4.0 ENVIRONMENTAL IMPACTS

The environmental impacts of the Cassini mission were addressed in Chapter 4 of the 1995 Cassini EIS. Completing preparations for and implementing a normal, incident-free mission were determined to have no substantial impacts to the human environment for either the Proposed Action or any of the other mission alternatives, including the 2001 Mission. It is unlikely, given the present composition of the population in the region, that any given racial, ethnic, or socioeconomic group in the population would bear a disproportionate share of any environmental impacts. The ongoing mission safety analyses have yielded no information that changes those analyses, nor is there any change in the impacts associated with the No Action Alternative. The cumulative impacts of a normal Cassini mission which center around the SRMU exhaust emissions are unaffected by the results of the updated analyses. Details of the impact evaluations of a normal launch can be found in Sections 4.1, 4.2, 4.3 and 4.4 of the 1995 Cassini EIS.

4.1 RADIOLOGICAL IMPACT ASSESSMENT OF THE PROPOSED ACTION

Since completion of the Final EIS for the Cassini Mission (dated June 1995; issued in July 1995), NASA and DOE have continued the safety analysis process for the mission. This process was described in Section 4.1.5.1 of the 1995 Cassini EIS. The "Cassini Titan IV/Centaur RTG Safety Databook, Revision B" dated March 1997, (MMT 1997), describes accident probabilities and environments for the mission. DOE contractors have incorporated the MMT 1997 information into their accident analyses and recently completed their preparation of the Safety Analysis Report (SAR) "GPHS-RTGs in Support of the Cassini Mission" (LMM&S a-j). Results from these recent analyses, along with the companion SAR for the LWRHUs (EG&G 1997), are reported in this SEIS. While some of the individual results of the SARs differ from those reported in the April 1997 Draft SEIS and companion document HNUS 1997, the overall mission risk remains similar.

The Draft SEIS was issued in April 1997 with the best available information available at that time. A separate report (HNUS 1997) was prepared that summarized the methodology and interim results available from the NASA/DOE safety analysis process for the Cassini mission. Since that time, definition of the probabilities and accident environments for launch area accidents that might involve fallback of the SRMU propellant and the "full stack intact impact" accident have been completed (MMT 1997). The DOE contractor has incorporated that information into the accident analyses and completed their RTG SAR (LMM&S g, LMM&S h, LMM&S j). This final SEIS incorporates the results of these recently completed analyses.

As with the Draft SEIS (DSEIS), the analytical results reported in this Final SEIS (FSEIS) do not include consideration of *de minimis*. To review analytical results both with and without *de minimis*, please refer to Appendix D.

4.1.1 Radiological Accident Impact Analysis

4.1.1.1 Safety Analysis Process

The process used in the safety analyses to determine the risk associated with the Cassini mission is fundamentally similar to the process used for the earlier Galileo and Ulysses missions and is illustrated in Figure 4-1. NASA has defined those accidents which might occur during the pre-launch, early launch, late launch, and EGA segments of the mission in the Cassini Titan IV/Centaur RTG Safety Databook (MMT 1997). The JPL swingby plan (JPL 1993b), and supplement (JPL 1997), address those accidents which may occur during the interplanetary trajectory. Together, MMT 1997 and JPL 1993b/JPL 1997 define the accidents, associated probabilities of occurrence, and accident environments that might threaten the RTGs and RHUs.

The source terms are determined by evaluating the response of the RTGs and RHUs to the defined accident environments (LMM&S a-j, EG&G 1997). For each combination of accident and environment, techniques such as computer simulations (again, similar to those performed for the Galileo and Ulysses missions), and analyses based upon empirical data from safety tests and evaluations are used to determine the probability of rupture or breach of the iridium RTG clads and the platinum-rhodium RHU clads which contain the PuO_2. For simulations in which clad failure occurs, the mass of the PuO_2 released from the clad is determined, along with information on particle size, particle density and release location. For clad failures in the vicinity of burning propellant, the source term also includes the amount of PuO_2 vaporized and the fireball buoyancy effects.

The source terms for each case are then evaluated to determine the consequences of the release to the environment and to people. The approach used is again quite similar to that used for the Galileo and Ulysses missions, as well as the 1995 Cassini EIS. Each source term is evaluated to determine how it transports and disperses from the point of release, including the effects of weather, deposition and resuspension. Long-term (50-year) passive exposure from inhalation of resuspended material and ingestion of foodstuffs is considered, as well as the more immediate airborne and ground-based external exposures. The consequence reported consists of the overall radiological effect of the source term via all of these pathways over a period of 50 years (immediate or short-term exposure, plus subsequent exposures over a 50-year period) and is expressed in terms of radiological dose (rem), potential health effects (latent cancer fatalities) and area of land potentially contaminated above the EPA recommended guideline level (7.4×10^3 Bq/m^2 [0.2 µCi/m^2]) at which the need for further action needs to be considered.

The final element of the analysis is the combination of the first three steps in Figure 4-1 into an overall estimate of risk. This is accomplished by weighting the consequences determined for each accident case by the respective probability of occurrence and conditional probability of release. The measure of risk is then the probability-weighted sum of consequences.

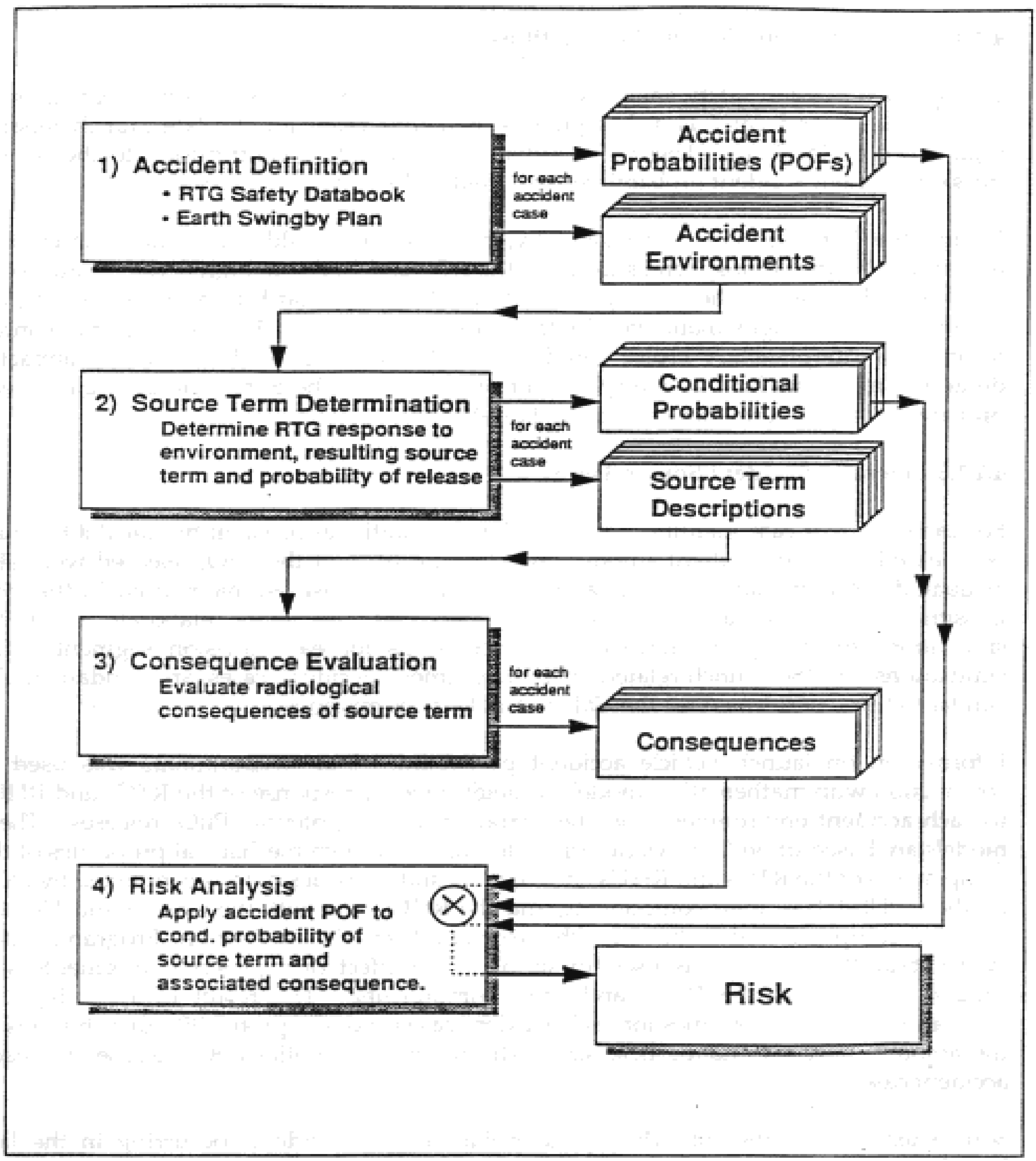

Figure 4-1 Overview: Basic Elements in the Nuclear Launch Safety Risk Analysis Process

4-3

Figure 4-1 Overview: Basic Elements in the Nuclear Launch Safety Risk Analysis Process

4.1.1.2 Accident Scenarios and Probabilities

The updated mission safety analyses include detailed evaluations of 14 accident cases for the pre-launch and early launch segments, and four cases for the late launch mission segment, plus the EGA. These 19 accident cases and their contribution to the overall mission segment accident probabilities are listed in Table 4-1.

During the Earth gravity assist swingby, malfunctions could cause the spacecraft to reenter the Earth's atmosphere, subjecting the RTG and RHUs to high aerodynamic loads and thermal stresses. The mean probability of short-term Earth impact (i.e., during the VVEJGA Earth swingby maneuver) by the spacecraft is 8.0×10^{-7}. Loss of spacecraft control during the interplanetary cruise could potentially result in long-term Earth impact a decade to millennia later as the spacecraft orbits around the Sun. The estimated mean probability of long-term Earth impact is 2.0×10^{-7}.

4.1.1.3 Potential Accident Source Terms

For each accident case identified, the associated conditional probability that PuO_2 would be released and the resultant amount and characteristics of the PuO_2 released were also evaluated. Rather than the expectation and maximum case estimates used in the 1995 Cassini EIS, the updated mission safety analyses use more elaborate computer simulations for the probabilities and source terms for each mission segment. The simulations for the launch-related mission segment accident cases are fundamentally similar to those performed for the Galileo and Ulysses missions.

Information on launch vehicle accident probabilities and environments was used in conjunction with mathematical models to determine the response of the RTGs and RHUs to each accident environment and the characteristics of potential PuO_2 releases. These models are based upon (1) physical principles, (2) the known mechanical properties of the components of the RTGs and RHUs and (3) the results of series of tests conducted by DOE on the GPHS-RTGs, their components, and the RHUs. As with the Galileo and Ulysses EIS's, a computer code, the Launch Accident Scenario Evaluation Program, Titan IV/Centaur (LASEP-T), was used to simulate the effect of explosions, fragments and ground impacts on the RTGs and their components. The result of repeating the simulation thousands of times for each accident case produces probability distributions of the amount, location and particle size distribution of potential PuO_2 releases for each accident case.

Source terms from the sub-orbital and orbital reentry accidents occurring in the late launch mission segment were estimated using techniques similar to the early launch mission segment. Probabilistic sampling techniques were employed to account for the variations in location of the event, the source term if hard rock surfaces are hit, the number of modules that might hit rock, meteorological conditions, and population densities.

Table 4-1. Accident Case Descriptions [a] [b]

Mission Segment	Accident Case Number	Case Description	Mean Initiating Probability
Pre-Launch	0.0	On-Pad Explosion, Configuration 1	6.7×10^{-5}
Pre-launch Total [b]			6.7×10^{-5}
Early Launch	1.1	Total Boost Vehicle Destruct (TBVD)	4.2×10^{-3}
	1.2	Command Shutdown and Destruct (CSDS)	6.6×10^{-4}
	1.3	TBVD with SRMU Aft Segment Impact	8.1×10^{-4}
	1.4	SRMU Explosion	1.2×10^{-4}
	1.5	Space Vehicle (SV) Explosion	7.6×10^{-14}
	1.6	TBVD without Payload Fairing (PLF)	9.1×10^{-6}
	1.7	CSDS without PLF	1.5×10^{-6}
	1.8	SV Explosion without PLF	1.4×10^{-6}
	1.9	Centaur Explosion	1.4×10^{-4}
	1.10	Space Vehicle/RTG Impact	2.3×10^{-4}
	1.11	Payload Fairing/RTG Impact	1.9×10^{-6}
	1.12	Payload Fairing/RTG Impact, RTG Falls Free	1.9×10^{-6}
	1.13	Full Stack Intact Impact	1.6×10^{-6}
Early Launch Total [b]			6.2×10^{-3}
Late Launch	3.1	Sub-Orbital Reentry	1.4×10^{-3}
	5.1	Sub-Orbital Reentry from CSDS Configuration 5	1.2×10^{-2}
	5.2	Orbital Reentry, Nominal	8.0×10^{-3}
	5.3	Orbital Reentry, Off-Nominal Elliptic Decayed	3.0×10^{-7}
Late Launch Total [b]			2.1×10^{-2}
VVEJGA		Short Term Reentry	8.0×10^{-7}
Overall Mission Total [b]			2.8×10^{-2}

a. See HNUS 1997, Section 4.1 and LMM&S 1997 a for more information on the accident case descriptions.
b. Only accidents which threaten the RTGs or RHUs with a potential for release of PuO_2 are included.

Since the 1995 Cassini EIS, more detailed reentry analyses have been completed that provide additional insights into various branch-point probabilities in the source term event trees for the EGA (LMM&S b&c). This has allowed refinements to many of the values in the event trees that result in different probabilities for each of the potential end states for the PuO_2. As with the earlier mission phase accidents, probabilistic sampling techniques were employed to account for the variations in parameters that could affect the source term, such as reentry angle, latitude band of reentry, altitude of fuel releases, location of the event, the source term if rock or soil surfaces are hit, and the number of modules that might fail.

For additional detail about source terms see Appendix D and LMM&S b, c, g & h and EG&G 1997.

4.1.2 Environmental Consequences and Impacts

4.1.2.1 Radiological Consequences and Risk Methodology

The Cassini nuclear launch safety risk analysis performed for each of the accident cases identified for the RTGs and RHU's is fundamentally similar to that performed for the Galileo and Ulysses missions and for the 1995 Cassini EIS. The updated analysis, however, extends the techniques developed in the earlier analyses and applies probabilistic techniques to each of the source term probability distributions. Calculations include (1) collective radiation dose (50-year), (2) latent cancer fatalities (health effects) over a 50-year period induced by exposure to released PuO_2, (3) maximum individual dose and average individual risk, (4) land area contaminated above the EPA guideline level for considering the need for further evaluation, and (5) radiological risk.

For further information on radiological consequences and risk methodology see LMM&S d-h and EG&G 1997. It should be noted that although the Cassini spacecraft will carry 129 RHUs, the updated analyses presented in this SEIS are based on an inventory of 157 RHUs.

4.1.2.2 Radiological Consequences and Risks

The summary of radiological consequences and mission risks is presented in Table 4-2. The mean, 5-, 50-, 95- and 99-percentiles values of health effects are presented.

It should be noted that the radiological consequences and risks are reported in Table 4-2 for the GPHS-RTGs, the LWRHU's, and as "Combined." The results reported for the GPHS-RTGs can be found in the Safety Analysis Report for the RTGs (LMM&S a-j). Those reported for the LWRHUs can be found in the Safety Analysis Report for the RHUs (EG&G 1997). The "Combined" consequences and risks reported in Table 4-2 are probability-weighted to account for the results of both the above referenced safety analyses. See Appendix D, page D-2 for a sample calculation.

Table 4-2 Summary of Radiological Consequences and Missions Risks

Mission Segment	Source	Total Probability[a]	Maximum Individual Dose[b], rem	Land Area Contaminated[c], km^2 (mean)	Health Effects Over 50 Years [d] (w/o *de minimis*)					Mission Risks[e] (mean)
					5%	50%	Mean	95%	99%	
Pre-Launch	GPHS-RTG	$5.2x10^{-5}$	$1.3x10^{-2}$	$1.5x10^{0}$	$3.3x10^{-3}$	$2.8x10^{-3}$	$6.6x10^{-2}$	$5.7x10^{-2}$	$1.8x10^{-1}$	$3.4x10^{-6}$
	LWRHU	$1.1x10^{-5}$	$2.5x10^{-3}$	g	$1.6x10^{-2}$	$1.7x10^{-2}$	$1.9x10^{-1}$	$2.2x10^{-1}$	$4.1x10^{0}$	$2.1x10^{-6}$
	Combined[f]	$5.2x10^{-5}$	$1.4x10^{-2}$	$1.5x10^{0}$	$3.4x10^{-3}$	$6.4x10^{-3}$	$1.1x10^{-1}$	$1.0x10^{-1}$	$1.0x10^{0}$	$5.5x10^{-6}$
Early Launch	GPHS-RTG	$6.7x10^{-4}$	$2.1x10^{-2}$	$1.6x10^{0}$	$4.2x10^{-5}$	$6.3x10^{-3}$	$7.1x10^{-2}$	$1.7x10^{-1}$	$1.2x10^{0}$	$4.7x10^{-5}$
	LWRHU	$1.8x10^{-4}$	$5.6x10^{-4}$	g	$8.1x10^{-4}$	$5.8x10^{-3}$	$4.2x10^{-2}$	$4.4x10^{-2}$	$1.3x10^{0}$	$7.6x10^{-6}$
	Combined[f]	$6.7x10^{-4}$	$2.1x10^{-2}$	$1.6x10^{0}$	$2.6x10^{-4}$	$7.8x10^{-3}$	$8.2x10^{-2}$	$1.8x10^{-1}$	$1.5x10^{0}$	$5.5x10^{-5}$
Late Launch	GPHS-RTG	$2.1x10^{-3}$	$1.1x10^{0}$	$5.7x10^{-2}$	$3.1x10^{-4}$	$8.2x10^{-3}$	$4.4x10^{-2}$	$2.3x10^{-1}$	$5.5x10^{-1}$	$9.2x10^{-5}$
	LWRHU	$3.9x10^{-9}$	$7.7x10^{-6}$	g	h	h	$2.4x10^{-6}$	h	h	$8.9x10^{-15}$
	Combined[f]	$2.1x10^{-3}$	$1.1x10^{0}$	$5.7x10^{-2}$	$3.1x10^{-4}$	$8.2x10^{-3}$	$4.4x10^{-2}$	$2.3x10^{-1}$	$5.5x10^{-1}$	$9.2x10^{-5}$
VVEJGA	GPHS-RTG	$6.3x10^{-7}$	$6.5x10^{2}$	$1.9x10^{1}$	$4.0x10^{0}$	$1.1x10^{2}$	$1.4x10^{2}$	$3.6x10^{2}$	$4.8x10^{2}$	$8.8x10^{-5}$
	LWRHU	$8.0x10^{-7}$	$2.1x10^{-2}$	$1.7x10^{-1}$	$4.3x10^{0}$	$7.4x10^{0}$	$1.3x10^{1}$	$3.9x10^{1}$	$7.0x10^{1}$	$1.0x10^{-5}$
	Combined[f]	$8.0x10^{-7}$	$5.1x10^{2}$	$1.5x10^{1}$	$7.4x10^{0}$	$9.4x10^{1}$	$1.2x10^{2}$	$3.2x10^{2}$	$4.5x10^{2}$	$9.8x10^{-5}$
Overall Mission	GPHS-RTG	$2.8x10^{-3}$	$9.7x10^{-1}$	$4.5x10^{-1}$	$1.1x10^{-3}$	$3.2x10^{-2}$	$8.2x10^{-2}$	$2.9x10^{-1}$	$8.0x10^{-1}$	$2.3x10^{-4}$
	LWRHU	$1.9x10^{-4}$	$7.6x10^{-4}$	$7.1x10^{-4}$	$2.0x10^{-2}$	$3.7x10^{-2}$	$1.0x10^{-1}$	$2.2x10^{-1}$	$1.7x10^{0}$	$2.0x10^{-5}$
	Combined[f]	$2.8x10^{-3}$	$9.7x10^{-1}$	$4.5x10^{-1}$	$2.5x10^{-3}$	$3.5x10^{-2}$	$8.9x10^{-2}$	$3.0x10^{-1}$	$9.2x10^{-1}$	$2.5x10^{-4}$

a. Product of initating accident and conditional PuO_2 release probabilities.
b. Maximally exposed individual dose, mean estimate.
c. Land area potentially contaminated above $7.4x10^3$ Bq/m^2 (0.2 $\mu Ci/m^2$).
d. Health effects are incremental latent cancer fatalities.
e. Risk calculated as the total probability times health effects.
f. The combined impacts of the GPHS-RTG and LWRHU analyses are probability weighted.
g. Estimated impacts are extremely small.
h. No statistics generated due to low probability of release and small source terms.

For 5-, 50-, 95-, and 99- percentile values of maximum individual dose, land area contaminated, and collective 50-year radiation dose, refer to Appendix D. The dose and health effects consequences presented assume no implementation of accident contingency plans or any other mitigation actions by governmental authorities. A value less than or equal to the 5-percentile level of consequences would be expected to occur 5 percent of the time (i.e., 1 in 20). Similarly, a value greater than or equal to the 95-percentile consequence level would be expected to occur 5 percent of the time.

The combined total probability that a pre-launch mission segment accident would result in a PuO_2 release is $5.2x10^{-5}$, or 1 in 19,200. The mean 50-year health effect consequence is $1.1x10^{-1}$ or 0.11 health effects. The mean area of land contaminated above the EPA guideline level predicted for this mission segment is $1.5x10^{0}$ or 1.5 km^2 (0.58 mi^2). The mean maximum individual dose associated with the pre-launch mission segment is $1.4x10^{-2}$ or 0.014 rem over 50 years--a dose that represents about 0.093% of the average individual's 50-year exposure to natural background radiation. The risk contribution attributed to the pre-launch mission segment is 2.2% of the overall mean mission risk. At the 95-percentile level, the predicted health effects and land contamination for this segment is equal to or less than $1.0x10^{-1}$ or 0.10 health effects and (from Section 4.1.2.5 of this SEIS), 5.5 km^2 (2.1 mi^2). At the 99-percentile level, the predicted health effects and land contamination for this segment will be equal to or less than $1.0x10^{0}$ or 1.0 health effects and (from Section 4.1.2.5 of this SEIS), 8.6 km^2 (3.3 mi^2).

The combined total probability that an early launch mission segment accident would result in a PuO_2 release is $6.7x10^{-4}$, or 1 in 1,490. The mean health effect consequence is $8.2x10^{-2}$ or 0.082. The mean area of land contaminated above the EPA guideline level predicted for this mission segment is $1.6x10^{0}$ or 1.6 km^2 (0.62 mi^2). The mean maximum individual dose associated with the early launch mission segment is $2.1x10^{-2}$ or 0.021 rem over 50 years--a dose that represents about 0.14% of the average individual's 50-year exposure to natural background radiation. The risk contribution attributed to the early launch mission segment is 22% of the overall mean mission risk. At the 95-percentile level, the predicted health effects and land contamination for this segment will be equal to or less than $1.8x10^{-1}$ or 0.18 health effects and (from Section 4.1.2.5 of this SEIS), 6.1 km^2 (2.4 mi^2). At the 99-percentile level, the predicted health effects and land contamination for this segment will be equal to or less than $1.5x10^{0}$ or 1.5 health effects and (from Section 4.1.2.5 of this SEIS), 20 km^2 (7.7 mi^2).

The combined total probability that a late launch mission segment accident would result in a PuO_2 release is $2.1x10^{-3}$, or 1 in 476. The mean health effect consequence is $4.4x10^{-2}$ or 0.044. The mean maximum individual dose associated with the late launch mission segment is $1.1x10^{0}$ or 1.1 rem over 50 years--a dose that represents 7.3% of the average individual's 50-year exposure to natural background radiation. The risk contribution attributed to the late launch mission segment is 37% of the overall mean mission risk. The area of land contaminated above the EPA guideline level predicted for this mission segment is $5.7x10^{-2}$ or 0.057 km^2 (0.022 mi^2). At the 95-percentile level, the predicted health effects and land contamination for this segment will be equal to or less than $2.3x10^{-1}$ or 0.23 health effects and (from Section 4.1.2.5 of this SEIS), 0.24 km^2 (0.093 mi^2). At the 99-percentile level, the predicted health effects and land contamination for this segment will be equal to or less than $5.5x10^{-1}$ or 0.55 health effects and (from Section 4.1.2.5 of this SEIS), 0.34 km^2 (0.13 mi^2).

The combined total probability that an EGA mission segment accident would result in a PuO_2 release is $8.0x10^{-7}$, or less than 1 in 1 million. The mean health effect consequence is $1.2x10^2$ or 120. The mean area of land contaminated above the EPA guideline level predicted for this mission segment is $1.5x10^1$ or 15 km^2 (5.8 mi^2). The mean maximum individual dose associated with the EGA mission segment is $5.1x10^2$ or 510 rem over 50 years, about 34 times the average individual's 50 year exposure to natural radiation. This mean maximum individual dose is accounted for in the 120 estimated health effects noted above. It should be noted that this estimate is at a probability of less than 1 in 1 million. At the 95-percentile level, the predicted health effects and land contamination for this segment will be equal to or less than $3.2x10^2$ or 320 health effects and (from LMM&S), 37 km^2 (14 mi^2). At the 99-percentile level, the predicted health effects and land contamination for this segment will be equal to or less than $4.5x10^2$ or 450 health effects and (from LMM&S), 55 km^2 (21 mi^2). The risk contribution attributed to the EGA mission segment is 39% of the overall mean mission risk.

In the unlikely event that the spacecraft becomes non-commandable anytime after injection into its interplanetary trajectory, and control could not be reestablished, the spacecraft's orbit around the Sun could eventually cross that of the Earth, and the spacecraft could impact the Earth a decade to millenia later. The combined total probability of such an impact is $2x10^{-7}$, or 1 in 5 million, and the amount of PuO_2 released could be similar to that released in a short-term EGA accident. However, there are uncertainties related to the amount of PuO_2 released. The uncertainties include the timing of the reentry which has a bearing on the composition of the PuO_2, given the 87.75-year half-life of Pu - 238. The radiological consequences of a long-term reentry are therefore assumed to be similar (same order of magnitude) to those estimated for the short-term EGA.

Overall, the consequences predicted for the Cassini mission are low when compared with other risks. Using a typical natural (background) radiation dose of 0.3 rem/yr and a health effects estimator of $5x10^{-4}$ latent cancer fatalities/rem, the risk to an individual of developing fatal cancer from a 50-year exposure to background radiation is estimated at $7.5x10^{-3}$, or 1 in 133. This estimated lifetime risk from background radiation is over five orders of magnitude (i.e., 100,000 times) higher than the Cassini mission segment with the highest average individual risk (late launch; see Appendix D, Table D-8), estimated at $1.8x10^{-8}$ or less, or a probability of less than 1 in 55 million of any given individual in the potentially exposed population incurring a fatal cancer due to exposure from an accidental PuO_2 release.

4.1.2.3 Uncertainty Analysis

In addition to the best estimate analysis, a study of the underlying test data and model input parameters used to estimate accident consequences and risks has been conducted (LMM&S f, h). Because of uncertainty, the mean consequence of the overall mission or a given mission segment has a distribution of possible values where the best estimate for this analysis lies near the median of that distribution. Table 4-3 summarizes the risks for various mission segments and the total mission from accidental PuO_2 release. The 95 percent confidence level risk is two orders of magnitude higher than the best estimate, and the 5 percent confidence level is about two orders of magnitude lower than the best estimate.

Table 4-3 Summary of Uncertainty Analyses: GPHS-RTG Mission Risks

Mission Segment	Mean Risk	5% Confidence Level	50% Confidence Level	95% Confidence Level
Pre-Launch	$3.4x10^{-6}$	$7.6x10^{-8}$	$6.0x10^{-6}$	$4.2x10^{-4}$
Early Launch	$4.7x10^{-5}$	$5.1x10^{-6}$	$6.2x10^{-5}$	$7.9x10^{-4}$
Late Launch	$9.2x10^{-5}$	$4.1x10^{-7}$	$7.3x10^{-5}$	$1.3x10^{-2}$
EGA Reentry (Short Term)	$8.8x10^{-5}$	$1.2x10^{-6}$	$7.5x10^{-5}$	$4.6x10^{-3}$
Total Mission	$2.3x10^{-4}$	$8.3x10^{-6}$	$2.2x10^{-4}$	$1.9x10^{-2}$

4.1.2.4 Emergency Response Planning

In accordance with the Federal Radiological Emergency Response Plan (FRERP), prior to the launch of the Cassini spacecraft with RTGs and RHUs onboard, comprehensive radiological contingency plans will be in place. These contingency plans, similar to the ones developed for the Galileo and Ulysses missions, would ensure that any accident, whether it involves a radiological release or not, will be met with a well-developed and tested response. The plans will reflect the combined efforts of Federal agencies, including NASA, DOE, DOD, EPA and the Federal Emergency Management Agency, and the State of Florida and local organizations involved in emergency response. (For additional details, see response to comment no. 8-1 in Appendix E.)

4.1.2.5 Potential Clean Up Costs Associated with Land Contamination

While the need for mitigation, and the cost involved, would be based upon actual conditions, and the amount of land area contaminated by an accident, the 1995 Cassini EIS developed an estimated range of cleanup costs for a postulated early launch accident near the launch site. Potential costs were estimated by taking the land area potentially contaminated at greater than the EPA guideline level (7.4×10^3 Bq/m^2; 0.2 µCi/m^2), and multiplying by a range of costs (escalated to 1994 dollars) developed by the EPA for mitigation both with ($50 million/km^2) and without ($5 million/km^2) removal and disposal of contaminated soil at a near-surface facility. Using the land area potentially contaminated by a near-launch site accident (1.5 km^2 [0.58 mi^2]), the EIS estimated the potential costs to range from about $7.5 million (without removal and disposal), to about $75 million (with removal and disposal). Table 4-4 of this SEIS uses the same methodology and unit costs as the 1995 Cassini EIS in developing cost estimates for the mean, 95- and 99-percentile land area contamination estimates provided by the updated analyses.

Table 4-4 Summary of Potential Cleanup Costs Associated with Land Contamination

Mission Segment	Consequence Level [a]	Land Area Contaminated [b] (km^2)	Cleanup Cost without Removal and Disposal [c] ($ millions)	Cleanup Cost with Removal and Disposal [c] ($ millions)
Pre-launch	mean	1.5	7.5	75
	95%	5.5	27.5	275
	99%	8.6	43	430
Early Launch	mean	1.6	8.0	80
	95%	6.1	30.5	305
	99%	20	100	1000

a. Estimated land areas are presented for the mean and 95- and 99-percentile levels of the consequence distribution functions.
b. Land area estimated contaminated above 7.4×10^3 Bq/m^2 (0.2 µCi/m^2).
c. Assumes $5 million dollars/km^2 for cleanup without removal and disposal of contaminated materials; and $50 million dollars/km^2 for cleanup with removal and disposal of contaminated materials

4.1.3 Radiological Impacts of the Secondary and Backup Launch Opportunities

Impacts of pre-launch, early-launch, and late-launch accidents associated with the secondary and backup launch opportunities for the proposed action are expected to be approximately the same as for the primary Titan IV/SRMU launch opportunity presented in Table 4-2. The analysis was prepared for the secondary launch opportunity, and is applicable to the backup opportunity.

Updated analyses of the potential impacts of a short-term reentry accident associated with each Earth swingby of the VEEGA trajectory are reported in HNUS 1997. Those analyses were performed using the same techniques and models used for the primary launch opportunity. Like the reentry accident with the VVEJGA trajectory, the updated analyses for the VEEGA reentries indicate that more of the RTG components are likely to survive the reentry conditions, resulting in less vaporization of the PuO_2 in the upper atmosphere and lower world-wide impacts. As with the VVEJGA reentry, the updated analyses indicate that high-altitude vaporization of a large fraction of the PuO_2 is less likely than indicated in the EIS. This results in lower estimates of mean source terms and mean radiological impacts than reported earlier in the 1995 Cassini EIS.

The accident risks and impacts of a short-term inadvertent reentry for both the secondary and backup launch opportunities using VEEGA trajectories are predicted to be similar. The updated analyses indicate that the total probability of a PuO_2 release from the RTGs and RHUs with the two Earth swingby portions of the VEEGA trajectory is $3.4x10^{-7}$ (1 in 2.9 million). The updated analyses also indicate that the mean impacts from an inadvertent reentry could be 227 health effects with 21 km^2 (8.1 mi^2) of land contaminated above the EPA guideline level. As with the VVEJGA accident impact estimates, larger impacts would be predicted at lower probabilities. The estimated health effects risk for the Earth swingby portions of the secondary and backup mission is $7.6x10^{-5}$.

The probability of a long-term inadvertent reentry from the interplanetary cruise portion of the VEEGA trajectory prior to the final gravity assist is $5.9x10^{-7}$. No additional analyses are available of the estimated impacts of such an accident. The reader is referred to Section 4.1.6.2 of the 1995 Cassini EIS for discussion of the potential impacts of an inadvertent long-term reentry accident.

4.2 RADIOLOGICAL IMPACT ASSESSMENT OF THE 2001 MISSION ALTERNATIVE

The 2001 Mission Alternative would be similar to the Proposed Action in that it would include the Cassini spacecraft with the Huygens Probe and the Titan IV (SRMU)/Centaur launch vehicle, as described in Sections 2.1.3 through 2.1.5 of this SEIS. The primary opportunity of this mission alternative, however, would insert the Cassini spacecraft into a non-EGA trajectory. The launch would have a similar mission timeline as described in Section 2.1.7 of this SEIS. This mission alternative would have a primary launch opportunity during the first 2.5 weeks of March 2001 from CCAS, and would use a 10.3-year VVVGA trajectory, as depicted in Figure 2-5. The first Venus swingby would occur in August 2001, the second in September 2002, and the third in November 2005, with Cassini arriving at Saturn in June 2011 for the four-year tour of the Saturnian system (JPL 1994). A backup opportunity in May 2002 would use a VEEGA. This alternative was discussed in detail in Section 2.4 of the 1995 Cassini EIS.

Radiological impacts of pre-launch, early-launch, and late-launch accidents associated with either the primary VVVGA or backup VEEGA launch opportunities are expected to be approximately the same as for the primary Titan IV/SRMU launch opportunity presented in Table 4-2.

With the primary VVVGA trajectory, there would be no opportunity for a short-term inadvertent reentry but a long-term inadvertent reentry risk would remain. However, with the backup VEEGA trajectory, both short- and long-term inadvertent risks would be present and be approximately the same as indicated for the secondary and backup (VEEGA) primary launch opportunities presented in Section 4.1.4 of this SEIS.

Prior to launch of either the primary or backup opportunity, comprehensive radiological emergency plans would be in place and implemented as discussed for the Proposed Action in Section 4.1.2.4 of this SEIS.

4.3 THE NO-ACTION ALTERNATIVE

There would be no adverse environmental impacts associated with the No-Action alternative; however, there would be major adverse programmatic and potentially adverse international relations impacts from a cancellation of the Cassini mission. In addition, cancellation of the mission would result in the loss of existing United States engineering and scientific expertise and capabilities. For further discussion of the impacts of the No-Action alternative, see Section 4.4 of the 1995 Cassini EIS.

4.4 ADVERSE ENVIRONMENTAL IMPACTS THAT CANNOT BE AVOIDED

The unavoidable adverse environmental impacts associated with both the Proposed Action and the remaining 2001 Mission alternative are related primarily to the effects of solid rocket motor emission during the first few seconds of the launch. These impacts remain unchanged by the ongoing mission safety analyses. For details, refer to Section 4.5 of the 1995 Cassini EIS.

4.5 INCOMPLETE OR UNAVAILABLE INFORMATION

The recently available analyses referenced in this SEIS constitute the full analytical documentation relied upon in this NEPA process. Risk estimates may subsequently become available and could potentially vary from the risk estimates reported in this SEIS. Such subsequent information may occur as a result of statistical variance from the ongoing separate and independent nuclear launch safety analysis and evaluation for Presidential decision-making.

With respect to the long-term inadvertent reentry accident, the performance and behavior of the materials used in the RTGs after many years (a decade to a millennia) in a space environment are highly uncertain. Therefore, the response of the GPHS modules and GISs in the long-term inadvertent reentry were therefore assumed to be similar (same order of magnitude) to those estimated for the short-term VVEJGA inadvertent reentry.

4.6 RELATIONSHIP BETWEEN SHORT-TERM USES OF THE HUMAN ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

Neither the short-term uses of the environment nor the enhancements to long-term productivity addressed in the 1995 Cassini EIS are affected by the updated mission safety analyses. Should an accident occur causing a release, short-term uses of contaminated land could be curtailed, pending mitigation. Refer to Section 4.7 of the 1995 Cassini EIS for additional details.

4.7 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

For both the Proposed Action and the 2001 Mission alternative, quantities of various non-renewable resources, such as energy and fuels, iridium metal, plutonium and other materials, would be irreversibly and irretrievably committed. These remain unchanged by the updated mission safety analyses. Additional details can be found in Section 4.8 of the 1995 Cassini EIS.

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