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

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R. HEACOCK

November 27, 1974

Mission Design Environmental Statement

REPLY TO
ATTN OF: SL

Mr. Ray Heacock
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91103

Dear Ray:

A copy of the Environmental Statement for the Mariner Jupiter/ Saturn 1977 (MJS77) Program has been sent to you under separate cover.

Sincerely yours,

Arthur Reetz /s/

Arthur Reetz
Program Engineer
Outer Planets Missions

ENVIRONMENTAL STATEMENT

for the

MARINER JUPITER/SATURN 1977 PROGRAM

FINAL STATEMENT

OCTOBER 1974

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON, DC 20546

(NASA-TM-79736) ENVIRONMENTAL STATEMENT FOR THE MARINER JUPITER/SATURN 1977 PROGRAM Final Statement (National Aeronautics and Space Administration) 42 p

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ENVIRONMENTAL STATEMENT

for the

MARINER JUPITER/SATURN 1977 PROGRAM

FINAL STATEMENT

OCTOBER 1974

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON, DC 20546

SUMMARY

( ) Draft (X) Final Environmental Statement

Responsible Federal Agency: National Aeronautics and Space Administration
Washington, D.C. 20546

Official Contact: Mr. Warren Keller, Program Manager
Outer Planets Missions/Code SL
NASA Headquarters
Washington, D.C. 20546
Phone (202) 755-3790

1. NAME OF ACTION: (X) Administrative Action
   ( ) Legislative Action

2. BRIEF DESCRIPTION: The Mariner Jupiter/Saturn 1977 Program is a continuation of a series of planetary and interplanetary space exploration missions using unmanned spacecraft. Two spacecraft will be launched in 1977 by Titan/Centaur launch vehicles from Cape Canaveral, Florida, to the vicinity of the planets Jupiter and Saturn.

3. SUMMARY OF ENVIRONMENTAL EFFECTS: There are insignificant adverse environmental effects from the products of the launch vehicle and from the radioisotope thermoelectric generators in the spacecraft.

4. SUMMARY OF MAJOR ALTERNATIVES CONSIDERED: No alternate launch vehicle is available at this time. However, alternate power sources for the spacecraft such as solar cells, nuclear reactors, fuel cells, and batteries were considered.

5. COMMENTS:
   a. Comments requested from: EPA, DoD, Dept. of State, Dept. of Commerce, and the AEC.
   b. Comments received from: EPA, Dept. of State, and the AEC.

6. SUBMITTAL DATE:
   a. Final Environmental Statement submitted to CEQ and made available to the public in November 1974.
   b. Draft Statement to CEQ in June 1973.

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1.0 PROGRAM DESCRIPTION AND OBJECTIVES

The Mariner Jupiter/Saturn 1977 (MJS77) Program is sponsored by the Planetary Programs Office, Office of Space Science (OSS), of the National Aeronautics and Space Administration (NASA) with overall project management responsibility assigned to the Jet Propulsion Laboratory.

The mission involves the launch of two identical Mariner-type spacecraft in August and September of 1977 using two Titan III-E/Centaur D-IT launch vehicles. The mission has important scientific objectives related to each of the target planets, some of their satellites, and the inter-planetary space between and beyond the planets. Mariner-type spacecraft, designed specifically for the outer planet missions, will be launched by the Titan/Centaur vehicles. The mission objectives of each flight will differ to the degree necessary to maximize the total science return from the mission.

The mission consists of a series of planetary encounters over intervals of several years. Time between planetary encounter is spent in utilizing the science instruments to gather interplanetary data as the spacecraft traverses regions progressively farther removed from the influence of the sun. Trajectory correction maneuvers will be performed prior to closest approach at each planet.

The overall science objectives of the program are to conduct exploratory investigations of the Jupiter and Saturn planetary systems and of the interplanetary medium out to Saturn. Primary emphasis will be placed on the conduct of comparative studies of the Jupiter and Saturn systems by obtaining measurements of the environment, atmosphere, surface and body characteristics of the planets and one or more of the satellites of each planet; studies of the nature of the rings of Saturn; and exploration of the interplanetary (or interstellar) medium at increasing distances from the sun.

2.0 LAUNCH VEHICLE AND SPACECRAFT DESCRIPTION

This section provides a description of the launch vehicle and the spacecraft.

2.1 Launch Vehicle - The launch vehicle for this mission will be a Titan III-E/Centaur D-IT combination using the 4.26 meter (14 ft) diameter Centaur Standard Shroud. Launches will be conducted from Launch Complex 41 at Cape Canaveral Air Force Station, Florida, using the capabilities of the Integrate-Transfer-Launch Concept, the Vertical Integration Building, and the Solid Motor Assembly Building to the maximum extent possible within the requirements of these missions. This vehicle configuration is managed for NASA missions by the Lewis Research Center, Cleveland, Ohio.

The Titan III-E configuration for these missions consists of three stages: two solid rocket motors that ignite simultaneously at launch and boost the space vehicle off the launch pad, and two liquid bipropellant stages (Titan Stages I and II) that ignite consecutively to further accelerate the space vehicle. The Titan stages are guided by the Centaur guidance system from shortly after liftoff.

The Centaur stage has two thrusting periods for these missions. The first accelerates the space vehicle into a 167 kilometer (90 nautical miles) altitude parking orbit. The second, after the desired coast period, further accelerates the combination toward the required planetary trajectory. The Centaur stage is left in a heliocentric orbit following spacecraft separation.

2.2 Description of Near-Earth Trajectories - Figure 1 depicts the envelope limits of the instantaneous impact points for the currently planned launch azimuth range of from 95° to 108° (measured east of north), for the two Mariner Jupiter/Saturn 1977 launch vehicles. The impact points are shown for the following launch vehicle jettison hardware:

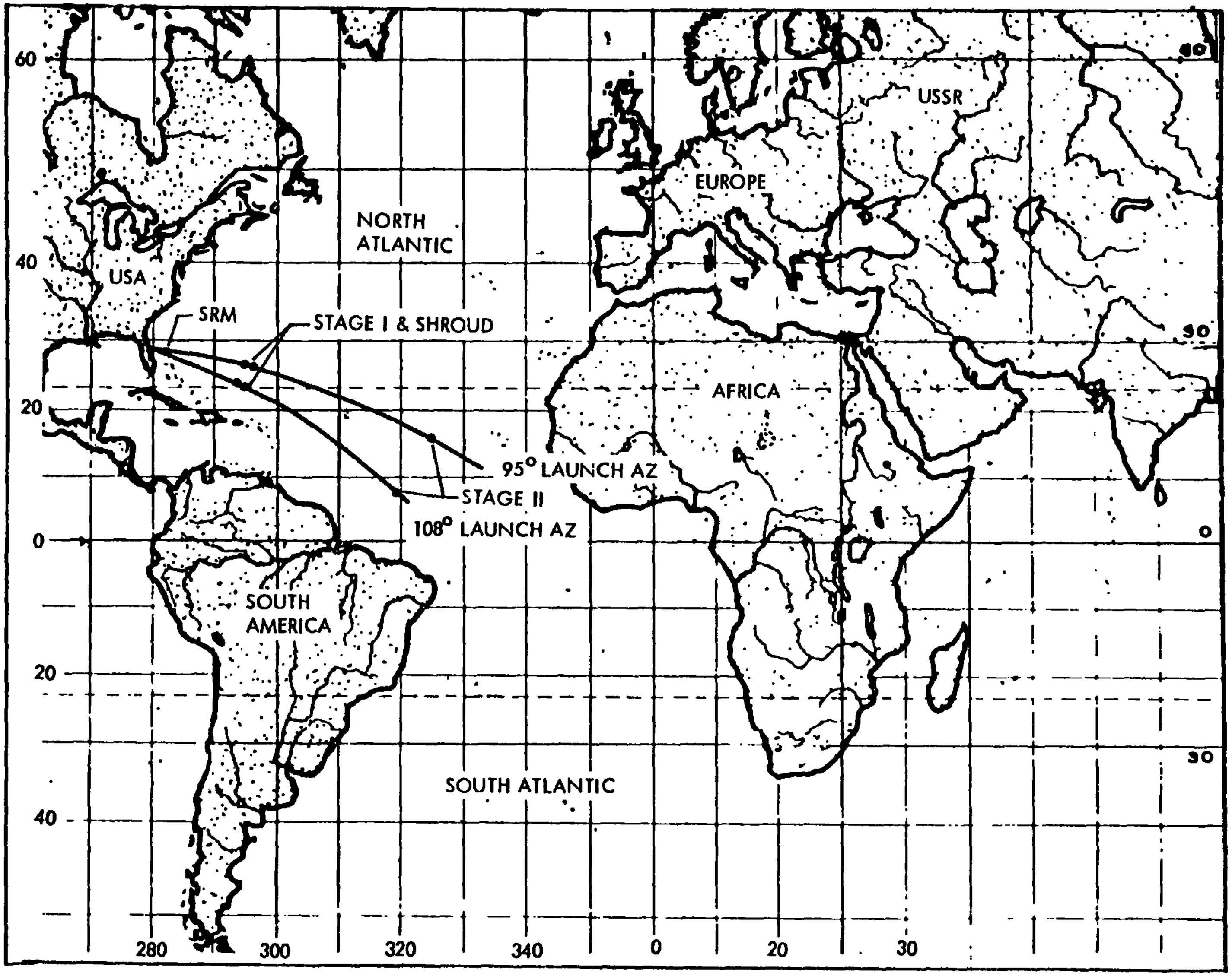

FIGURE 1 - Envelope of Instantaneous Impact Points for the Mariner Jupiter/Saturn 1977 Launch Vehicles

1. Titan Solid Rocket Motors (SRM)
2. Titan Stage I
3. Centaur Standard Shroud
4. Titan Stage II

The vehicle impact points traverse an area entirely over the ocean. After jettison of Titan Stage II and a portion of the Centaur first burn, the Centaur and attached payload will have achieved orbital velocity.

2.3 Spacecraft

2.3.1 Description of Spacecraft - The Mariner Jupiter/Saturn spacecraft weighs 2010 kilograms (4432 lb). The following subsystems will contribute the bulk of the material which could have a potential environmental impact:

2.3.1.1 Structure Subsystem - The structure subsystem consists of a ten-sided frame assembly approximately 1.79 meters (5.9 ft) across and 0.45 meters (1.48 ft) high. The design is anticipated to be based heavily on the Mariner and Viking Orbiter spacecraft used in previous interplanetary missions. The bus structure, which has ten electronic chassis bays, provides primary structural attachments and alignment for a high gain antenna 3.66 meters (12 ft) in diameter, propulsion assembly, radioisotope thermoelectric generator (RTG) deployable boom, science instruments boom and platform, star trackers, launch vehicle adapter, attitude control gas assemblies, and bus mounted science.

2.3.1.2 Power Subsystem - Three multi-hundred watt (MHW) radioisotope thermoelectric generators (RTG's) provide the electrical power to operate the electronic equipment on board the spacecraft. A conceptual drawing of the MHW/RTG is shown in Figure 2. The RTG's which are in a stowed position for launch, are mounted on a deployable boom which will extend well beyond the perimeter of the antenna after launch to reduce radiation interference with scientific instruments. Transient spacecraft power requirements which exceed the capability of the RTG power source will be met by the use of a capacitor bank.

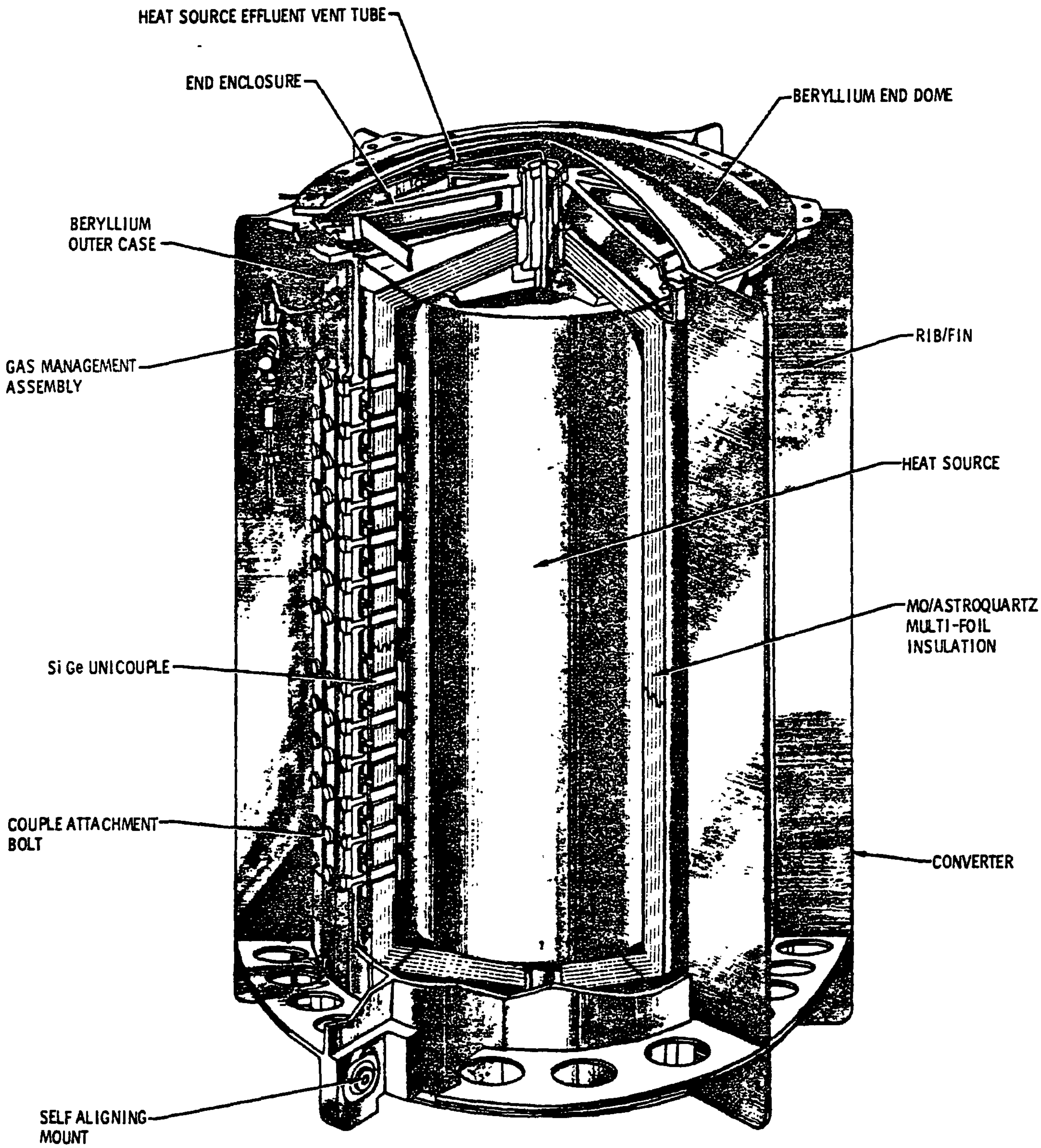

FIGURE 2 - MHW Radioisotope Thermoelectric Generator

Each sealed radioisotope thermoelectric generator has within it a heat source, shown pictorially in Figure 3, consisting of a reentry aeroshell and 24 independent self-contained modular fuel elements. Each modular fuel element is a multi-layed sphere containing a 252 gram (0.554 lb) solid ceramic sphere of pressed plutonium dioxide (PPO). Each fuel sphere provides an initial thermal power of 100 $\pm$ 2 watts. The thermal output is due to the radioactivity of the ^{238}Pu (plutonium isotope 238) fuel. The radioactivity of each fuel sphere is about 3340 curies. (The bulk of activity, 3100 curies, is due to ^{238}Pu with a half-life of 86.4 years and the remainder to other isotopes of plutonium; viz., 102 curies of ^{241}Pu, half-life 13 years; 2.1 curies of ^{239}Pu, half-life 24,900 years; and 1.5 curies of ^{240}Pu, half-life 6600 years.) The total fuel in the three RTG's is 18.2 kilograms (39.9 lb) of PPO with a total initial radioactivity of 240,000 curies.

The fuel sphere radiation is characterized by 5.4 million electron volt (MeV) alpha particles, a continuous gamma ray spectrum with less than 1% of the spectral energy contained in photons of over 3 MeV energy, and a continuous neutron spectrum peaking at approximately 1 MeV and with measured energy up to 10 MeV.

In addition to the fuel each fuel sphere assembly is comprised of a 0.05 centimeter (0.20 inch) thick iridium post impact containment shell which is vented for helium release and a 1.17 centimeter (0.460 inch) thick graphite impact shell. The graphite impact shell provides impact protection to the fuel sphere and its post impact containment shell under conditions associated with impact at heat source terminal velocity. In the event of an abnormal launch resulting in reentry and Earth impact, the post impact containment shell is designed to provide containment of the fuel for a period of a least one year after a reentry event. The post impact containment shell 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.

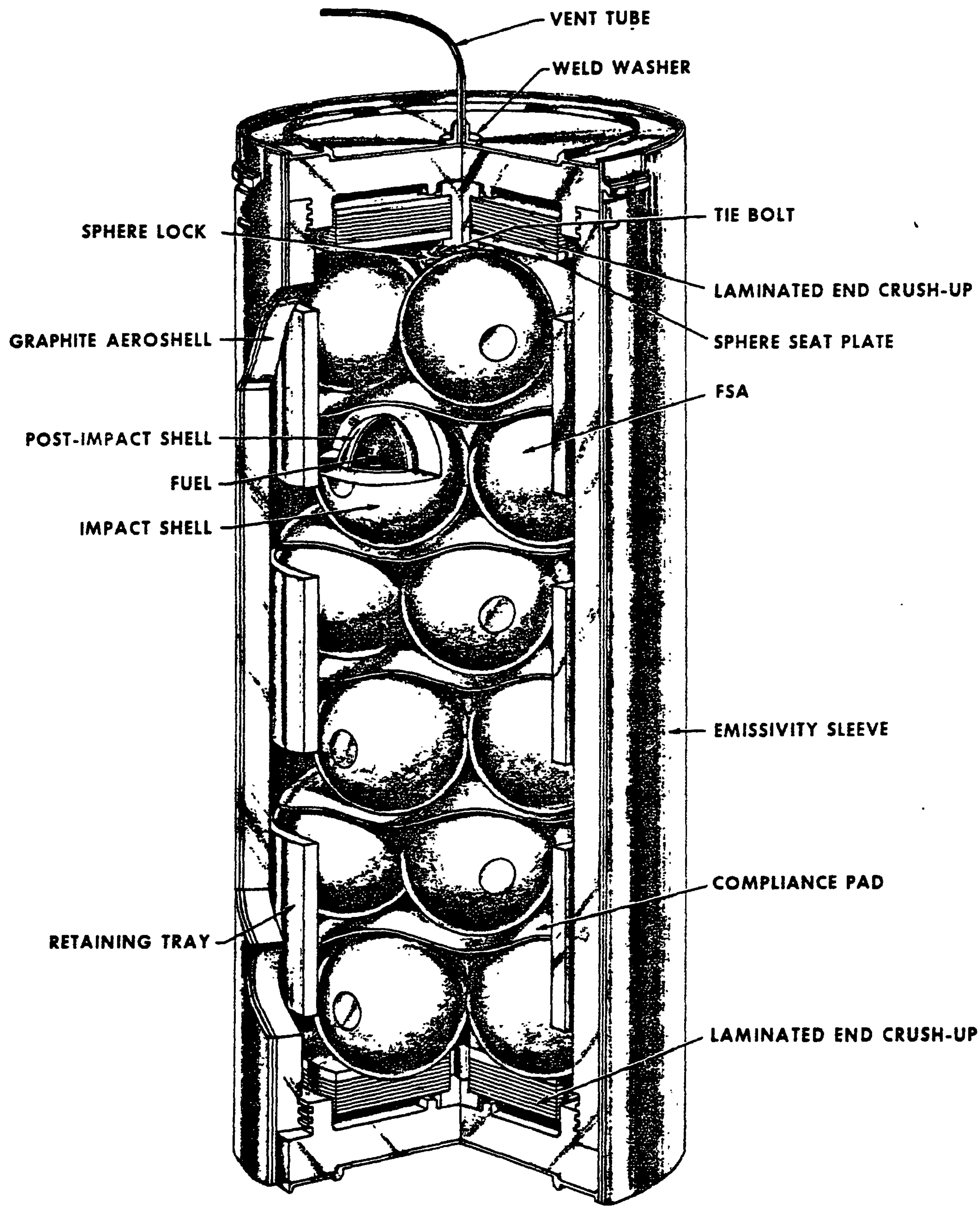

FIGURE 3 - MHW Heat Source Configuration

The modular fuel elements are arranged in six planes of four spheres each and are held in place in groups of eight by segmented graphite retaining rings with conical seats (Figure 3). Woven graphite cloth compliance pads are positioned between each modular fuel element assembly plane to achieve a tight fit. The three graphite ring assemblies are inserted into a graphite reentry aeroshell cylinder. At both ends of the retaining ring assemblies, graphite crush-up material is provided for additional impact protection. End caps complete the assembly. The graphite reentry aeroshell acts as the primary heat source structural member as well as providing the protection required by the individual modular fuel elements during the aerothermodynamic heating encountered during an abort suborbital, orbital, or superorbital reentry.

The heat source is surrounded by the thermoelectric converter. The converter consists of beryllium outer case with beryllium pressure end domes, internally mounted titanium heat source supports, silicon germanium thermocouple unicouple assemblies which attach through the outer case, molybdenum/Astroquartz multifoil insulation, and peripheral components and end assemblies. The beryllium outer case is the primary structural member of the RTG and is used for attachment to the spacecraft structure and for radiating waste heat from the generator. The total weight of the beryllium used in each generator is 4.88 kilograms (10.73 lb). The outer case and pressure domes are machined from beryllium HP-10, in hot pressed block form.

2.3.1.3 Propulsion Subsystem - This subsystem consists of a solid rocket motor to inject the spacecraft into the required interplanetary trajectory. After injection, the solid motor case is separated from the spacecraft. The solid motor is the TE-M-364-4 as used on the Pioneer Jupiter mission and is discussed in Reference 1. About 16 hydrazine monopropellant engines are provided for thrust vector control during the solid motor operation and for trajectory correction and attitude control during the interplanetary cruise and planetary encounter. A single hydrazine tank supplies all the engines and remains with the spacecraft after separation. The tank contains about 88.7 kilograms (195 lb) of hydrazine and 0.5 kilograms (1.1 lb) of helium pressurant.

2.3.1.4 Temperature Control Subsystem - This subsystem is comprised of those items whose primary function is to maintain spacecraft temperature within acceptable limits. To minimize the use of electrical power for thermal control, radioisotope heater units (RHU's) are used to supply heat for the sun sensors, the magnetometer sensors, attitude control jet assemblies, etc. Current plans call for nine 1-watt (thermal) RHU's for each spacecraft. Except for the form of the fuel, the RHU's will be structurally identical to the 1-watt RHU's used on the Pioneer Jupiter mission. For Pioneer, each heater contained 30 curies of ^{238}Pu in the form of plutonia molybdenum cermet (PMC). For MJS77, each RHU will contain 30 curies of ^{238}Pu as shard plutonium dioxide (PPO). The PPO is contained in a fuel capsule consisting of a 0.508 millimeter (0.02 inch) tantalum 10% tungsten liner which is encased in a 1.016 millimeter (0.04 inch) T-111 strength member. The strength member is sealed within a 0.254 millimeter (0.01 inch) platinum rhodium clad. The fuel capsule is in a reentry heat shield consisting of pyrolytic and POCO graphites which will protect the capsule should it be subjected to a reentry heat pulse.

2.3.1.5 Subsystems Containing Electronics, Electrical Equipment, and Cabling - The radio, computer command, data and cabling subsystems, as well as subsystems mentioned above, contain devices, materials, and electronics equivalent to or based on the designs used for Pioneer and Viking unmanned planetary spacecraft. As shown in their impact statement, the possible effects on the environment by these subsystems are negligible.

3.0 ASPECTS OF THE PROGRAM WHICH MAY AFFECT ENVIRONMENTAL QUALITY

Aspects of the Mariner program which may affect environmental quality will be discussed in two areas: those related to the launch vehicle and those related to the spacecraft.

3.1 Launch Vehicle - An environmental statement covering potential environmental effects of NASA/OSS launch vehicles already exists (Reference 1). The stages of the Titan/Centaur configuration used in the Mariner Jupiter/Saturn 1977 missions are sufficiently discussed in Reference 1 that additional analyses and discussions are not deemed to be warranted here.

3.2 Spacecraft - The discussion of potential environmental impact resulting from spacecraft activities is broken down into that relating to normal launches and that relating to abnormal launches.

3.2.1 Normal Launch - The normal launch will result in the launching of a Mariner spacecraft on a trajectory which will leave the vicinity of the Earth and never return. Thus, the normal launch poses no risk to man or to man's Earth environment.

During the prelaunch and launch operations, operational personnel may be exposed to direct gamma and neutron radiation from the RTG's and the RHU's. The exposure to these personnel will be minimized by the use of shielding and by limiting work times around the generators and heater units. This will limit the exposures of individuals to levels that will not exceed those limits (Reference 2) recommended by the National Committee for Radiation Protection and the Federal Radiation Council (now part of the Office of Radiation Programs, Environmental Protection Agency.)

3.2.2 Abnormal Launch - Abnormal launches resulting in impact of the Earth by spacecraft debris, or scattering of debris at or near the launch site, will result in exposure of the environment to:

1. Electronic and electrical equipment including cabling (less than 150 kilograms)

2. Structure, Mechanical Devices, Antenna (about 400 kilograms)

3. Hydrazine Propellant (88.7 kilograms)

4. TE-M-364-4 Motor

5. Radioisotope Thermoelectric Generators

6. Radioisotope Heater Units

The effects on the environment of the first three items will be less than from the Earth impact of the launch vehicle. The conclusion of the Launch Vehicle Environmental Impact Statement that there are insignificant adverse environmental effects can be extended to these three spacecraft items. As discussed in Reference 3, the TE-M-364-4 motor has insignificant effects on the environment.

Potential environmental impact due to the radioactive fuel elements of the RTG's and RHU's and the beryllium outer case of the RTG must be considered for abnormal launches which result in dispersal of these substances. Dispersal may be due to atmospheric entry heating, impact in the ocean or on land, or corrosion.

In the case of the RHU's, detailed safety studies performed for those on the Pioneer spacecraft (Reference 3) led to the conclusion that it is virtually impossible to have fuel releases from the heaters. The MJS RHU's are structurally identical to the Pioneer heaters; therefore, they do not impose any risk to people and the environment when considered with the probabilities and consequences of potential accidents. The Mariner Jupiter/Saturn 1977 RHU's are being designed with safety considerations similar to those used for the Pioneer RHU's.

On the basis of previous spaceflight experience, preliminary Titan/Centaur abort environment data have been developed (Reference 4). The predicted probability of achieving a normal launch is approximately 0.94. Those abnormal launches where the spacecraft escapes from the gravitational attraction of the Earth will not involve any environmental impact different from a normal launch. The probability of occurence for mission failure involving earth escape is about

0.01. Therefore, the probability that a radioactive system will not return to earth is about 0.95.

The probability of a failure near the launch pad is less than 0.001. The RTG has been designed to withstand the most severe environment at the launch site. Therefore, in the event an abort, including launch vehicle destruct, occurs with impact in the launch area the plutonium fuel capsule is expected to survive with no release of the radioactive material. Following recovery, the capsule will be returned to the U. S. Atomic Energy Commission for reprocessing and rease of the fuel.

There is no credible sequence of events for which nuclear criticality would be possible for the RTG fuel. 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 5). In order for nuclear criticality to occur, the fuel spheres would have to be melted, at least 8.6 kilograms 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.

An extensive safety testing program is being conducted to determine the response of the MHW heat source and to demonstrate the integrity of radioisotope containment when exposed to the most severe launch and reentry environments. These environments include: launch dynamic environments, severe aerothermodynamic stresses due to atmosphere reentry, hard impact, booster explosion, and penetration from shrapnel on the launch pad. These tests are being performed by the Atomic Energy Commission in connection with their development program of the multi-hundred watt RTG's.

The testing program on the RTG's includes:

- Liquid propellant fire thermochemical effects
- Solid propellant fire effects

- Pad abort sequential tests
- Air drop tests
- Launch pad explosion effects
- Vibration tests
- Aerothermal tests
    - Impact velocity drop tests
    - Subsonic ablation tests
    - Hypersonic ablation tests
    - Thermal conductivity tests

In addition to these tests the following related tests and analyses are to be completed on the heat source and/or generator:

- Fuel characterization
- Material characterization
- Engineering tests
- Impact, reentry thermal response, ablation, terminal velocity

The results (Reference 6) of these tests, combined with previous tests and studies of the launch abort environments and their probabilities for previous similar systems, lead to the conclusion that the probability of radioactive fuel being released given an accident, is less than one chance in a thousand (<0.001). Since the probability of a launch pad abort is estimated at <0.001, the probability of fuel release due to a launch pad abort is less than one chance in a million ($<10^{-6}$). If any fuel is released only a small fraction would be respirable, and it is unlikely that anyone would receive a lung burden of as much as 0.005 microcuries (5 rem per year) the level established as the limit for the general public.

Of the remaining possible launch failures, about 0.03 will occur in the ascent phase resulting in ocean impact, and about 0.02 will result in earth orbital insertion. Following orbital decay, about 75% will impact in the oceans.

Thus, the most probable fate of returning to Earth will be impact in the ocean. In the event impact occurs early in flight, acoustic beacons ("pingers") located near the spacecraft on the Centaur launch vehicle will assist in locating the nuclear systems and returning them to radiological control if they are at recoverable depths.

The consequences of an RTG heat source impacting in the ocean where recovery is not possible has been investigated for the MJS77 program for the case where the entire fuel loading of the three MHW/RTG's was exposed to the ocean environment. Dissolution of plutonium in the seawater requires diffusion of the water into the fuel sphere assemblies, some dissolution followed by subsequent diffusion of the dissolved plutonium out of the fuel sphere assemblies. Because of the very low rate of dissolution of the PPO fuel, such a series of events would take hundreds of years and during the same time the radioactive ^{238}Pu would be decaying to somewhat less hazardous materials.

Experimental results (Reference 6) for the PPO fuel used in the MHW/RTG yield an extremely low solubility in seawater, about 0.0068 microcuries per square millimeter per day. This amount is equivalent to a dissolution rate of 0.09 micrograms of ^{238}Pu per gram of PPO per day. Comparative analyses show that if a person were to obtain his entire annual protein diet from fish (72 kilograms) grown in the contaminated area, the calculated maximum annual intake of ^{238}Pu would be 0.024 microcuries. This is to be compared to a recommended maximum permissible intake of 4 microcuries per year (Reference 2). The conclusion drawn from the analyses is that the amount of ^{238}Pu which can possibly find its way into the marine biota on the human diet would be well within established limits.

The effects of radiation dose on marine organisms for the above case has also been analyzed. The highest Pu concentration factor that has been observed for marine animals was that for zooplankton reported by Pillai, et. al. (Reference 7). Taking the maximum seawater concentration of ^{238}Pu predicted by the Carter-Okubo shear diffusion model for a 0.0021 curie per day dissolution rate and assuming that plankton come to equilibrium with water having a ^{238}Pu concentration of 4.3×10^{-10} microcuries per cubic centimeter, the concentration of ^{238}Pu in the plankton would be 1.1×10^{-6} microcuries per gram. This activity concentration delivers approximately 110 millirads per year of alpha radiation to the plankton, which is some 2.7 times the estimated dose rate derived by consideration of cosmic rays and ^{40}K (Potassium isotope 40) in the seawater. The effects of such dose rates cannot be predicted accurately, but the biomass of plankton involved would be very small and no population effects would be expected.

A summary of the risks for internal exposure of radioactive RTG fuel for previous missions is shown in Table I, where probabilities for one or more individuals receiving an inhalation dose of ^{238}Pu greater than 0.016 microcuries are presented. Similar data will be available for the MJS77 mission when the MJS77 Safety Analyses are completed in the summer of 1976. Early assessments of the MJS77 mission based on its launch vehicle configuration, RTG structural integrity, the PPO iridium containment, and solubility of the plutonium oxide fuel indicate that the risks for previous systems are conservative, i.e. there would be less risk associated with the MJS77 mission.

The probability of releasing fuel and exposing anyone as the result of an on-pad abort is quite small (less than 1 in 10^6). To release fuel the RTG would have to be destroyed, a fuel capsule must fall next to a large piece of solid propellant, and the graphite and iridium containment must be breached. If all of these unlikely events occur, then a small quantity of fuel could possibly be vaporized. Inasmuch as the pad is a controlled area, the probability of exposing anyone is much less than 10^{-6}. The release of fuel as a result of aborts with impact away from the pad, but in the launch area, is even less likely because the solid propellant will be dispersed and less likely to be in the immediate vicinity of the RTG's.

To release fuel on reentry requires extreme conditions including high velocity, destruction of the reentry protection shell, ablation of the graphite impact shell, and impact on a

TABLE I

SUMMARY OF RISKS FOR RANDOM IMPACT

POPULATION DENSITY (PEOPLE/SQUARE MILE)	PROBABILITY OF ONE OR MORE INDIVIDUALS ACCUMULATING GREATER THAN 0.016 MICROCURIES IN THE LUNGS*		
	NIMBUS	APOLLO	PIONEER
0 - 1	8.1×10^{-4}	3×10^{-4}	3×10^{-4}
1 - 100	8.3×10^{-4}	6×10^{-4}	3×10^{-4}
100 - 500	8.5×10^{-5}	9×10^{-5}	5×10^{-5}
500 - 1000	1.4×10^{-5}	2×10^{-5}	1×10^{-5}
1000 - 5000	9.0×10^{-6}	6×10^{-6}	5×10^{-6}

* 0.016 microcuries, if maintained in the lungs, is equal to a radiation dose of 15 rem per year, the level established for radiation workers.

hard surface. Although one can assume these conditions, the expected mode of operation does not lead to significant fuel release. There may be small quantities of condensed plutonium outside the iridium containment on the graphite. However, this will not produce exposures to individuals unless the individuals become closely involved in handling or working with the hardware without protection.

The number of individuals who could be exposed to plutonium as a result of an abort and fuel release has been estimated to range from 0 to 50 receiving more than 0.005 microcuries lung burden and 0 to 1 receiving more than 0.016 microcuries. Obviously, the number of individuals involved and the level of exposure will be influenced by population densities, time of day, weather conditions, soil types, and many other related conditions. No meaningful model can be generated to select the actual location and conditions that would exist in the event of an abort.

Safety analyses and tests are being conducted by the U. S. Atomic Energy Commission in connection with their development program on the MHW/RTG. The first user of the MHW/RTG will be the U.S. Air Force on their Lincoln Experimental Satellite (LES 8&9) which will be launched during 1975. Two modifications of the LES RTG's will be made for the MJS77 spacecraft: (1) the iridium metal outer clad which surrounds the entire heat source assembly will be eliminated (iridium containment of each individual fuel sphere is retained), (2) the graphite reentry aeroshell will be redesigned. Tests and analyses indicate that the removal of the heat source iridium clad will not adversely affect radiological operational safety. In addition, the aeroshell redesign will improve the thermal protection to the RTG during possible reentry conditions.

Tests and analyses of the beryllium outer case of the RTG have been performed by the U. S. Air Force for their Lincoln Experimental Satellite Program (Reference 6). The probabilities of various launch vehicle failures which could lead to the release of beryllium to the atmosphere have been examined for the MJS77 Program. Beryllium can only be released as the result of a fire or reentry burnup. During reentry the beryllium will be released at high altitude and dispersed along a path hundreds of miles long. In the event a launch abort fire burns the beryllium, it will also disperse the beryllium. The total mass of beryllium which could be dispersed by a failure is 14.6 kilograms (32.2 lb). However, the mixing caused by the fire plus the normal atmospheric dispersion would reduce the quantity of beryllium deposited on a unit surface of soil or water to an acceptable level in comparison to the naturally occurring beryllium.

In order to ensure the safety of individuals, a Radiological Control Center will be in operation during the prelaunch, launch and ascent phases of the missions. The Center will be manned by safety and medical representatives from NASA, DoD, AEC and EPA and will be able to: rapidly determine if radioactive material has been released, assess the extent of radiological dispersion, direct evacuation of people, decontaminate, and remove radioactive material.

4.0 ALTERNATIVES

The Mariner Jupiter/Saturn Program has been designed with consideration of the scientific return from the spacecraft, the available launch vehicles, and the total cost of performing the mission.

4.1 Launch Vehicle - The Titan/Centaur launch vehicle proposed for the Mariner Jupiter/Saturn Program is the only medium class vehicle which is capable of launching the payload required to carry out the mission objectives. The only other choices among existing vehicles would involve a vehicle which would be more expensive, consume more resources, and contribute a greater amount of environmental pollution.

4.2 Spacecraft - A study of alternatives such as solar cells, nuclear reactors, fuel cells, and batteries concluded that radioisotope thermoelectric generators are the only practical source of power that can be used on the Mariner Jupiter/Saturn spacecraft.

The considerations dictating the use of RTG power in the Mariner spacecraft were; (1) passage through the asteroid belt (low cross section), (2) operation in a Saturn solar flux some 100 times less than that in Earth orbit, (3) operation in the intense radiation field of Jupiter, (4) a requirement that the power supply operate at least 4 years after launch at Saturn encounter and if possible several years after Saturn encounter, (5) availability of systems with low weight-to-power ratios, and (6) maximum reliability.

Solar cells cannot meet requirements (1) through (4) stated above. Batteries and fuel cells cannot meet requirements (3) through (6). Nuclear reactors cannot meet requirement (5) for the power levels needed. Thus, the alternatives are obviously RTG power or abandonment of Mariner missions and other future outer planet missions.

5.0 THE RELATIONSHIP BETWEEN THE LOCAL SHORT-TERM USES OF THE ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

The Mariner Jupiter/Saturn missions represent passive payloads which in themselves have no adverse environmental impact aside from that associated with items in space, reentry items, and the launch process. Reentry items and the launch process represent minor transient effects while items remaining permanently in outer space have no impact on the Earth and its atmosphere.

It is expected that local short-term use of the environment in this program will provide cumulative and long-term beneficial effects by virtue of the knowledge which will accrue from the scientific experiments.

Flyby missions to Jupiter and Saturn provide the means of meeting two major scientific objectives: (1) remote sensing of the atmospheres and the surfaces of planets and satellites and (2) determination of the particles and field environment of these planets.

The atmospheric investigations include the identification of the major constituents and a determination of their relative abundance in planetary and satellite atmospheres. Atmospheric objectives also include determination of temperatures and pressures, checks of the radiation (thermal) balance, and investigations of atmospheric dynamics and cloud structure. Surface investigations of the satellites are primarily directed toward the recognition of surface features (mountains, craters, etc.) and the characterization of the surface composition (rock, dust, ice, etc.).

The particles and fields objectives of the mission are to determine the structure of planetary magnetic fields and to study the interaction of the planets with the plasma (solar wind) environment. Additional objectives are to study the wave-particle interactions associated with the trapping acceleration, diffusion and precipitation of charged particles, and to investigate the electromagnetic environment of the planets and satellites. Interplanetary objectives include studies of the interaction of the solar wind and the interstellar medium, and of the properties of galactic cosmic rays and the interstellar gas.

The Jovian Planets, Jupiter and Saturn, have strong relevance to the study and understanding of the origin and evolution of the solar system and should aid in understanding the processes that shape man's environment. There are marked differences between the Jovian Planets and the more familiar terrestrial planets that must be investigated for understanding of planetary evolution. With their differences in mass and density, atmospheric composition and circulation, and exposure to solar radiation, Jupiter and Saturn can provide significant new data on the physical processes at work on the Earth. The interplanetary medium and the reaches of space beyond the planetary orbits are also important to be investigated because they too can provide valuable clues to the development of the solar system and the environment of man.

The data return from each planet and satellite flyby is expected to exceed that returned from Mars by Mariners 6 and 7. The results will represent significant advances in knowledge of these planets, advances obtainable in no other way than by direct close-up observation.

For Jupiter and Saturn, the initial experiments will provide the elements of knowledge that will block out a fundamental model of each planet, offering a major step in understanding, and providing a basis for designing the more penetrating experiments to be performed by follow-on orbiters and probes. Data from the satellites, notably pictures that reveal their surface topography, may provide considerable insight into solar system history.

6.0 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

The launch vehicle and spacecraft consist of materials which are irretrievable once the launch process is initiated. However, the materials are relatively easily replaced and, in general, are replaceable from domestic resources with relatively insignificant expenditure of manpower and energy.

The largest weight of materials making up a launch vehicle are the propellants. These have previously been enumerated and defined in the NASA/OSS launch vehicle environmental statement (Reference 1).

In addition to propellants, other material constituents of the launch vehicle and spacecraft include metals such as steel, aluminum, nickel, chromium, titanium, iridium, lead, zinc, copper, silver, gold and platinum. Other materials include plastics and glass and plutonium dioxide (PPO). The quantities of materials of various kinds which are utilized are insignificant in comparison with those used in one year of production of automobiles (10,000,000 automobile units).

7.0 RESPONSES TO COMMENTS ON DRAFT

The draft environmental statement for the Mariner Jupiter/ Saturn Program was circulated in June 1973, and comments were received from the Environmental Protection Agency, The Department of State, and the Atomic Energy Commission (See Appendix). Responses to these comments are provided in this section.

7.1 General

7.1.1 Comment - In general, the draft statement does not include sufficient detailed information on the probability and/or consequences of accidents which could release plutonium to the environment, or the resulting radiological effects. The draft statement's reliance on the results of tests and analyses being conducted for another space program is also questioned due to the differences in the systems and the lack of test and analysis results. It is recognized that the specific information needed to reach a final conclusion as to the acceptability of the potential environmental impact from this project may not now be available, due to the fact that the launch is not planned until 1977. In order to be of maximum usefulness, we recommend that a supplement to the statement be issued which addresses the following detailed comments and supplies a significant amount of the requested specific information.

Response - The Mariner Jupiter/Saturn 1977 (MJS77) Program is an outgrowth of the Grand Tour concept studied in the 1960's and was undertaken in its present form with systems and mission design and development beginning in 1972. Environmental analyses were undertaken as early in the project as was meaningful and the draft environmental impact statement, published in June 1973, was prepared at the earliest date that reasonable estimates of potential environmental impacts could be described. Even at that time, the analyses, not complete for the multi-hundred watt (MHW) power sources intended for MJS77, had to rely heavily on comparable analyses conducted for the smaller systems on board the Pioneer 10 and 11 spacecraft. The comparisons were not made casually; the earlier analyses were extrapolated to the size and type of system planned for the Mariner Jupiter/Saturn 1977 spacecraft.

The development, test, and analysis process is a continuing one. The MHW systems, now under development by the Atomic Energy Commission, will have their first use in 1975 by the U. S. Air Force, with the corresponding safety analyses to be completed in late 1974. The safety analyses for the MHW systems on Mariner Jupiter/ Saturn will be completed in the summer of 1976, well before the 1977 launch. Sufficient information is available now, however, to permit preparation of this final environmental impact statement; nevertheless, it is still necessary to rely on certain information derived for previous missions. As new information is derived during the ongoing program, it will be examined in terms of potential environmental impact. If it is determined that the potential exists for environmental impact significantly different from that described herein, the necessary program actions will be undertaken and an amended environmental impact statement prepared.

7.2 Radiological Aspects

7.2.1 Comment - The assessment of radiological impact of abnormal missions relies very heavily on studies and test programs being conducted in connection with the Air Force Lincoln Experimental Satellite (LES) program. While the LES utilizes the same type of radioisotopic thermoelectric generator (RTG), it cannot be assumed that the testing program designed for the LES program will be sufficient to assess the potential impact of this program. It is our understanding that the potential accident environment during a pad abort could be more severe for the Mariner Jupiter/Saturn (MJS) launch than for the LES launch due to the difference in the booster configuration. If the LES testing and evaluation studies are to be used as the foundation for conclusions on the acceptability of the environmental effects of normal and abnormal occurrences in the MJS program, then the final statement must clearly indicate any significant differences between the programs and discuss the justification for applying the results of the LES testing to the MJS program.

Response - Testing and evaluation studies for the LES program will be used for the MJS77 Program only for those conditions where differences in launch vehicle configurations will have no significant effects on the conclusions reached. The MHW/RTG, except for the removal of the iridium outer clad and an improved graphite aeroshell design for the MJS77 program, is essentially the same for both LES 8 & 9 and MJS77. LES 8 & 9 will use the Titan III-C launch vehicle which has four stages, including a final transtage. MJS77 will use the three stage Titan III-E which is essentially a Titan III-C without the transtage. In addition, MJS77 will use a Centaur upper stage and a final propulsion module. Tests and analyses which are directed at determining the possible effects of the different launch vehicle configurations are being conducted specifically for the MJS77 program.

7.2.2 Comment - The draft statement further discusses the environmental consequences of a release of fuel from the RTG in relation to testing and analyses performed on the Pioneer program. Since the Pioneer RTG employed a different physical form of the plutonium fuel, an extrapolation of these test results or analytical findings must be supported by comparative analyses.

Response - Any extrapolation of Pioneer fuel (PMC) test results or analytical findings to MJS77 is supported by comparative analyses. For the most part, however, MJS77 results are based on tests and analyses of the PPO fuel used in the MHW/RTG's.

7.2.3 Comment - In order to allow EPA to reach a judgment as to the acceptability of the environmental effects from this proposed program, the supplement to the draft statement should present the following information:

(a) The probabilities of accidents which have the potential for releasing plutonium to the environment;

(b) the environmental levels of plutonium which may be present due to the accidents;

(c) the potential dose to humans arising from these levels of plutonium, including both the direct dose and the dose through environmental pathways; and

(d) the number of people who may be exposed and the resultant health effects.

Response -

(a) The probabilities of accidents are provided under Section 3.2.2.

(b) In the immediate vicinity of a land impact the plutonium is expected to be contained in the fuel spheres. However, if cracks occur or the fuel spheres are broken, small quantities of plutonium could be distributed locally. If impacts are in the ocean, the fuel capsule is not expected to break and the plutonium will be contained for a long period of time.

(c) The potential dose to humans is discussed in Section 3.2.2.

(d) The number of people who may be exposed are indicated by the probability of one or more individuals accumulating a lung burden greater than 0.016 microcuries. These probabilities (for the case of random impact) are given in Table I for the Nimbus, Apollo, and Pioneer Programs. Similar analyses are being conducted for the MJS77 Program. Preliminary assessment indicates that there will be less risk associated with the MJS77 mission than given for the previous programs. No significant health effects are anticipated for exposures less than 0.016 microcuries.

7.2.3.4 Comment - A 1964 study is used to support the conclusions on the dissolution characteristics of the radioactive material in seawater and the effects on plankton

Response - Dissolution characteristics of ^{238}Pu in seawater were obtained from experiments being conducted by Los Alamos Scientific Laboratories (Reference 6). The 1964 study by Pillai, et. al., (Reference 7) is thought to be the most recent investigation of the concentration factors, the ratio of the radioactivity in the marine organism to that of the seawater, for plutonium in certain selected marine organisms.

7.3 Non-radiological Aspects

7.3.1 Comment - It would appear that substantial quantities of aluminum oxide, a particulate, will be emitted by some of the launch vehicles. Therefore, the final statement should evaluate the air quality impact of particulate emissions in a fashion similar to the evaluation of hydrogen chloride and carbon monoxide performed in the draft statement. This evaluation should include particulate size distribution, peak downwind concentration and the anticipated duration of elevated levels in the lower atmosphere.

Response - Aluminum oxide emissions, not discussed in the draft environmental statement for Launch Vehicle and Propulsion Programs, are discussed in the corresponding final environmental statement published and distributed in August 1973. Exposure predictions are provided to the same degree as are data for carbon monoxide and hydrogen chloride. The particulate size range is up to 40 microns, with the distribution not yet well known, but under study in connection with other programs. Exposure durations would be on the order of minutes as the highly localized cloud of exhaust materials drifted downwind and dissipated. As stated in the final environmental statement, no hazard to either the public or controlled personnel is expected.

7.3.2 Comment - It would appear desirable to establish an air quality monitoring program for the various launch locations. Such a program could be utilized to insure that unexpected adverse environmental impacts do not go undetected and it would confirm pollutant concentration levels predicted by various models.

Response - NASA has established a comprehensive research program to validate the models used to predict exhaust product concentrations. Extensive measurements have been made for Scout, Delta, and Titan III launches and the data acquired compared to predictions. The research will continue until the models are fully validated, beyond which time extensive monitoring should no longer be required.

7.3.3 Comment - Launch site zones, showing predicted noise contours during launch of the Mariner Jupiter/Saturn Project Titan III/Centaur D-IT system launch vehicle in the uncontrolled areas, should be delineated for Launch Complex 41. All municipalities in the vicinity of the Kennedy Space Center should be notified of the launch schedule to minimize adverse potential community response. The anticipated sonic boom overpressure footprint, affecting uncontrolled populated areas during launch, should be included for each of the three possible flight trajectories, if applicable.

Response - Noise information is contained in the final environmental statement for NASA/OSS launch vehicles. It is unlikely that municipalities within the range where launch noise will be heard, will be unaware of the MJS launch schedule. The uniqueness of the program makes adverse community reaction unlikely. Sonic boom footprints will be imposed only upon unpopulated (ocean) areas.

7.3.4 Comment - In addition to the federal organizations indicated as having been sent copies of this draft statement for comment, an additional copy should be sent to the State of Florida since launch is planned to be from the Cape Kennedy launch site located in that state.

Response - The institutional environmental statement for the Kennedy Space Center, which covers all activities at the installation, have been sent to the State of Florida. Concerned Florida State and Brevard County offices have been provided draft copies of the MJS77 final environmental statement.

8.0 ABBREVIATIONS

MJS77	Mariner Jupiter/Saturn 1977
PMC	Plutonia Molybdenum Cermet
OSS	Office of Space Science
PPO	Pressed Plutonium Dioxide
RHU	Radioisotope Heater Unit
RTG	Radioisotope Thermoelectric Generator
LES	Lincoln Experimental Satellite
MHW	Multi-Hundred Watt

9.0 REFERENCES

1. Environmental Statement for the National Aeronautics and Space Administation, Office of Space Science, Launch Vehicle and Propulsion Programs, Final Statement, July 1973.

2. Title 10, Code of Federal Regulations, Part 20 for AEC licensed facilities, or in the case of AEC contractors, AEC Manual Chapter 0524.

3. National Aeronautics and Space Administration, Environmental Statement for Pioneer F/G Program, Final Statement, January 1972.

4. Preliminary RTG Safety Study Data for the MJS77 Mission, General Dynamics, Convair Aerospace Division, Document No. 986-3-74-057, July 3, 1974.

5. Bi-Monthly Progress Report, MHW RTG Program, Period from March 1, 1973 to April 30, 1973, General Electric Space Division, P. O. Box 8661, Philadelphia, PA 19101.

6. Multi-Hundred Watt Radioisotope Thermoelectric Generator Program, Final Safety Analysis Report, General Electric Space Division, Philadelphia, PA 19101, to be published January 1975.

7. Pillai, K.C., Smith, R. C., and Folsome, T. R., "Plutonium in the Marine Environment", Nature, Vol. 203, No. 4945, Aug. 8, 1964, pp 68-9.

10.0 APPENDIX

Comments received from the Environmental Protection Agency, Department of State, and the Atomic Energy Commission.

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

7 SEP 1973

Mr. Nathaniel B. Cohen
Director, Office of Policy Analysis
National Aeronautics and Space Administration
Washington, D.C. 20546

Dear Mr. Cohen:

The Environmental Protection Agency has reviewed the draft environmental statement for the Mariner Jupiter/Saturn Project and is pleased to provide you with our comments.

General Comments

In general, the draft statement does not include sufficient detailed information on the probability and/or consequences of accidents which could release plutonium to the environment, or the resulting radiological effects. The draft statement's reliance on the results of tests and analyses being conducted for another space program is also questioned due to the differences in the systems and the lack of test and analysis results. It is recognized that the specific information needed to reach a final conclusion as to the acceptability of the potential environmental impact from this project may not now be available, due to the fact that the launch is not planned until 1977. In order to be of maximum usefulness, we recommend that a supplement to the statement be issued which addresses the following detailed comments and supplies a significant amount of the requested specific information.

Radiological Aspects

The assessment of the radiological impact of abnormal missions relies very heavily on studies and test programs being conducted in connection with the Air Force Lincoln Experimental Satellite (LES) Program. While the LES utilizes the same type of radioisotopic thermoelectric generator (RTG), it cannot be assumed that the testing program designed for the LES Program will be sufficient to assess the potential impact of this program. It is our understanding that the potential accident environment during a pad abort could be more severe for the Mariner Jupiter/Saturn (MJS) launch than for the LES launch due to the difference in the booster configuration. If the LES testing and evaluation studies are to be used as the foundation for conclusions on

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the acceptability of the environmental effects of normal and abnormal occurences in the MJS program, then the final statement must clearly indicate any significant differences between the programs and discuss the justification for applying the results of the LES testing to the MJS program.

The draft statement further discusses the environmental consequences of a release of fuel from the RTG in relation to testing and analyses performed on the Pioneer program. Since the Pioneer RTG employed a different physical form of the plutonium fuel, any extrapolation of these test results or analytical findings must be supported by comparative analyses.

In order to allow EPA to reach a judgment as to the acceptability of the environmental effects from this proposed program, the supplement to the draft statement should present the following information:

1. The probabilities of accidents which have the potential for releasing plutonium to the environment;

2. The environmental levels of plutonium which may be present due to the accidents;

3. The potential dose to humans arising from these levels of plutonium, including both the direct dose and the dose through environmental pathways; and

4. The number of people who may be exposed and the resultant health effects.

In previous environmental statements for similar programs, much of this information was contained in Safety Analysis Reports and could be included by reference. In this case, however, no such documents are available, or have been referenced in the draft statement. Since the launch of this spacecraft is still approximately four years away, we can understand why some of the information we request may not now be available. We believe, however, that all of it is necessary before this agency can judge the acceptability of the potential environmental impact of the project. A supplement to the draft statement should be issued when a significant amount of this specific information is available.

<u>Non-radiological Aspects</u>

In general, the air quality considerations from the launch vehicle as presented in this draft statement and the launch vehicle draft statement cited as Reference 1 are considered adequate. Provided that the launch and ground tests do not occur during rain, minimum dispersion, or air stagnation, the emission of various air pollutants in the quantities and locations cited in Reference 1 to this draft statement should not create any significant long-term air quality deterioration. The following comments and/or requests apply to the launch vehicle and propulsion system draft statement:

1. It would appear that substantial quantities of aluminum oxide, a particulate, will be emitted by some of the launch vehicles. Therefore, the final statement should evaluate the air quality impact of particulate emissions in a fashion similar to the evaluation of hydrogen chloride and carbon monoxide performed in the draft statement. This evaluation should include particulate size distribution, peak downwind concentration and the anticipated duration of elevated levels in the lower atmosphere.

2. It would appear desirable to establish an air quality monitoring program for the various launch locations. Such a program could be utilized to insure that unexpected adverse environmental impacts do not go undetected and it would confirm pollutant concentration levels predicted by various models.

Launch site zones, showing predicted noise contours during launch of the Mariner Jupiter/Saturn Project Titan III/Centaur D-IT system launch vehicle in the uncontrolled areas, should be delineated for Launch Complex 41. All municipalities in the vicinity of the Kennedy Space Center should be notified of the launch schedule to minimize adverse potential community response. The anticipated sonic boom overpressure foot print, affecting uncontrolled populated areas during launch, should be included for each of the three possible flight trajectories if applicable.

In addition to the Federal organizations, indicated as having been sent copies of this draft statement for comment, an additional copy should be sent to the State of Florida since launch is planned to be from the Cape Kennedy launch site located in that state.

In light of our review of this draft statement and in accordance with EPA procedure, we have rated the draft statement as "Category 3" (Inadequate). A supplement to this draft statement, which contains a significant amount of the information requested, would be necessary before this Agency can reach even a tentative conclusion as to the

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environmental acceptability of the proposed program. We have enclosed a detailed explanation of our classification system for your information. In addition, we would be pleased to discuss our classification or comments with you or members of your staff.

Sincerely,

Rebecca W. Hanmer

for Sheldon Meyers
Director
Office of Federal Activities

Enclosure

DEPARTMENT OF STATE

Washington, D.C. 20520

BUREAU OF INTERNATIONAL SCIENTIFIC AND
TECHNOLOGICAL AFFAIRS

July 10, 1973

Mr. Ralph E. Cushman
National Aeronautics and
Space Administration
Special Programs Coordinator
Office of NASA Comptroller
Washington, D.C. 20546

Dear Mr. Cushman:

This refers to the draft environmental impact statement for the Mariner Jupiter/Saturn Project that NASA recently circulated for comment. We have reviewed the draft assessment and are favorably impressed with the quality of the evaluation and the studies that are underway to assure that all prudent health, safety and environmental constraints are observed. In our judgment, however, it obviously would be preferable from the standpoint of the environmental review if NASA already had in hand the results of the various nuclear safety studies which are now in process. Pending the completion of these studies we view this environmental assessment as tentative and recommend that the final statement include the results of these studies.

We also recommend that the statement be available for public review and comment after the results of the nuclear safety studies have been included in the statement.

We hope you will find these comments to be helpful and will be happy to discuss them with you further.

Sincerely yours,

William C. Salmon

William C. Salmon
Deputy Director
Office of Environmental
Affairs

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UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

JUL 18 1973

Mr. Nathaniel B. Cohen, Director
Office of Policy Analysis
National Aeronautics and Space
Administration
Washington, D. C. 20546

Dear Mr. Cohen:

This is in response to your letter of June 15, 1973 transmitting for review and comment a copy of the NASA Environmental Statement for the Mariner Jupiter/Saturn Project. The statement has been reviewed by Commission staff who discussed specific sections with you and your staff. We have the following additional comments to offer. In general, the statement seems to assume a rather high degree of technical knowledge and familiarity with special terms. It might be helpful if the final statement were toned down to a level more readily understood by the public.

A 1964 study is used to support the conclusions on the dissolution characteristics of the radioactive material in seawater and the effects on plankton. We feel that there are more recent studies that could be used and cited. The statement "the effects of radiation dosimetry on marine organisms" on page 1? is misleading since dosimetry refers to the techniques for measuring a radiation dose.

Thank you for the opportunity to review the statement.

Sincerely,

Robert J. Catlin

Robert J. Catlin, Director
Division of Environmental Affairs

EIS for the Mariner Jupiter/Saturn 1977 Program (MJS77)

SUMMARY OF CONCLUSIONS

The probability of an expendable launch failure with a return of the radioactive system to earth is .05. The probability of a failure near the launch pad is less than .001.

The potential environmental impact due to dispersal of radioactive fuel elements in the event of an abnormal launch.

A. RHU's: "...virtually impossible to have fuel releases from the heaters." This conclusion is based on the detailed safety studies performed for the Pioneer spacecraft, whose RHU's were structurally identical to those of the Mariner.

B. RTG's:

1. "The RTG has been designed to withstand the most severe environment at the launch site. Therefore, in the event an abort, including launch vehicle destruct, occurs, with impact in the launch area the plutonium fuel capsule is expected to survive with no release of the radioactive material."

2. "There is no credible sequence of events for which nuclear criticality would be possible for the RTG fuel."

3. An extensive safety testing program is being conducted by the AEC to demonstrate the integrity of the radioisotope containment when exposed to the most severe launch and reentry environments. Results--the probability of a fuel release, given an accident, is <.001.

a. Therefore the probability of a fuel release, given an a launch pad abort, is <10 E-6. If any fuel is released, only "a small fraction would be respirable, and it is unlikely that anyone would receive a lung burden of as much as .005 microcuries (5 rem per year) the level established as the limit for the general public."

b. "Of the remaining possible launch failures, about .03 will occur in the ascent phase resulting in ocean impact, and about .02 will result in earth orbital insertion. Following orbital decay, about 75% will impact in the oceans."

-"Thus the most probable fate of returning to Earth will be impact in the ocean." At the slow decay rate of Pu-238, a person consuming his entire annual protein diet from fish grown in the contaminated area would receive a maximum annual intake of .024 microcuries

-"to release fuel on reentry requires extreme conditions.... Although one can assume these conditions, the expected mode of operation does not lead to significant fuel release." Exposure is insignificant "unless the individuals become closely involved in handling or working with the hardware without protection."

c. The number of individuals who could be exposed as a result of an abort and fuel release:

>.005 uci lung burden: 0-50
>.016 uci lung burden: 0-1

RESPONSES TO COMMENTS OF DRAFT

1. C: Does not include sufficient detailed information on the probabilities and/or consequences of accidents which could result in Pu releases.

   R: The draft EIS was prepared at the earliest date reasonable. Even as the final is being prepared, the analyses are not complete. If subsequent analysis indicates that the potential environmental impact is significantly different than described, an amended EIS will be prepared.

2. C: It cannot be assumed that the testing program designed for the LES will be sufficient to assess the potential impact of this program, due to differences in the booster configuration.

   R: Test results for the LES program will be used only for those conditions where differences in launch vehicle configurations will have no significant effects on the conclusions reached. Tests and analyses which are directed at determining the possible effects of the different launch vehicle configurations are being conducted specifically for this program.

3. C: The testing and analyses performed on the Pioneer program requires comparative analyses because the Pioneer used a different physical form of Pu fuel.

   R: Any extrapolation of Pioneer test or analytical results <u>is</u> supported by comparative analyses. "For the most part, however, MJS77 results are based on test analyses of the PPO fuel used in the MHW/RTG's." (NOTE: there is an internal contraction here. It was previously stated that the analyses for the MHW "power sources intended for MJS77, had to rely <u>heavily</u> on comparable analyses conducted for the smaller systems on board the Pioneer 10 and 11 spacecraft."

4. C: Present the following information:

   a. Accident probabilities with potential for Pu release.
   b. Environmental levels of Pu due to these accidents
   c. Potential doses to humans