows the same, extremely limited soluability in fresh water that it demonstrates in seawater. In addition, virtually all of the plutonium which might be released to the ground/ground water system would be recovered in the decontamination operations mentioned in Section 2.7 (page 22).
J-6	Reference revised Section 4.2.2.2 (page 45).
J-7	Reference revised Appendix A (page A-4)
J-8	Reference revised Section 10.1 (page 72).
J-9	The report mentioned presents a "rock" fraction of the Earth's surface of 23 percent, which is considerably larger than the hard surface fraction of two percent (based on a later study) used in the nuclear safety analysis. The discrepancy is explained by the fact that the Geological Survey report definition of "rock" includes up to 20 inches of dirt cover. Tested impact penetration depths in soil rarely approach this value. The smaller fraction is more appropriate for correlation with the bare granite surfaces that hard surface impact is assessed at in the safety test programs.

J-7 The terms HSA and GIS should be included in the glossary; these
are used on page C-8, last paragraph. The reference to section
J-8 3.2.4 on page 72 (par. 10.1) should also refer to appendix B,
sections B.1.4 to B.1.6.

J-9 Finally, we call your attention to a pertinent report prepared by the Geological Survey for what was then the U.S. Atomic Energy Commission for the specific purpose of evaluating natural hard surfaces in regard to impact of satellites carrying nuclear material: Goldberg, Jerald M., and others, 1965, World distribution of soil, rock, and vegetation: TEI-865. This report was released in the open files of the Survey Library in Reston, Virginia and copies are available from Mr. Jack Rachlin, U. S. Geological Survey, National Center 928, Reston, Virginia 22092.

We appreciate the opportunity to review and comment on this statement and hope that these remarks will be of assistance to you in developing the final environmental statement.

Sincerely yours,

Stanley R Doremus

Deputy Assistant Secretary of the Interior

Dr. Billy E. Welch
Special Assistant for Environmental
Quality
Department of the Air Force
Washington, D. 20330

APPENDIX K

COMMENTS FROM UNITED STATES NUCLEAR REGULATORY COMMISSION

K-1

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

AUG 4 1975

Mr. Billy E. Welch, Ph.D
Special Assistant for
Environmental Quality
Department of the Air Force
Washington, D. C. 20330

Dear Mr. Welch:

This is in response to your letter of June 2, 1975, inviting our comments on the Draft Environmental Statement on the Lincoln Experimental Satellites 8 and 9 Programs.

We have reviewed the statement and present the following comments:

K-1 1. The DES lacks indication that an adequate safeguard program will be implemented to protect the approximately 30 kilograms of plutonium 238 during R.T.G. fabrication, transportation and storage.

K-2 2. The DES also lacks discussion of the health physics monitoring program that will be in effect during R.T.G. storage and installation at the Cape Canaveral launch site.

K-3 3. §4.3.4 classifies the risk identified in the last paragraph of §4.3.3 as avoidable on the basis that retrieval from orbit capability is being developed. The document would be strengthed if an estimated cost of retrieval were given.

K-4 4. Reference 26 (The Tamplin-Cochran paper submitted to support an NRDC petition concerning "Hot Particle" standards) is not an adequate reference to establish that plutonium in a wound could cause cancer, as implied in §3.2.3, Paragraph 2. Letters from the attending physicians in the two alleged cases are on file in the NRC Public Document Room and disagree with such an interpretation.

K-5 5. We would note that NCRP Report Number 43, issued January 15, 1975, supports further the position espoused in Appendix B, §B.1.4 concerning misuse of the linear response hypothesis and could be added as a reference.

AUG 4 1975

Thank you for providing us with the opportunity to review this Draft Environmental Statement.

Sincerely,

Daniel R. Muller

Daniel R. Muller, Assistant Director
for Environmental Projects
Division of Reactor Licensing

cc: Dr. Gerald Brubaker
Council on Environmental Quality
Executive Office of the President
722 Jackson Place, N. W.
Washington, D. C. 20006 (5)

Comment	Response
K-1	Reference revised Section 2.6 (page 20)
K-2	Reference revised Section 2.6 (page 20)
K-3	Reference revised Section 6.5 (page 61)
K-4	There was no intention to establish such a correlation. Reference revised Section 3.2.3 (page 31)
K-5	Reference revised Appendix B (page B-7)

APPENDIX L

COMMENTS FROM
UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
WASHINGTON, D.C. 20545

AUG 6 1975

Dr. Billy Welch
Department of the Air Force
Room 4D873, Pentagon
Washington, D. C. 20330

Dear Dr. Welch:

This is in response to Colonel Herbert E. Bell's memorandum of July 17, 1975, requesting comments on the Air Force's Draft Environmental Statement on the Lincoln Experimental Satellites 8 and 9 Program. The Statement has been reviewed by the Energy Research and Development Administration staff, and we have no further significant comments to offer on it.

We appreciate the opportunity to review the Statement.

Sincerely,

W. H. Pennington
Assessments and Coordination Officer
Division of Biomedical and Environmental Research

NO RESPONSE REQUIRED

APPENDIX M

COMMENTS FROM UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

AUG 12 1975

Dr. Billy Welch, SAF/ILE
Office of the Secretary of the Air Force
Washington, D.C. 20330

Dear Dr. Welch:

The Environmental Protection Agency has reviewed the draft environmental statement on the Lincoln Experimental Satellites 8 and 9 (LES 8/9) Program and is pleased to provide you with our comments.

General Comments

The draft environmental statement for the LES 8/9 Program is by far the most complete statement issued for a radioisotopic powered spacecraft reviewed by EPA since the inception of the NEPA process. Although we have identified certain areas where we believe more information should be included and with which we do not completely agree, nevertheless, we believe that it reflects a forthright attempt at presenting a discussion of all of the potential impacts and acknowledges those areas in which uncertainty still exists.

M-1 The draft environmental impact statement does not provide a sufficient assessment of potential health effects impacts from plutonium releases for either the abort or premature reentry conditions, and therefore does not provide an adequate basis for a cost-benefit evaluation. We recognize the possibility of restrictions based on national security considerations, but believe that a major deficiency exists in this area. In the absence of a more complete rationale for the lack of this information, we believe that the total range of potential environmental impacts must be addressed.

Plutonium - Risk Assessment

The draft environmental impact statement does not contain an analysis of the consequences of accidents which could release plutonium to the environment. For each accident which has the potential for releasing plutonium to the environment, the following information should be presented:

M-1 (1) the environmental levels of plutonium which may result from such accidents;

(2) The potential individual and population dose commitment arising from these levels of plutonium, including both the direct dose and the dose through environmental pathways; and

(3) The number of people who may be exposed and the resultant cumulative number of health effects.

M-2 We understand that the numerical values for both the probability of release and the source term given in Table 6 have been revised since the draft statement was prepared. The revised values are required for a realistic evaluation of the potential consequences of accidents and should be used in preparing the final statement.

Plutonium - Bioeffects and Standards

M-3 The discussion of the biological effects in man resulting from exposure to plutonium is grossly deficient. In performing the risk assessment mentioned above, we suggest that reference be made to the very extensive material developed in WASH-1535 LMFBR EIS on the subject of the transport of plutonium in the biosphere and its potential biological effects in man.

M-4 The information presented in Appendix B relative to plutonium standards may be misleading. The National Council on Radiation Protection and Measurements (NCRP) and the International Commission on Radiological Protection (ICRP) issue recommendations but do not promulgate statutory regulations or standards. The functions of the former Atomic Energy Commission pertaining to the establishment of generally applicable environmental standards, as well as the functions of the former Federal Radiation Council, were transferred to the U.S. Environmental Protection Agency by Reorganization Plan No. 3 of 1970.

M-5 The discussion on the Linear Theory of Radiation Effects in the above appendix appears to be directed to the non-applicability of the linear non-threshold approach rather than to its prudent use in the establishment of standards. We believe the Federal position is the acceptance of this model for use in the establishment of standards, recognizing the uncertainties in its use at low doses and low dose rates. A copy of our recent policy statement concerning the relationship between radiation dose and effect is enclosed for your information.

M-6 The section on health effects implies a condemnation of the policy of considering health effects, without which the trade-offs between potential health risks for various alternatives cannot be made. It is recommended that the policy of considering health effects be employed in the evaluation of the potential biological impact of the LES 8/9 Program.

Ground Transportation Accidents

M-7 The information presented in the draft statement regarding ground transportation accidents is not adequate to support a conclusion concerning the acceptability of such transportation. Two safety analysis reports for shipping containers were referenced which apparently contain evaluations regarding the capability of the containers to maintain their integrity under the specified accident test conditions. However, no information was presented as to the relationship of the test conditions to actual accident conditions which may be experienced in the transport of the LES 8/9 RTG's. In addition, no estimate was presented regarding the probability of an accident occurring during ground transportation of the heat sources or RTG's. In our opinion, there is a finite probability, although small, that a shipping accident involving the release of plutonium could occur during ground transportation. The final statement should include a more complete discussion of this subject.

Alternate Power Sources

M-8 It was stated in the draft statement that all alternatives to the use of plutonium fueled RTG's were explored in great detail; however, the detailed discussion of the cost-benefit balance of the various alternatives were not presented. The discussion of all alternatives, which could satisfy the mission requirements, should be sufficiently complete to enable the public to understand how the benefits and costs were brought into balance for each evaluated alternative. The discussion of acceptable alternative power sources should be expanded in the final statement with the presented cost-benefit analysis quantifying to the fullest extent practicable the various factors considered. This discussion of the rationale for the specific RTG's selected is extremely important because of the potential environmental impact from the plutonium, whereas the use of other alternatives, such as solar cells, could avoid this potential radiological risk.

Miscellaneous Comment

M-9 In section 3.1.2, one consistent set of units expressing concentration should be used to permit the comparison intended. Further, the concentration units of the number "6×10^{-7}" should be stated.

In accordance with EPA procedures, we have classified the LES 8/9 Program as ER (Environmental Reservations) and rated the draft statement as Category 2 (Insufficient Information). We will be pleased to discuss our comments and the classification with you or a member of your staff.

Sincerely yours,

Sheldon Meyers

Sheldon Meyers
Director
Office of Federal Activities (A-104)

Enclosure

POLICY STATEMENT

Relationship Between Radiation Dose and Effect

Office of Radiation Programs
Office of Air and Waste Management
U.S. Environmental Protection Agency
Washington, D. C. 20460

ISSUED: March 3, 1975

EPA Policy Statement on Relationship Between Radiation Dose and Effect

The actions taken by the Environmental Protection Agency to protect public health and the environment require that the impacts of contaminants in the environment or released into the environment be prudently examined. When these contaminants are radioactive materials and ionizing radiation, the most important impacts are those ultimately affecting human health. Therefore, the Agency believes that the public interest is best served by the Agency providing its best scientific estimates of such impacts in terms of potential ill health.

To provide such estimates, it is necessary that judgments be made which relate the presence of ionizing radiation or radioactive materials in the environment, i.e., potential exposure, to the intake of radioactive materials in the body, to the absorption of energy from the ionizing radiation of different qualities, and finally to the potential effects on human health. In many situations the levels of ionizing radiation or radioactive materials in the environment may be measured directly, but the determination of resultant radiation doses to humans and their susceptible tissues is generally derived from pathway and metabolic models and calculations of energy absorbed. It is also necessary to formulate the relationships between radiation dose and effects; relationships derived primarily from human epidemiological studies but also reflective of extensive research utilizing animals and other biological systems.

Although much is known about radiation dose-effect relationships at high levels of dose, a great deal of uncertainty exists when high level dose-effect relationships are extrapolated to lower levels of dose, particularly when given at low dose rates. These uncertainties in the relationships between dose received and effect produced are recognized to relate, among many factors, to differences in quality and type of radiation, total dose, dose distribution, dose rate, and radiosensitivity, including repair mechanisms, sex, variations in age, organ, and state of health. These factors involve complex mechanisms of interaction among biological chemical, and physical systems, the study of which is part of the continuing endeavor to acquire new scientific knowledge.

Because of these many uncertainties, it is necessary to rely upon the considered judgments of experts on the biological effects of ionizing radiation. These findings are well-documented in publications by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the National Academy of Sciences (NAS), the International Commission on Radiological Protection (ICRP), and the National Council on Radiation Protection and Measurements (NCRP), and have been used by the Agency in formulating a policy on relationship between radiation dose and effect.

It is the present policy of the Environmental Protection Agency to assume a linear, nonthreshold relationship between the magnitude of the radiation dose received at environmental levels of exposure and ill health produced as a means to estimate the potential health impact of actions it takes in developing radiation protection as expressed in criteria, guides, or standards. This policy is adopted in conformity with the generally accepted assumption that there is some potential ill health attributable to any exposure to ionizing radiation and that the magnitude of this potential ill health is directly proportional to the magnitude of the dose received.

In adopting this general policy, the Agency recognizes the inherent uncertainties that exist in estimating health impact at the low levels of exposure and exposure rates expected to be present in the environment due to human activities, and that at these levels the actual health impact will not be distinguishable from natural occurrences of ill health, either statistically or in the forms of ill health present. Also, at these very low levels, meaningful epidemiological studies to prove or disprove this relationship are difficult, if not practically impossible, to conduct. However, whenever new information is forthcoming, this policy will be reviewed and updated as necessary.

It is to be emphasized that this policy has been established for the purpose of estimating the potential human health impact of Agency actions regarding radiation protection, and that such estimates do not necessarily constitute identifiable health consequences. Further, the Agency implementation of this policy to estimate potential human health effects presupposes the premise that, for the same dose, potential radiation effects in other constituents of the biosphere will be no greater. It is generally accepted that such constituents are no more radiosensitive than humans. The Agency believes the policy to be a prudent one.

In estimating potential health effects it is important to recognize that the exposures to be usually experienced by the public will be annual doses that are small fractions of natural background radiation to at most a few times this level. Within the U.S. the natural background radiation dose equivalent varies geographically between 40 to 300 mrem per year. Over such a relatively small range of dose, any deviations from dose-effect linearity would not be expected to significantly affect actions taken by the Agency, unless a dose-effect threshold exists.

While the utilization of a linear, nonthreshold relationship is useful as a generally applicable policy for assessment of radiation effects, it is also EPA's policy in specific situations to utilize the best available detailed scientific knowledge in estimating health impact when such information is available for specific types of radiation, conditions of exposure, and recipients of the exposure. In such situations, estimates may or may not be based on the assumptions of linearity and a nonthreshold dose. In any case, the assumptions will be stated explicitly in any EPA radiation protection actions.

The linear hypothesis by itself precludes the development of acceptable levels of risk based solely on health considerations. Therefore, in establishing radiation protection positions, the Agency will weigh not only the health impact, but also social, economic, and other considerations associated with the activities addressed.

Comment	Response
M-1	In accordance with the practices of the INSRP, which reflect the NCRP position expressed in Section B.5 of Appendix B, such information is not available relative to the P74-1 Project. However, to the extent that one believes health effects estimations are meaningful, some perspective on this aspect of the risk associated with the P74-1 Project may be obtained by considering calculations performed in WASH-1535. One of the respirable plutonium source terms considered in WASH-1535 was 800 millicuries, roughly comparable to the source terms listed in Table 6 (page 44) of this Statement. A comprehensive and conservative environmental pathway analysis was performed to convert this source term into population dose commitments (in man-rem) over 70 years to the lung, bone, liver, and gonads. A range of possible factors (all based on the linear, non-threshold dose-effect assumption) to convert dose commitments to numbers of potential health effects were then derived from data in National Academy of Science-National Research Council, The Effects on Populations of Exposure to Low Levels of Ionizing Radiation. When applied to the dose commitments associated with the 800 millicurie source term, this range of factors yielded a range total possible health effects (both somatic and genetic) that varied from less than one health effect to a maximum of three health effects. Although there would be several differences in a similar analysis performed for the P74-1 potential plutonium releases, the result from WASH-1535 would appear to be roughly comparable to the largest number of health effects which could be associated with the P74-1 Project.
M-2	Reference revised Table 6 (page 44).
M-3	No biological effects in man have been attributed to exposure to plutonium. Reference has been made to the material of WASH-1535 both in the body of the Statement and in the response to comment M-1.
M-4	Reference revised Section 3.2.4 (page 32) and revised Appendix B, Section B.2 (pages B-2 and B-3).
M-5	The discussion on the Linear Theory of Radiation Effects in Section B.5 of Appendix B has been rewritten to reflect the position of the EPA as well as that of the NCRP.

M-6 The policy of performing linear dose-effect, non-threshold health effects estimations is questioned. It is not certain that the health effects would reflect the potential situation and could lead to erroneous conclusions. As such they were not performed for this project.

M-7 Reference revised Appendix C, Section C.1 (page C-2).

M-8 Reference revised Section 6.6 (page 62)

M-9 Reference revised Section 3.1.2 (page 24)