4 ENVIRONMENTAL CONSEQUENCES

This Chapter of the Draft Environmental Impact Statement (DEIS) for the New Horizons mission presents information on the potential environmental impacts of an Atlas V 551 launch. The impacts are examined for two areas: (1) the local area surrounding Cape Canaveral Air Force Station (CCAFS), Florida, and (2) the global environment.

4.1 ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION

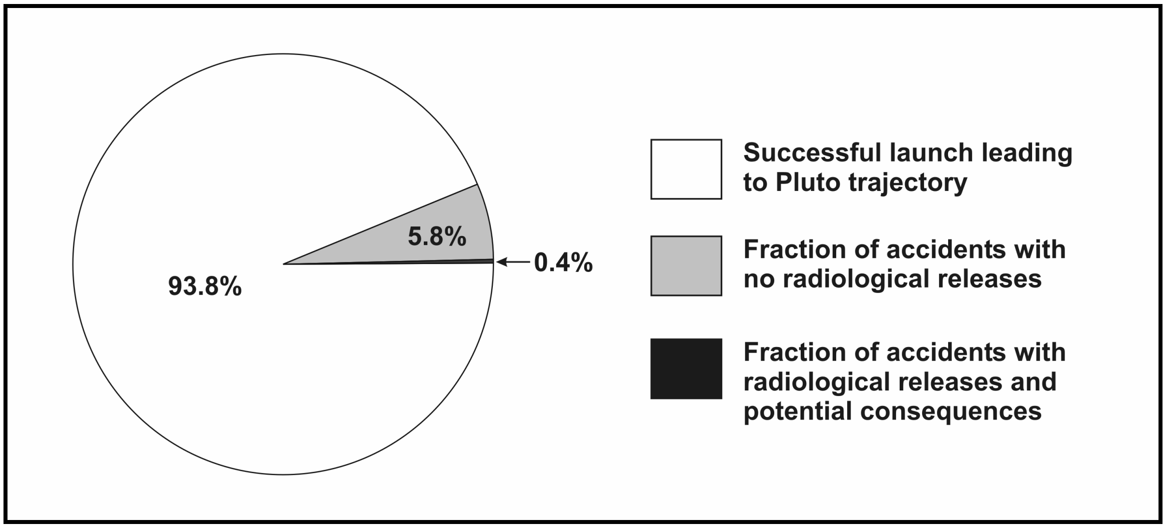
The National Aeronautics and Space Administration (NASA) proposes to continue preparations for and to implement the New Horizons mission to Pluto and its moon, Charon, and to the Kuiper Belt that lies beyond Neptune's orbit. The New Horizons spacecraft would perform science observations of Pluto and Charon as it flies past these bodies, and could be directed to perform similar science observations as it flies past of one or more Kuiper Belt Objects (KBO).

The New Horizons spacecraft would be launched on an Atlas V 551 launch vehicle from Space Launch Complex-41 (SLC-41) at CCAFS. The primary launch opportunity occurs in January – February 2006, with arrival of the spacecraft at Pluto as early as 2015. A backup launch opportunity could occur during February 2007, with arrival at Pluto in either 2019 or 2020, depending on the exact launch date.

This section of the DEIS first presents the environmental impacts of preparing for launch and the environmental impacts resulting from a normal launch event. These impacts are summarized in Sections 4.1.1 and 4.1.2, respectively. Environmental impacts associated with Atlas launches from CCAFS have been previously addressed in the U.S. Air Force's (USAF) *Final Environmental Impact Statement for the Evolved Expendable Launch Vehicle Program* (USAF 1998) and *Final Supplemental Environmental Impact Statement for the Evolved Expendable Launch Vehicle Program* (USAF 2000) and in NASA's *Final Environmental Assessment for Launch of NASA Routine Payloads on Expendable Launch Vehicles from Cape Canaveral Air Force Station, Florida and Vandenberg Air Force Base, California* (NASA 2002). The USAF has assessed environmental impacts of Atlas V launches through 2020 based upon an annual average launch rate of 10 launches per year from CCAFS (USAF 2000). Launch of the Atlas V for the New Horizons mission would be included in and not increase this previously approved launch rate.

The potential nonradiological environmental impacts of a launch accident are discussed in Section 4.1.3. Section 4.1.4 addresses radiological impacts which may result from a launch accident.

As shown in Figure 4-1, the most likely outcome of implementing the New Horizons mission (938 out of 1,000) is a successful launch of the spacecraft to Pluto. If, however, a launch accident were to occur, such an unlikely accident is not expected to result in a release of the plutonium dioxide (PuO_2) in the radioisotope thermoelectric generator (RTG).



Source: Adapted from DOE 2005

FIGURE 4-1. LAUNCH-RELATED PROBABILITIES

Various sections of this DEIS refer to a launch success probability of approximately 94 percent for the New Horizons Atlas V launch vehicle. This is an estimate for the vehicle to successfully complete all pre-launch operations, first stage flight, Centaur second stage flight, third stage flight, and conclude with successful insertion of the spacecraft into the proper Earth escape trajectory. The methodology used to calculate this estimate utilized flight histories of all United States and Russian launch vehicles flown since 1988. This flight history consists of earlier versions of Atlas and Titan launch vehicles manufactured by the Lockheed Martin Corporation, Delta launch vehicles manufactured by the Boeing Aerospace Company, and Zenit and Energia launch vehicles manufactured by Russian aerospace companies. This is done to provide some assurance to the estimate that all past applicable and partially applicable flight failure experiences are considered in the reliability estimate of the Atlas V launch vehicle for the New Horizons mission. This estimate therefore does not necessarily reflect the demonstrated reliability of the Atlas V, which in fact may be higher. This analytical approach for the overall mission launch reliability is considered by NASA to be conservative, and is based upon the best available information at the time of the analysis. NASA continues to evaluate the mission launch reliability analysis. The Atlas V is a new configuration of the Atlas family of launch vehicles, and there have been three successful flights of Atlas V vehicles to date. The results of NASA's continuing evaluations may eventually be different from the results presented in this DEIS as the Atlas V completes additional launches scheduled prior to the proposed New Horizons launch in 2006. Successful completion of those scheduled missions would be expected to produce an increase to the reliability estimate of the Atlas V launch vehicle for the New Horizons mission reported in this DEIS.

4.1.1 Environmental Consequences of Preparing for Launch

Launch activities for the New Horizons mission would be subject to Federal, State, and local environmental laws and regulations, and USAF regulations and requirements (see

Section 4.8). Atlas launch vehicles are routinely launched from CCAFS and processing the launch vehicle for the New Horizons mission would be considered a routine activity.

Payload and launch vehicle processing at Kennedy Space Center (KSC) and CCAFS would involve a number of industrial activities that include the use of hazardous materials, and would generate hazardous wastes, other solid and liquid wastes, and air emissions. Such material would include but not be limited to propellants, oils, solvents, primers, sealants, and process chemicals. NASA or its contractors would acquire hazardous materials and would dispose generated hazardous wastes. In addition, CCAFS has programs for pollution prevention and spill prevention. Airborne emissions from liquid propellant loading and off-loading of spacecraft and launch vehicles are closely monitored using vapor detectors. Systems for loading hypergolic fuels (which ignite spontaneously when mixed) use air emission controls (USAF 1998). Thus, processing the spacecraft and Atlas V launch vehicle for the New Horizons mission is not expected to cause adverse environmental impacts.

Some spacecraft and launch vehicle integration personnel could be exposed to radiation during pre-launch testing and integration of the RTG to the New Horizons spacecraft. Integration and launch processing activities involving ionizing and non-ionizing radiation at KSC and CCAFS are subject to extensive review and authorization of all activities by the local radiation protection authority prior to initiation of any operation. Such operations are actively monitored by launch site radiation safety personnel to ensure adherence to approved operating and emergency procedures and to maintain operational personnel exposures at levels that are as low as reasonably achievable (USAF 1999, NASA 2001).

4.1.2 Environmental Impacts of a Normal Launch

The primary environmental impacts of a normal launch of the New Horizons mission on an Atlas V 551 would be associated with airborne exhaust emissions from propellant combustion, particularly from the solid propellant in the solid rocket boosters (SRB). Exhaust from the liquid propellant first stage of the Atlas V (consisting of rocket propellant-1 (RP-1) and liquid oxygen (LO_2)) would have relatively minor impacts.

4.1.2.1 Land Use

CCAFS is designated a Federal entity and has its own land use and zoning regulations. Brevard County and the City of Cape Canaveral have jurisdiction over the land areas adjacent to CCAFS and the general plans of Brevard County and the City of Cape Canaveral designate compatible land uses around CCAFS. Land areas on and around SLC-41 are currently within the launch operations land use category. Therefore, launch of an Atlas V is consistent with the designated land uses of CCAFS and KSC (USAF 1998, NASA 2003).

4.1.2.2 Air Quality

Rocket launches are discrete events that can cause short-term impacts on local air quality from launch vehicle exhaust emissions. Winds would rapidly disperse and dilute the launch emissions to background concentrations. After ignition of the first stage and the first few seconds of liftoff through launch vehicle ascent, the exhaust emissions would form a buoyant cloud at the launch pad. This high-temperature cloud would rise quickly and stabilize at an altitude of a few hundred meters near the launch area. The cloud would then dissipate through mixing with the atmosphere. The exhaust products would be distributed along the launch vehicle's trajectory as the vehicle moves through the atmosphere. Airborne emissions from a normal launch at CCAFS would not be expected to result in adverse impacts to the off-site public (USAF 1998, USAF 2000). The nearest residential areas to CCAFS are about 13 to 16 kilometers (km) (8 to 10 miles (mi)) to the south in the cities of Cape Canaveral and Cocoa Beach.

Exhaust emissions would occur over a period of minutes as the launch vehicle ascends through the atmosphere. Exhaust emissions occurring up to an altitude of about 9,150 meters (30,000 feet) from the surface are typically considered lower atmospheric emissions. A normal Atlas V launch would result in combustion emissions from the first stage main engine and the SRBs. The Atlas V main engine primarily produces carbon monoxide (CO), carbon dioxide (CO_2), water vapor, oxides of nitrogen (NO_X), and carbon particulates as combustion products. The Atlas V SRBs primarily produce oxidation products of aluminum oxide (Al_2O_3), CO, hydrogen chloride (HCl), and nitrogen (N_2). Under the high temperatures of the SRB's exhaust the CO would be quickly oxidized to CO_2, and the N_2 may react with ambient oxygen to form nitrogen oxides (NO_X). Most of these emissions would be removed from the atmosphere over a period of less than one week, yielding no long-term accumulation of these products (USAF 1998).

Previous analyses have shown that emissions from a normal launch of an Atlas V with SRBs would not create long-term adverse impacts to air quality in the region (USAF 2000). The entire State of Florida, and therefore the CCAFS area, is in attainment for all National Ambient Air Quality Standards (NAAQS) constituents (see Table 3-2), including the proposed $PM_{2.5}$ fine particle standard based on preliminary data (FDEP 2002, 69 FR 23857). Based on the USAF findings cited above, emissions from launch of the New Horizons mission at CCAFS would not be sufficient to jeopardize the attainment status of the region.

4.1.2.3 Noise

Estimated noise levels for an Atlas V have been previously reported (USAF 1998, USAF 2000). Noise impacts associated with launches occur due to sound from the launch pad from ignition through lift-off. Increased noise levels would occur for only a short period (typically less than two minutes) during the vehicle's early ascent, and diminish rapidly as the vehicle gains altitude and moves downrange (USAF 1998).

Based on modeling, the overall sound pressure level at the launch site for a typical Atlas V 551 launch would be about 130 decibels (dBA) (USAF 2000). Non-essential workers would be removed from the launch area prior to the New Horizons liftoff, and those remaining would be exposed to noise levels anticipated to be below Occupational Safety and Health Administration regulations for unprotected workers (140-dBA maximum and 115-dBA over a 15-minute average).

During an Atlas V launch, the noise levels at the nearest communities (Cape Canaveral and Cocoa Beach, both to the south about 13 to 16 km (8 to 10 mi) from the launch pad) have been estimated to be in the 70 to 73 dBA range (USAF 2000). While some area residents may be momentarily annoyed by noise during the New Horizons launch, such noise would be transient and would present no health hazard.

Sonic booms would be generated by normal launch of the New Horizons Atlas V, but would occur offshore over the Atlantic Ocean. No adverse impact to human populations would be expected. Ships and other vessels in the area would be warned in advance of the launch event and would not be adversely affected (USAF 1998).

4.1.2.4 Geology and Soils

The New Horizons Atlas V launch would result in deposition of solid rocket exhaust products (primarily Al_2O_3 particulates and HCl) onto soils. Deposition of Al_2O_3 in the form of dust would occur primarily in the vicinity of the launch complex, but depending on the particle size distribution and winds, appreciable deposition could also occur downwind. Wet deposition of HCl could occur as exhaust chlorides mix with entrained deluge water and with water contained in the exhaust of the first stage engine. The majority of HCl, however, would be swept into the flame trench at the launch pad. Wet deposition of chlorides would be limited to within a few hundred meters of the launch pad and could temporarily increase acidification of soil. If a rainstorm passes through the exhaust cloud shortly after launch, wet HCl deposition could occur at further distances from the launch complex. The soils at CCAFS are well buffered, however, and are not expected to be adversely affected (Schmalzer et al. 1998, USAF 1998). No long-term adverse impacts to geology or soils at CCAFS would be expected from the New Horizons launch.

4.1.2.5 Hydrology and Water Quality

About 2.27 million liters (600,000 gallons) of water are used during launch of an Atlas V for cooling, acoustic damping, post-launch washdown, fire suppression, and potable uses. Groundwater and surface water resources and water quality could be potentially impacted by the disposal of water used for a launch, and by the deposition of launch exhaust products into nearby surface water bodies.

<u>Groundwater</u>. The City of Cocoa, which pumps water from the Floridan Aquifer, is contracted to supply water to CCAFS and Patrick Air Force Base. The City of Cocoa has sufficient capacity to supply sources to meet usage demands for launch of the New Horizons mission.

Water used at SLC-41 during the launch would be collected and treated, if necessary, prior to being released to grade in accordance with a Florida Department of Environmental Protection wastewater discharge permit, or released to the wastewater treatment plant. The water discharged to grade would percolate through soil to the groundwater table and flow west towards the Banana River (USAF 1998). The water would be further neutralized during its passage through the soil, such that some of the contaminants not removed during treatment would also be removed. It is not expected that groundwater quality would be substantially affected by this discharge of water.

Surface Water. Depending on meteorological conditions, the Atlas V exhaust cloud could drift over the Atlantic Ocean or the Banana River. Surface waters in the immediate area of the exhaust cloud might acidify from deposition of HCl if a rainstorm passes through the exhaust cloud. The large volumes of water bodies in the vicinity of CCAFS, combined with their natural buffering capacity, suggest that the increased acidity caused by HCl deposition would return to normal levels within a few hours (USAF 1996). Al_2O_3 particulates would also settle from the exhaust cloud. Al_2O_3 particulates are relatively insoluble in local surface waters and would settle out of the water column as sediment. Long-term elevation of aluminum levels in the water column would not be expected.

No long-term adverse impacts to hydrology or water quality would be expected due to a normal launch of the New Horizons mission.

4.1.2.6 Offshore Environment

The offshore environments at CCAFS would be impacted by the jettisoned launch vehicle sections (i.e., the depleted first stage, payload fairing (PLF), and SRB casings) in pre-approved drop zones (see Section 4.1.2.11). Any small amounts of residual propellants would be released to the surrounding water. Metal parts would eventually corrode, but toxic concentrations of the metals would be unlikely because of the slow rate of the corrosion process and the large volume of ocean water available for dilution. Since RP-1 is only weakly soluble in water, any residual RP-1 fuel in the first stage would form a localized surface film which would evaporate within hours. The residual propellant in the SRB casings would dissolve slowly and should not reach toxic concentrations except in the immediate vicinity of the casings (USAF 1998).

4.1.2.7 Biological Resources

Biological resources are not expected to be adversely affected by the New Horizons Atlas V launch except for those fauna and flora in the immediate vicinity of SLC-41. Impacts to vegetation from other launch vehicles (e.g., Atlas II, Delta II, Titan IVB) were observed up to about 800 m (2,625 ft) from the launch pads. Potential impacts from the Atlas V could include scorched vegetation, ground fires, and partial to nearly complete defoliation of trees within 70 to 100 m (230 to 328 ft). Acidic deposition and high temperatures from the exhaust cloud could damage or kill biota within the immediate vicinity of the launch pad, however, long-term population effects on terrestrial biota would not be expected. Jettisoned launch vehicle sections (the SRB casings, first stage, and PLF) that land in the ocean would be subject to corrosion and release of residual propellant. However, it is unlikely that these vehicle sections would have an adverse impact on marine species.

Terrestrial and Aquatic Biota. Short-term impacts to terrestrial fauna and flora in the immediate vicinity of the launch complex could be expected due to the New Horizons launch. Aquatic biota in nearby water bodies, such as the Banana River and the near-shore areas of the Atlantic Ocean, should not be adversely affected by acidic deposition from the exhaust cloud (USAF 1996). A fish kill occurs after most Space Shuttle launches from KSC as a direct result of surface water acidification (Schmalzer et al.

1998). However, there have been no fish kills reported in either the Banana River or the near-shore areas of the Atlantic Ocean from HCl and Al_2O_3 deposition from normal launch of a Delta II (NASA 1995b). Since the Atlas V for the New Horizons mission would use about one fifth the quantity of solid propellant used by the Space Shuttle, fish kills would not be anticipated.

During the launch, wildlife in the vicinity of the launch site would be temporarily disturbed due to noise, generally amounting to a startling effect. Marine species could be impacted by sonic booms, however the effects of such impacts are not clearly known (USAF 1998, USAF 2000). Because launches are infrequent events, no long-term impacts would be anticipated on wildlife and marine species from noise from the New Horizons launch.

Threatened or Endangered Species. No scrub jay mortality would be expected from the New Horizons launch, based on studies during and following Titan IV launches from SLC-41 in 1990. Fire started by a launch in 1990 caused extended jay scolding behavior and the scrub jays avoided the burned area for about one month (USAF 1998). Other bird species, such as wood storks and bald eagles, may be temporarily disturbed, but no long-term effects would be anticipated.

Sea turtles are sensitive to lighting near nesting beaches. If lighting inland is brighter than the reflected light of the moon and stars on the ocean, hatchlings may become confused, head the wrong way, and never reach the water. Sea turtle nesting typically occurs from May through October, and CCAFS has a light management plan that addresses mitigation of impacts to nesting sea turtles during night-time launches (USAF 1998). Because the New Horizons mission's primary and backup launch periods occur in January and February and the launch would occur during daylight hours, impacts to nesting sea turtles would not be anticipated.

4.1.2.8 Socioeconomics

Launch of the proposed New Horizons mission from CCAFS would be part of the normal complement of launches at CCAFS. Thus, a single launch would result in negligible impacts to socioeconomic factors such as demography, employment, transportation, and public or emergency services.

4.1.2.9 Environmental Justice

Launch of the proposed New Horizons mission would not be anticipated to result in disproportionately high and adverse impacts to low income or minority populations. Further details are presented in Appendix C.

4.1.2.10 Cultural/Historic/Archaeological Resources

No cultural or archaeological resources would be impacted, nor are there buildings or sites that are listed or eligible for listing in the National Register of Historic Places, at SLC-41 (USAF 2000).

4.1.2.11 Health and Safety

At CCAFS, procedures would be in place for the New Horizons mission launch operations, and would include considerations for a normal launch, launch-related accidents, fire protection, alarm, fire suppression, flight termination, and explosive safety (USAF 1998, USAF 2000). Using procedures established for existing launch systems, risks to installation personnel and the general public would be minimized to acceptable levels during both a normal and aborted launch, in accordance with the USAF's *Eastern and Western Range Safety Requirements* (USAF 1997).

The most significant potential health hazard during the New Horizons launch would be exposure to HCl emitted from the SRBs. Range Safety at CCAFS would use models to predict launch hazards to the public and on-site personnel prior to the launch. These models calculate the risk of injury resulting from toxic exhaust gases from normal launches, and from potentially toxic concentrations due to a failed launch. The launch could be postponed if the predicted collective public risk of injury from exposure to toxic exhaust gases exceeds acceptable limits (USAF 1997). This approach takes into account the exhaust plume's concentration, direction, and dwell time, and emergency preparedness procedures (USAF 2000).

Range Safety would monitor launch surveillance areas to ensure that risks to people, aircraft, and surface vessels are within acceptable limits. For the New Horizons mission, a launch trajectory would be created and modified to ensure safety on the ground and at sea, and control areas and airspace would be closed to the public as required. The underlying areas at risk from falling debris or jettisoned stages would be cleared until all launch operations are completed. The SRB casings would land closest to shore, in pre-approved drop zones centered at distances of approximately 230 km (143 mi) from shore. PLF sections and the first stage would land much further from shore, also in pre-approved drop zones (USAF 2000). These distances would be highly dependent on the specific New Horizons launch trajectory characteristics, and other factors such as wind effects.

The USAF would disseminate a Notice to Aviators through the Federal Aviation Administration (FAA), and air traffic in a FAA-designated area around the launch corridor would be controlled. Radar surveillance for intruding aircraft within a 93 km (50 nautical miles) radius of the launch site would be conducted beginning 30 minutes prior to the scheduled launch and continue until the launch is complete. The USAF also would ensure that a Notice to Mariners within a predetermined impact debris corridor is disseminated beginning 10 working days prior to launch. The U.S. Coast Guard would transmit marine radio broadcast warnings to inform vessels of the effective closure time for the sea impact debris corridor. Warning signs would be posted in various Port Canaveral areas for vessels leaving port (USAF 1998). In addition, Patrick Air Force Base would maintain a web site and toll-free telephone number with launch hazard area information for mariners and restricted airspace information for pilots.

4.1.2.12 Global Environment

This section briefly summarizes the potential for the normal launch of an expendable vehicle to contribute to ozone depletion and global climate change. Launch of the New

Horizons Atlas V would not be expected to make substantial contributions to the amounts of ozone-depleting chemicals or greenhouse gases in the atmosphere.

Troposphere. Launch of the proposed New Horizons mission would result in the deposition of exhaust products released along the launch vehicle's trajectory as it ascends through the troposphere. Exhaust products would mostly include HCl, NO_X, and Al_2O_3 particulates from the SRBs, and CO, CO_2, NO_X, and water vapor from stages using liquid propellants. While there could be ground-level impacts from these products, deposition of small quantities of some exhaust products in the troposphere could contribute to conditions such as global climate change. However, this material would be removed from the troposphere in a short period of time.

Stratosphere. Launch of the New Horizons mission would result in the deposition of small quantities of ozone-depleting chemicals from the combustion products released along the launch vehicle's trajectory through the stratosphere up to an altitude of about 50 km (31 mi). Because of uncertainties about the current loading of ozone-depleting chemicals in the stratosphere, the effects of a launch can be more accurately calculated as a percent increase in the rate of stratospheric ozone depletion relative to a launch not occurring.

Solid rocket motors use ammonium perchlorate as an oxidizer and chlorine compounds are released during combustion, which are the principal contributors to stratospheric ozone depletion from launch vehicles. The principal ozone-depleting chemicals in exhaust emissions from an Atlas V with SRBs would be HCl, NO_X, and Al_2O_3 particulates. The ozone depletion rates associated with each of these exhaust products have been previously estimated to be 3.1×10^{-5} percent per metric ton (mt) (2.8×10^{-5} percent per ton) for HCl emissions, 1.8×10^{-6} percent per mt (1.6×10^{-6} percent per ton) of NO_X, and 8.3×10^{-6} percent per mt (7.5×10^{-6} percent per ton) of Al_2O_3 (Jackman et al. 1998). NO_X contributes to destroying stratospheric ozone about 17 times less than HCl and about 4.5 times less than Al_2O_3 (Jackman 1998). The depletion rates for NO_X, HCl, and Al_2O_3 have been used in combination with the estimated mass of combustion products potentially emitted to the stratosphere by various launch vehicles to develop an estimate of annual average global ozone depletion (USAF 1998, USAF 2000, NASA 2002). While a large fraction of launch emissions would occur in the lower atmosphere and not reach the stratosphere, the estimates were based on a conservative assumption that all emissions occurred in the stratosphere. The annual average ozone depletion rate for the normal launch of an Atlas V with SRBs has been estimated to be almost zero (USAF 2000).

Exhaust products from SRBs have greater potential for stratospheric ozone depletion than exhaust products from liquid propelled motors. Therefore, impacts from SRBs have been studied more extensively than impacts from liquid propellant motors.

Global Climate Change. Solar energy is absorbed by the Earth and a portion of this energy is radiated back to space. Global warming occurs when increasing concentrations of certain gases (called greenhouse gases) in the atmosphere trap the re-radiated solar energy within the atmosphere causing the Earth's average surface temperature to rise. Examples of greenhouse gases are water vapor, CO_2, methane, nitrous oxide (N_2O), ozone, perfluorocarbons, and hydrofluorocarbons. Indirect contributors to greenhouse gases include compounds such as CO, NO_X, and non-methane hydrocarbons. These photochemical gases can influence the rate of creation and destruction of gases that, in turn, may influence global climate change.

Over the last 100 years, the Earth's average surface temperature has risen by about 0.5° Celsius (°C) (1° Fahrenheit (°F)). This increase may be due to the addition of greenhouse gases from human activities. A rise in the Earth's average surface temperature could impact the climate, which in turn may lead to changes in the biosphere (e.g., changes in rainfall patterns and sea surface levels), which could have impacts on fauna, flora, and the human environment. In 2002, the United States had total net emissions of greenhouse gases of about 6.2×10^{12} kilograms (kg) (1.3×10^{13} pounds (lb)), measured in terms of CO_2 equivalent, of which about 83 percent was CO_2 emissions (EPA 2004a).

Launch of an Atlas V with SRBs would result in the emission of greenhouse gases to the atmosphere. Primary exhaust emissions would consist of CO_2, with trace emissions of nitrous oxide (N_2O) emitted by the SRBs, NO_X species, HCl, and water vapor. The exhaust would also contain carbon monoxide (CO), most of which would quickly react with oxygen in the atmosphere to form CO_2 under the high temperatures of the SRB exhaust. Emission estimates from a variety of expendable launch vehicles have been previously reported (USAF 1998, USAF 2000). The total emissions into upper atmospheric layers of all exhaust products from an Atlas V 551 was estimated to be about 9.8×10^4 kg (2.2×10^5 lb), on the order of 10^{-6} percent of the net emissions of greenhouse gases emitted by the United States in 2002. Therefore, launch of the Atlas V for the New Horizons mission would not be anticipated to substantially contribute to global climate change.

4.1.2.13 Orbital and Reentry Debris

During the launch sequence of the Atlas V for the New Horizons mission (see Figure 2-8), the SRB casings, the first stage, and the PLF would be jettisoned and fall into the Atlantic Ocean in predetermined drop zones (see Section 4.1.2.11) well before reaching Earth orbit. Shortly after separating from the first stage, the Centaur second stage would be ignited, accelerating the Centaur and the attached third stage and spacecraft to low Earth parking orbit. After a brief coast period, the Centaur engine would be reignited, accelerating to Earth escape velocity. After propellant depletion, the Centaur would be separated from the third stage prior to ignition of the third stage motor. After propellant burnout, the third stage would be separated from the New Horizons spacecraft. The second and third stages would continue separately into interplanetary space. Therefore, a normal launch of the Atlas V for the New Horizons mission would not contribute to orbital or reentry debris.

4.1.3 Environmental Impacts of Potential Accidents Not Involving Radioactive Material

As shown in Figure 4-1, an accident occurring during launch of the New Horizons mission is unlikely (62 out of 1,000). If an accident were to occur, then the highest conditional probability outcome (approximately 58 out of 62) is that such an accident would not involve release of PuO_2 from the RTG.

The potential environmental impacts associated with Atlas V accidents have been discussed in previous USAF environmental documentation (USAF 1998, USAF 2000), summarized here and augmented with new information where applicable. A variety of accidents could occur during preparations for and launch of an Atlas V. Only two types of nonradiological accidents would have potential off-site consequences: a liquid propellant spill occurring after the start of propellant loading operations, and a launch failure. The potential consequences of these accidents are presented below.

4.1.3.1 Liquid Propellant Spills

A typical Atlas V uses about 284,089 kg (626,309 lb) of RP-1 and LO_2 for the first stage, and about 20,672 kg (45,573 lb) of liquid hydrogen (LH_2) and LO_2, with about 127 kg (280 lb) of hydrazine for the Centaur second stage (USAF 2000, ILS 2001). The New Horizons spacecraft would use about 80 kg (176 lb) of hydrazine for the primary mission (APL 2003d). The first stage and second stage fueling operations are performed in accordance with CCAFS propellant loading protocols. Standard procedures such as use of closed loop systems are practiced, which would minimize worker exposure and the potential for fuel releases.

Accidental leaks or spills of RP-1, LO_2, LH_2, and hydrazine could occur during propellant loading and unloading activities. USAF safety requirements specify that plans and procedures be in place to protect the workforce and the public during fueling operations (USAF 1997). Spill containment would be in place prior to any propellant transfer to capture any potential release. Hydrazine transfer would involve a relatively small amount of liquid through a relatively small transfer system, so any leakage would be held to an absolute minimum. The atmospheric dispersion of hydrazine from a liquid propellant accident has not been modeled, but it is expected that, because of the limited quantities involved, there would be no impact to the public in off-site areas.

Spill kits located in the work area would be used if a release is detected during RP-1 loading. Personnel would be present in the immediate area to handle any release. Workers would be required to wear personal protective equipment while loading RP-1 and hydrazine, and all unprotected workers would be removed from the area prior to loading. The operator would remotely close applicable valves to minimize any release and safe the system.

If a spill or release is detected during LO_2 and LH_2 loading at the launch pad, the operator would remotely close the applicable valves to minimize the amount of liquid released, and safe the system. Water deluge would be used only if heat is detected in the area of concern.

4.1.3.2 Launch Failures

A launch vehicle accident either on or near the launch pad within a few seconds of lift-off presents the greatest potential for impact to human health, principally to workers. For the proposed New Horizons mission, the most significant potential health hazard during a launch accident would be from the HCl emitted from burning solid propellant from the SRBs. Range Safety at CCAFS uses models to predict launch hazards to the public and on-site personnel prior to every launch. These models calculate the risk of injury resulting from toxic gases, debris, and blast overpressure from potential launch failures. Launches are postponed if the predicted collective public risk of injury exceeds acceptable limits, which are applied separately for the risk of injury from exposure to toxic gases, debris, and blast overpressure (USAF 1997). This approach takes into account the probability of a catastrophic failure, the resultant plume's toxic concentration, direction, and dwell time, and emergency preparedness procedures (USAF 2000).

Range Safety requirements mandate destruct systems on liquid propellant tanks and SRBs (see Section 2.1.6.5). In the event of destruct system activation, the propellant tanks and SRB casings would be ruptured, and the entire launch vehicle would be destroyed. A catastrophic launch failure would involve burning solid propellant and the ignition of liquid propellant (i.e., hydrazine, RP-1, LH_2, and LO_2). The potential short-term effects of an accident would include a localized fireball, falling debris from explosion of the vehicle, release of uncombusted propellants and propellant combustion products, and for on-pad or very low altitude explosions, death or damage to nearby biota and brush fires near the launch pad. Unburned pieces of solid propellant with high concentrations of ammonium perchlorate could fall on land or into nearby bodies of water. Perchlorate could leach into surrounding soil or water resulting in high concentrations in the immediate vicinity of the propellant fragment, and could result in adverse, localized impacts to the terrestrial or aquatic environment. Some mortality to biota in those areas could be expected until the solid propellant is fully dissolved. However, pieces of unburned solid propellant falling on land would be collected and disposed as hazardous waste. Similarly, large pieces falling in fresh water areas would be collected and disposed, minimizing the potential for perchlorate contamination (DOD 2003).

The USAF modeled postulated accidents at CCAFS involving combustion of Atlas V propellants (USAF 2000). Representative meteorological conditions were used in the analyses to model movement of the exhaust cloud. Release and combustion of both liquid and solid propellants were assumed to be involved. For the modeled accidents, the principal constituents resulting from burning propellant were CO, Al_2O_3, and HCl, but also included H_2, H_2O, and CO_2. Although Al_2O_3 would be deposited from the explosion cloud as it was carried downwind, little wet deposition of HCl would be expected unless rain falls through the cloud of combustion products. The estimated concentrations of combustion products resulting from these postulated accidents were found to be well within applicable Federal, State, and USAF standards. Based upon these analyses, emissions resulting from an accident during the New Horizons mission Atlas V launch would not be expected to exceed any of the applicable standards, and would not create adverse impacts to air quality in the region.

The USAF analysis did not take into account the potential combustion products from a third stage solid rocket motor. If ignited during a launch accident, the solid propellant in the third stage motor for the New Horizons mission would also emit CO, Al_2O_3, HCl, H_2, H_2O, and CO_2 as combustion products. However, the solid propellant in this motor would account for less than 1 percent of the total inventory of solid propellant aboard the Atlas V for the New Horizons mission. Therefore, these combustion products would not be expected to significantly factor into the previously estimated concentrations.

Parts of the exploded vehicle would fall back to Earth. Except for on-pad or near-pad accidents, most of the fragments would fall into the Atlantic Ocean, where the metal parts would eventually corrode. Toxic concentrations of metals would be unlikely because of slow corrosion rates and the large volume of ocean water available for dilution (USAF 1996).

Debris from launch failures has the potential to adversely affect managed fish species and their habitats in the vicinity of the launch site. Ammonium perchlorate in the solid propellant used in the Atlas V SRBs contains chemicals that, in high concentrations, have the potential to result in adverse impacts to the marine environment. The USAF has consulted with the National Marine Fisheries Service (NMFS) on essential fish habitat regarding launches of Atlas V vehicles from CCAFS (USAF 2000). Launch of the New Horizons mission from CCAFS would be covered under this consultation.

Residual RP-1 fuel is weakly soluble, would spread over the surface of the water, and should evaporate within a few hours, resulting in only a short-term impact to aquatic biota. Due to the relatively small quantities involved for the New Horizons mission, hydrazine either would be burned or be dispersed in the atmosphere without entering the ocean.

Beginning two hours before launch, a Brevard County Emergency Management Center representative would be present at a CCAFS launch console with direct audio and video communications links to the Center. The USAF also has a direct emergency phone line to the Florida State Emergency Response Center.

4.1.4 Environmental Impacts of Potential Accidents Involving Radioactive Material

As shown in Figure 4-1, it is unlikely (62 out of 1,000) that an accident would occur during launch of the New Horizons mission. If an accident were to occur, the highest conditional probability outcome (approximately 58 out of 62) is that such an accident would not involve release of PuO_2 from the RTG. There remains, however, a lower conditional probability (approximately 4 out of 62, or an overall probability of 4 out of 1,000) that such an accident would involve release of some PuO_2 from the RTG to the environment. NASA and the U.S. Department of Energy (DOE) have assessed the potential environmental impacts of launch accidents involving release of PuO_2. This section summarizes the results from DOE's *Nuclear Risk Assessment for the New Horizons Mission Environmental Impact Statement* (DOE 2005).

NASA and DOE and its contractors have conducted several safety assessments of launching and operating spacecraft using RTGs (e.g., the Galileo mission in 1989, the Ulysses mission in 1990, and the Cassini mission in 1997). In developing the nuclear risk assessment for this DEIS, NASA and DOE have drawn from an extensive experience base that involves:

- testing and analysis of the RTG and its components (e.g., fueled clads and aeroshell modules) (see Section 2.1.3.2) under simulated launch accident environments;

- evaluating the probability of launch-related accidents based on evaluations of system designs and launch histories, including extensive studies of the January 1997 Delta II accident at CCAFS; and
- estimating the outcomes of the response of the RTG and its components to the launch accident environments.

DOE's risk assessment for this DEIS (DOE 2005) was prepared in advance of the more detailed Final Safety Analysis Report (FSAR) being prepared in accordance with DOE Directives and to support the formal launch approval process required by Presidential Directive/National Security Council Memorandum 25 (PD/NSC-25), *Scientific or Technological Experiments with Possible Large-Scale Adverse Environmental Effects and Launch of Nuclear Systems into Space*. The FSAR for the New Horizons mission will be developed in a manner similar to those for past missions. Prior to the availability of the FSAR, information and results presented in the DOE risk assessment and summarized in this DEIS were developed based on consideration of risk assessments performed for previous missions (e.g., Cassini and the Mars Exploration Rovers), with additional supplemental analyses where considered appropriate. The resulting approach for DOE's risk assessment consists of a combination of scaling selected results for past missions on a per-curie inventory basis for specific launch accidents and accident environments, coupled with additional analyses as required for the New Horizons mission.

4.1.4.1 Risk Assessment Methodology

The nuclear risk assessment for the New Horizons mission considers (1) potential accidents associated with the launch and their probabilities and resulting environments; (2) the response of the RTG to such accident environments in terms of varying amounts of radioactive material released (source terms) and the release probabilities; and (3) the radiological consequences and risks associated with such a release. The risk assessment was based on a typical radioactive material inventory of 132,500 curies (Ci) of plutonium (Pu)-238 (an alpha-emitter with a half life of 87.7 years) in the form of plutonium dioxide (PuO_2). The activity includes minor contributions from other related plutonium and actinide radionuclides (see Table 2-3). The PuO_2 in the RTG to be used on the New Horizons spacecraft would consist of a mixture of fuel of differing ages, yet to be finalized. Based on the latest information, the inventory in the RTG is estimated to be in the range of 108,000 to 124,000 Ci. A reduction in the assumed inventory from 132,500 Ci would lead to an estimated proportional decrease in the results reported in DOE 2005 and summarized in this DEIS.

The basic steps in the risk assessment methodology are presented in Figure 4-2. The nuclear risk assessment for the New Horizons mission DEIS began with the identification of the initial launch vehicle system failures and the subsequent chain of accident events that could ultimately lead to the accident environments which could threaten the RTG. These launch vehicle system failures were based on Atlas V system reliabilities and estimated failure probabilities (ASCA 2005).

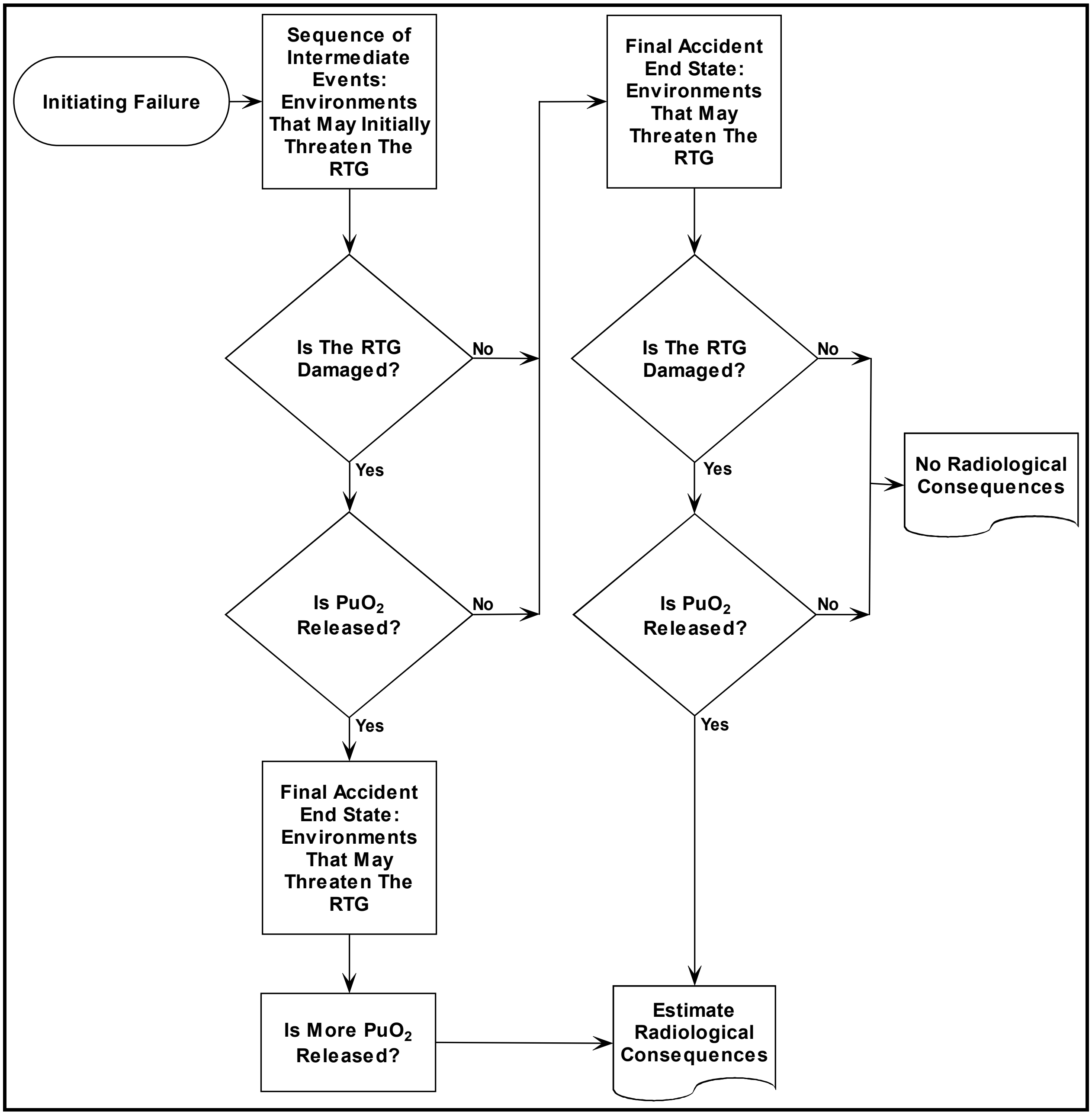


FIGURE 4-2. THE RADIOLOGICAL RISK ASSESSMENT METHODOLOGY

Some intermediate accident events, such as activation of the third stage solid rocket motor (SRM) breakup system (BUS), and final accident configurations, such as the RTG impacting the ground near burning solid propellant, have the potential to create accident environments that could damage the RTG and result in the release of PuO_2.

Based on analyses performed for earlier missions that carried radioisotope devices[1], DOE identified the specific accident environments that could potentially threaten the RTG. Four environments were identified for consideration for the New Horizons mission DEIS:

(1) mechanical impact;

(2) thermal energy;

(3) fragment impacts; and

(4) explosion overpressure.

The first three of these accident environments were identified as posing the greatest threat to the RTG. The specific environments of greatest concern are (1) ground impact of various intact configurations; (2) fire environments resulting from burning solid propellant; and (3) third stage motor fragments resulting from activation of the BUS.

DOE determined the response of the RTG and aeroshell modules to these accident environments and estimated the amount of radioactive material that could potentially be released. Results of DOE's RTG testing and analyses program were used to determine if a release of radioactive material from the RTG could potentially occur. The release fractions (the fraction of the PuO_2 that would be released to the environment) were determined by considering three primary accident environments: mechanical impact, burning solid propellant, and the fragments resulting from BUS activation. The source term results for RTG component mechanical impacts were determined by scaling relevant results based on analyses performed for the Cassini mission. The source terms for mechanical impacts associated with ground impact configurations and the solid propellant fire were based on the methodology used for the MER missions with specific adjustments made to account for three types of particle size distributions and the solid propellant amount and geometry specific to the Atlas V. The source terms for the BUS activation fragment environment were estimated with new analyses.

Consequences of postulated releases were estimated by scaling of selected results from previous missions and additional analyses to reflect conditions specific to the Atlas V and the New Horizons mission, including: population growth, plume configuration, launch complex location, meteorology, various types of particle size distribution, and solid propellant amount and geometry. Consequence values for population dose, maximum exposed individual dose, population health effects[2], and land contamination were estimated at both mean and 99th percentile values.

While the results from safety analysis work performed in the past were used for this analysis, adjustments were made for population growth to 2006 for the local area (out

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[1] RTGs and radioisotope heater units (which contain about 2.7 grams (0.1 ounce) of PuO_2, and generate 1 watt of heat for passive thermal control). Radioisotope heater units are not required for the New Horizons mission.

[2] Additional latent cancer fatalities due to a radioactive release (i.e., the number of cancer fatalities resulting from this release that are in addition to those cancer fatalities which the general population would normally experience from other causes).

to 100 km (62 mi) from the launch site) and globally. Where specific analyses were performed (e.g., the solid propellant fire and BUS activation fragment environments), values of health effects per curie were calculated taking into account the location of SLC-41, the vertical plume configuration associated with potential accidents involving the Atlas V, meteorological conditions for the primary launch opportunity (January – February 2006), and particle size distribution.

The New Horizons mission was divided into six phases. Risk estimates were generated for each mission phase by combining the probabilities and consequences for each relevant accident. The risk estimates for all mission phases were then combined to produce a mission risk estimate.

4.1.4.2 Launch Accidents and Accident Probabilities

For this risk assessment, the New Horizons mission was divided into six mission phases on the basis of mission elapsed time (the time (T) in seconds (s) relative to launch) reflecting principal launch events.

- Phase 0—Pre-Launch: 60 hours < T < 0 s, during which the RTG is installed, final preparations for launch are made to the vehicle, the Flight Termination System (FTS) is armed, and the first stage main engine is ignited and undergoes "health check"[3];
- Phase 1—Early Launch: 0 s < T < 40 s, from when the SRBs are ignited until the vehicle clears land, after which most debris and intact vehicle configurations resulting from an accident would impact water;
- Phase 2—Late Launch: 40 s < T < 90 s, when the vehicle reaches an altitude of 30 km (100,000 ft), above which reentry heating could occur;
- Phase 3—Pre-Orbit: 90 s < T < 622 s, at the first Centaur engine thrust cutoff and the Command Destruct System (CDS) is disabled;
- Phase 4—Orbit: 622 s < T < 2,158 s, from after reaching parking orbit to Earth escape; and,
- Phase 5—Escape: T > 2,158 s, when Earth escape velocity is achieved.

Information on potential accidents and accident probabilities was developed by NASA based on inputs provided by the launch vehicle manufacturer, the third stage manufacturer, and the spacecraft provider. Accidents and their associated probabilities were developed in terms of initiating failures, defined as the first system-level indication of an anomaly that could lead to a launch abort (i.e., safe hold or termination of the launch countdown), catastrophic accident, or mission failure. An example of an initiating failure would be a trajectory control malfunction resulting in the launch vehicle deviating from its planned trajectory. An initiating failure is the beginning of a sequence

[3] The engine undergoes an automatic health check beginning at T–2.72 s. Should a malfunction be detected before T=0, the engine would be shutdown and the launch would be aborted.

of intermediate events that can lead to a range of possible end states, including accident configurations involving the RTG and various launch vehicle stages[4] and the New Horizons spacecraft. For example, FTS activation following a trajectory control malfunction could lead to the RTG impacting the ground. Associated with the accident configuration end states are the four environments that could damage the RTG and result in the release of PuO_2.

The end states that can result from the initiating failures are determined to a large extent by the FTS actions (see Section 2.1.6.5) that would or would not occur during the accident progression following the initiating failure. Important FTS considerations affecting the accident configurations are summarized below.

- The BUS would break up the Stage 3 SRM in order to minimize the possibility of coincident ground impact of the SRM and the SC. The BUS would be safed (automatically deactivated) at T+40 s, after which there would be no potential for land impact in the launch area.
- The Automatic Destruct System (ADS) would destruct the Stage 1 liquid-propellant tanks and the SRBs. The ADS would be safed prior to separation of Stages 1 and 2.
- The Centaur ADS (CADS) would destruct the Stage 1 tanks, the SRBs, the Stage 2 (Centaur) tanks, and the Stage 3 SRM (through the two small CSCs and the BUS). The CADS would be safed prior to separation of Stages 1 and 2.
- The CDS would be activated by the Mission Flight Control Officer (MFCO) and would destroy the launch vehicle in the same manner as a CADS activation. The MFCO would likely issue a CDS in case of a trajectory or attitude control malfunction where the launch vehicle deviation from the planned trajectory violates specific Range Safety criteria for continuation of a safe launch. Should the MFCO response time needed for CDS activation be insufficient, ground impact of the entire vehicle could occur. The CDS would be safed after the first Centaur engine burn.

The Pre-Launch ($T < 0$ s) initiating failures, their probabilities, and the resulting Pre-Launch accident end states are summarized in Table 4-1. The total probability of all Pre-Launch initiating failures is 1.9×10^{-7} (or 1 in 5,300,000). These initiating failures include primarily Centaur tank failures and service valve failures. The Pre-Launch initiating failures generally involve, and are dominated by, conditions that can be mitigated by existing systems and procedures, leading to launch abort rather than accident conditions that threaten the RTG. The overall probability of ground impact configurations occurring that threaten the RTG is 2.9×10^{-8} (or 1 in 34,000,000). These ground impact configurations include the Intact Stage 3/SC, the Destructed Stage 3/SC (occurring when only the two small CSCs below the SRM are activated), and the Intact RTG. The Intact Stage 3/SC configuration would result from initiating failures occurring

[4] For brevity in the following discussion, the first, second, and third stages of the New Horizons Atlas V and spacecraft are sometimes referred to as Stages 1, 2, and 3, and SC respectively.

prior to FTS activation. The FTS conditions leading to BUS activation would result in a breakup of the spacecraft, separating the RTG from the spacecraft; the RTG could then remain intact until ground impact or could break apart, freeing the aeroshell modules to impact the ground separately.

TABLE 4-1. INITIATING FAILURES THAT CONTRIBUTE TO PRE-LAUNCH END STATES

Initiating Failure	Initiating Failure Probability	Launch Abort	Ground Impact Configurations			
			Low-Speed Stage3/SC	Intact Stage3/SC	Destructed Stage3/SC	Intact RTG
Centaur LO_2 Tank Failure	9.0×10^{-9}	•	•	•	•	•
Centaur LH_2 Tank Failure	9.0×10^{-9}	•	•	•	•	•
LO_2 SRV [(a)] Failure	1.7×10^{-7}	•		•		
Inadvertent FTS Activation	3.5×10^{-12}				•	•
Total Probability	**1.9×10^{-7}**	**1.6×10^{-7}**	**1.1×10^{-14}**	**2.9×10^{-8}**	**3.5×10^{-15}**	**3.5×10^{-12}**

Source: DOE 2005

(a) SRV = Self-Regulating Valve
Note: Differences in summations may be due to rounding.

The Post Launch ($T \geq 0$ s) initiating failures during Phases 1 through 5 include:

- ground support equipment failures during liftoff;
- trajectory and attitude control malfunctions;
- propellant tank failures;
- catastrophic failures of the first or second stage main engines;
- structural failures;
- inadvertent FTS activation; and
- staging failures.

The specific Post Launch initiating failures, their probabilities, and the resulting Post Launch end states are summarized in Table 4-2 by mission phase. While the total probability of all Post Launch initiating failures is 6.2×10^{-2} (or 1 in 16), the vast majority of these, nearly 94 percent, would not result in accident conditions that lead to release of PuO_2 from the RTG. The Post launch initiating failures can lead to one or more of the following end states.

- Phase 1 launch-area ground impact configurations, which include:
  - the complete Atlas V launch vehicle (called Full Stack Intact Impact (FSII));
  - the Intact Stage 2/Stage 3/SC with RTG attached;

TABLE 4-2. INITIATING FAILURES THAT CONTRIBUTE TO POST LAUNCH END STATES

Initiating Failure	Initiating Failure Probability	Accident End States by Mission Phase									
		Phase 1 Ground Impact Configurations						2	3	4	5
		FSII	Intact Stage2/ Stage3/SC	Intact Stage3/SC	Destructed Stage3/SC	Intact SC	Intact RTG	Water Impact	Suborbital Reentry	Orbital Reentry	Escape
Stage1 Main Engine Catastrophic Failure	9.4×10^{-2}	•	•		•		•	•	•		
GSE [a] Stage1 LO_2 Decoupler Failure	4.5×10^{-5}	•	•		•		•				
GSE Ground Wind Damper Failure	2.7×10^{-4}	•	•		•		•	•			
GSE Decoupler Failures	9.0×10^{-5}	•			•		•	•			
Attitude Control Malfunction	1.6×10^{-2}	•	•		•		•	•	•	•	•
Trajectory Control Malfunction	1.6×10^{-2}	•			•		•	•	•	•	•
SC Attach Fitting Structural Failure	1.0×10^{-6}	•			•	•	•	•	•	•	
Stage3 Attach Fitting Structural Failure	1.0×10^{-6}			•				•	•	•	•
GSE Bolts Fail to Release	2.7×10^{-5}		•		•		•				
GSE Tank Events	7.2×10^{-8}		•		•		•			•	•
Inadvertent FTS Activation	1.3×10^{-5}				•		•	•	•	•	
Stage1 Structural Failure	2.6×10^{-7}		•		•		•	•	•		
Stage1 Propellant Tank Failure	1.4×10^{-5}		•		•		•	•	•		
SRB Containment Failure	8.0×10^{-3}		•		•		•	•	•		
SRB Inadvertent Separation	9.6×10^{-5}		•		•		•	•	•		
PLF Structural Failure	2.3×10^{-5}		•		•		•	•	•		
Stage2 Structural Failure	4.1×10^{-7}			•	•		•	•	•	•	
Stage2 Propellant Tank Failure	8.6×10^{-5}			•	•		•	•	•	•	•
PLF Fails to Separate	1.2×10^{-4}								•		
Stages 1 and 2 Fail to Separate	2.3×10^{-5}								•		
Stages 1 and 2 Recontact	4.6×10^{-7}									•	•
Stage2 Main Engine Catastrophic Failure	4.5×10^{-3}								•	•	•
Stage2 Thrust Misdirected	4.3×10^{-5}									•	•
Stage2 Engine Fails to Restart	2.9×10^{-4}										•
Stages 2 and 3 Fail to Separate	5.6×10^{-3}										•
Stages 2 and 3 Recontact	1.6×10^{-4}									•	•
Stage3 SRM Fails to Ignite	2.2×10^{-5}										•
Stage3 SRM Case Rupture	3.5×10^{-4}										•
Stage3 Thrust Misdirected	2.0×10^{-4}									•	•
Stage3 Insufficient Thrust	2.0×10^{-4}										•
Stage3 and SC Fail to Separate	4.5×10^{-4}										•
SC Propellant Tank Failure	1.0×10^{-6}										•
Total Probability	**6.2×10^{-2}**	**2.5×10^{-6}**	**5.5×10^{-7}**	**2.0×10^{-8}**	**6.4×10^{-7}**	**9.1×10^{-9}**	**6.4×10^{-3}**	**7.8×10^{-3}**	**1.8×10^{-2}**	**3.8×10^{-3}**	**2.5×10^{-2}**

Source: DOE 2005, ASCA 2005

(a) GSE = Ground Support Equipment

Note: Differences in summations may be due to rounding.

  - the Intact Stage 3/SC with RTG attached;
  - the Destructed Stage 3/SC with RTG attached;
  - the Intact SC with RTG attached; and,
  - the Intact RTG.
- Phases 2 through 5 end states, which include:
  - Water impact;
  - Sub-orbital reentry;
  - Orbital reentry; and,
  - Escape.

4.1.4.3 RTG Response to Accident Environments

Accident environments associated with potential accidents include blast (explosion overpressure), fragments, thermal energy (from burning liquid and solid propellants), surface impact, and reentry environments. The nature and severity of the accident environments and the design features of the RTG and its components determine the response of the RTG and its components to the accident environments. These responses are then characterized in terms of the probability of release and the source terms.

Safety testing in combination with modeling of the response of the RTG and its components to accident environments allow estimates to be made of the probability of release of PuO_2 and the amount of the release for the range of accidents and environments that could potentially occur during the New Horizons mission. The aeroshell module, its graphite impact shells (GIS) and the iridium clads encapsulating the PuO_2 provide substantial protection against potential release of PuO_2 in accident environments. The primary accident environments of concern and the potential response of the RTG and its components to these environments are summarized below.

- <u>Explosion Overpressure and Fragments</u>: Explosions of the Stage 1 and Stage 2 liquid propellants and the resulting fragments are not expected to pose any significant threat to the RTG or its components. The RTG is expected to remain intact, and any release of PuO_2 from fueled clads would be small (ranging from a few milligrams to less than 0.5 grams (g) (0.02 oz), or about 6.2 Ci). Explosive burning of the Stage 3 SRM propellant on impact would result in an overpressure and fragment environment. These conditions, however, would cause less damage than the mechanical impact threat described below.

- <u>Impact</u>: Fracturing of the aeroshell module and its graphite components under explosion, fragment, and mechanical impact conditions would provide energy-absorbing protection to the iridium clad. The results of DOE's safety tests of the RTG and its components indicate that small releases of PuO_2 (ranging from a few milligrams to less than 0.5 g (0.02 oz), or about 6.2 Ci) are likely as a result of the impact of bare fueled clads, aeroshell modules, or the RTG on hard surfaces (e.g., concrete) at their respective terminal velocities. An end-on impact of the RTG above the terminal fall velocity could result in higher releases (up to 16 g (0.6 oz), or about 197 Ci), such as could occur if the RTG is still attached to spacecraft hardware. Impact configurations such as FSII or Intact Stage 3/SC could result in higher releases (e.g., up to 150 g (5.3 oz), or about 1,845 Ci) if the third stage SRM impacts directly onto the RTG at velocities around 100 meters per second (m/s) (328 feet per second (ft/s)) or higher. The damage caused by the mechanical impact would be greater than that potentially caused by the overpressure and fragment environment associated with explosive burning of the SRM propellant upon ground impact.

- Thermal Energy: Exposure of released PuO_2 fuel to the high temperatures (ranging up to 2,827°C (5,120°F)) of burning solid propellant from the third stage SRM and the SRBs could lead to partial vaporization of the PuO_2. Exposure of a bare (or breached) iridium clad, following graphite component damage in an accident, could also result in clad degradation either through chemical interactions or melting, resulting in partial vaporization of the PuO_2. PuO_2 vapor releases from intact aeroshell modules are also possible in certain exposure conditions (e.g., modules lying beneath pieces of burning solid propellant larger than 113 kg (250 lb)). Under such conditions, temperatures inside the module could be high enough to degrade the iridium clads and vaporize some PuO_2, which in turn could permeate through the somewhat porous graphite materials.

- BUS Activation Fragment Environment: The BUS (see Section 2.1.6.5) offers a significant risk reduction measure by minimizing the probability of coincident ground impact of the third stage SRM and the RTG. At the same time, the environment resulting from BUS activation could result in a smaller residual threat to the RTG. For this reason, the BUS would be safed after the Atlas V clears land and is over the Atlantic Ocean. The BUS activation environment would likely result in the breakup of the spacecraft, but the RTG is predicted to remain intact. The BUS activation environment would result in high-velocity (up to 3,200 m/s (10,500 ft/s)) aluminum fragments from the CSCs, aluminum fragments from the payload attach fitting (PAF), and solid propellant fragments from the breakup of the SRM. The latter fragments could also have attached titanium case material, or the titanium case material could detach during the breakup and become fragments themselves. The CSC fragment velocities would likely be attenuated by the PAF, the RTG converter materials and the aeroshell modules, resulting in a relatively low conditional probability (estimated to be 0.001, given BUS activation) of having a small release (up to 1.0 g (0.04 oz), or 12.3 Ci). Other, less energetic CSC fragments, could damage aeroshell modules without damaging iridium clads. While such fragments could result in a number of holes in the RTG case, the case is predicted to remain intact.

  Solid propellant fragments from the SRM would have velocities in the range of 31 to 76 m/s (100 to 250 ft/s) with masses up to 120 kg (265 lb). Should any solid propellant fragments impact the RTG, side-on fragment impacts would likely not cause the RTG case or the aeroshell modules to fail. While aeroshell module damage is unlikely (with a conditional probability of graphite material damage of 0.05 given BUS activation), the motion of the aeroshell graphite material against the iridium clads could result in small breaches in the iridium with subsequent small releases (in milligram quantities) of PuO_2 from affected clads (with a conditional probability of release of 0.003 given BUS activation). Damage of the insulators inside the GISs is also possible due to internal motion of the graphite materials against the clads. The leading clads in up to five aeroshell modules (ten clads total) could be affected in this manner. The released fuel, however, would be retained within the intact modules, unless such modules had suffered damage due to solid propellant fragments. While the above responses to the BUS activation environment would occur at some altitude above ground, subsequent impacts or environments (such as ground impact and exposure to burning solid propellant) could result in additional releases from any iridium clads already breached. Edge-on titanium fragments could cause graphite damage (with a conditional probability of 0.035 given BUS activation), and lead to a small release (1.0 g (0.04 oz), or 12.3 Ci, with a conditional probability of 0.007 given BUS activation).

Most launch accidents in Phases 0 and 1 would lead to one of several types of ground impact configurations (e.g., FSII, Intact Stage 2/Stage 3/SC, Intact Stage 3/SC, Intact SC, and Intact RTG). The highest probability configuration in Phase 0 is the Intact Stage 3/SC due to a Centaur explosion due to failure of a self-regulating vent valve prior to activating the FTS. The highest probability configuration in Phase 1 is the Intact RTG resulting from a CADS activation or a CDS with BUS activation. While the RTG is predicted to remain intact following BUS activation, it is possible that some aeroshell and iridium clad damage would occur at altitude due to the BUS fragment environment. In any case however, small releases are likely upon ground impact. For certain high mechanical impact environments, such as an FSII or an intact impact of a Stage 3/SC configuration with the SRM above the RTG, larger PuO_2 releases are possible. Subsequent exposure of RTG hardware and PuO_2 to burning solid propellant could result in increased releases through partial vaporization of the PuO_2. The probability of exposure to burning solid propellant is higher in Phase 0 than Phase 1 because the SRBs are unpressurized in Phase 0, leading to less near-pad dispersal of burning solid propellant. Overall in Phases 0 and 1, given an accident, there is a relatively high conditional probability (0.78 and 0.25, respectively) of having small releases due to ground impacts (with some contribution due to the BUS activation fragment environment), and a relatively low conditional probability (0.28 and 0.015, respectively) for higher releases due to high threat mechanical impact environments and exposure to burning solid propellant.

No accidents have been identified in either Phase 2 or Phase 5 which could lead to a potential release of PuO_2. Accidents in Phase 2 would lead to water impacts of the RTG or aeroshell modules, which are designed to survive water impact. Accidents in Phase 5 would not lead to reentry of the RTG. In both Phases 3 and 4, accidents could lead to sub-orbital and orbital reentry heating and ground impact environments. Undamaged aeroshell modules are designed to survive reentry and subsequent impacts on water or soil at terminal velocity, but any impact on hard surfaces (e.g., rock or concrete) could result in small releases of PuO_2.

4.1.4.4 Accident Probabilities and Source Terms

In the nuclear risk assessment, DOE evaluated each of the identified end states and estimated the accident environments to which the RTG would likely be exposed. From that information, conditional probabilities that a release would occur and estimated source terms were developed based on the known response of an RTG to various accident environments.

As shown in Figure 4-1, the probability of a launch accident involving any release of PuO_2 is very small, approximately 4 in 1,000. The most severe accident environments would occur during launch area accidents that might expose the RTG to mechanical impacts, explosion overpressures and fragments, and fire environments from burning liquid and solid propellants.

A summary of the accident and source term probabilities by mission phase, along with mean and 99-th percentile source terms, is presented in Table 4-3. The 99-th percentile source term is the value predicted to be exceeded with a probability of 0.01 (1 in 100), given a release in an accident. In this context, the 99-th percentile value reflects the potential for larger releases at lower probabilities that could occur for accidents involving a release. Key results for the mean estimates are summarized below; the corresponding 99-th percentile estimates can be found in Table 4-3.

- Phase 0 (Pre-Launch): During the pre-launch period, prior to ignition of the SRBs, on-pad accidents could result in a release at a total probability of $2.2x10^{-8}$ (or 1 in 45,000,000). The mean source term is estimated to be about 72 Ci. The mean source term in Phase 0 is higher than that in Phase 1 primarily due to the higher conditional probability of exposure to a solid propellant fire environment. However, none of the ground impact conditions that could occur in Phase 0 is very likely. Most problems that could arise during Phase 0 can be successfully mitigated by safety systems and procedures, leading to safe hold or termination of the launch countdown.

- Phase 1 (Early Launch): During Phase 1, after which land impacts in the launch area are unlikely (i.e., probabilities ranging from 10^{-2} to 10^{-4}), the total probability of release is $1.6x10^{-3}$ (or 1 in 620) should an accident occur. The mean source term is estimated to be about 12 Ci.

  Most initiating failures occurring in Phase 1 would lead to activation of the FTS. The elements of the FTS are highly redundant and quite reliable. As a result, the expected outcome of a Phase 1 accident is that the intact RTG would fall free to the ground, where it would be subject to mechanical damage and potential exposure to burning solid propellant. The probability for this impact configuration with a release is $1.6x10^{-3}$ (or 1 in 620), with an estimated mean source term of less than 11 Ci (less than 0.01 percent of the PuO_2 inventory).

TABLE 4-3. ACCIDENT PROBABILITIES AND SOURCE TERMS

Mission Phase (Ground Impact Configuration)	Accident Probability	Conditional Probability of a Release (a)	Total Probability of a Release	Source Term, Ci	
				Mean	99-th Percentile (b)
0: Pre-Launch	$2.9x10^{-8}$	0.78	$2.2x10^{-8}$	71.9	217.0
(Stage 3/SC)	$(2.8x10^{-8})$	(0.78)	$(2.2x10^{-8})$	(71.9)	
(Intact RTG)	$(3.5x10^{-12})$	(0.78)	$(2.7x10^{-12})$	(29.0)	
1: Early Launch	$6.4x10^{-3}$	0.25	$1.6x10^{-3}$	11.8	98.2
(FSII)	$(2.5x10^{-6})$	(0.29)	$(7.1x10^{-7})$	(2610)	
(Stage2/Stage3/SC)	$(5.5x10^{-7})$	(0.10)	$(5.5x10^{-8})$	(767)	
(Stage3/SC)	$(6.6x10^{-7})$	(0.13)	$(8.7x10^{-8})$	(2520)	
(Intact SC)	$(9.1x10^{-9})$	(0.24)	$(2.2x10^{-9})$	(8.6)	
(Intact RTG)	$(6.4x10^{-3})$	(0.25)	$(1.6x10^{-3})$	(10.5)	
2: Late Launch	$7.8x10^{-3}$	—	—	—	—
3: Pre-Orbit	$1.8x10^{-2}$	0.04	$7.9x10^{-4}$	0.4	1.2
4: Orbit	$3.8x10^{-3}$	0.25	$9.4x10^{-4}$	0.9	5.3
5: Escape	$2.5x10^{-2}$	—	—	—	—
Overall Mission:	**$6.2x10^{-2}$**	**0.05**	**$3.3x10^{-3}$**	**6.0**	**48.6**

Source: DOE 2005

(a) The conditional probability of a release of PuO_2 given that an accident has occurred.
(b) Due to the nature of the methodology used in DOE's risk assessment (see Section 4.1.4.1), 99-th percentile source terms were not estimated for the individual ground impact configurations, listed in parentheses, which could occur during Phases 0 and 1.

Note: Differences in summations may be due to rounding.

A much less likely outcome of a Phase 1 accident involves failure of some or all of the FTS elements to perform properly. This could lead to ground impact of the RTG while still attached to the spacecraft and, perhaps, other launch vehicle stages. Since this would require multiple failures of safety systems, such ground impact configurations leading to a release are extremely unlikely, with probabilities ranging from less than 10^{-6} (less than 1 in 1 million) to nearly 10^{-10} (nearly 1 in 10 billion). However, because the RTG could impact the ground in very close proximity to the SRM and the SRBs, the potential for damage to the RTG is much greater. In the impact configurations leading to the largest estimated releases, such as the FSII and the Intact Stage 3/SC, less than 2 percent of the inventory might be released, with estimated mean source terms of 2,610 Ci and 2,520 Ci, respectively. The overall probabilities of a release from these impact configurations are $7.1x10^{-7}$ (or 1 in 1,400,000) and $8.7x10^{-8}$ (or 1 in 12,000,000), respectively.

- Phase 2 (Late Launch): All accidents that could occur in Phase 2 lead to impact of debris in the Atlantic Ocean with no release of PuO_2 from the RTG.
- Phase 3 (Pre-Orbit): Prior to attaining Earth parking orbit, accidents during Phase 3 could lead to prompt sub-orbital reentry within minutes of the accident

occurring. Breakup of the spacecraft during reentry could result in impacts of individual aeroshell modules along the vehicle flight path over the Atlantic Ocean and southern Africa. Should the aeroshell modules impact hard surfaces (e.g., rock), small releases of PuO_2 are possible at ground level. The total probability of a release in Phase 3 is estimated to be 7.9×10^{-4} (or 1 in 1,300). The mean source term is estimated to be less than 0.5 Ci.

- Phase 4 (Orbit): Accidents which occur after attaining parking orbit could result in orbital decay reentries from minutes to years after the accident, affecting Earth surfaces between approximately 28° North Latitude and 28° South Latitude. Post-reentry impact releases would be similar to those in Phase 3, except more aeroshell modules could impact hard surfaces due to differences in the probability of impact on hard surfaces within these latitude bands. The total probability of a release in Phase 4 is estimated to be 9.4×10^{-4} (or 1 in 1,100). The mean source term is estimated to be less than 1 Ci.

- Phase 5 (Escape): No accidents which lead to Earth escape conditions are expected to result in a release of PuO_2. The potential exists for a long-term (hundreds to thousands of years) inadvertent reentry should the spacecraft be left in an orbit around the Sun which crosses the Earth's orbit. Such a situation could occur if the Centaur engine would fail to restart after achieving Earth orbit, in which case the third stage and spacecraft would be separated from the Centaur, and the SRM would be fired. If the Centaur engine restarts successfully but the third stage SRM would fail to ignite, the spacecraft would still be separated. In either case the New Horizons spacecraft would have gained enough velocity to escape the Earth's gravitational field, but without sufficient energy to reach Pluto. The potential for either situation has been evaluated for a range of Earth-escape conditions (APL 2003c), and the probability of a long-term inadvertent reentry is estimated to be less than 1×10^{-7} (less than 1 in 10 million). This probability takes into account the use of spacecraft thrusters following escape to sufficiently alter the spacecraft's orbit and thereby minimize the potential for remaining in a long-term Earth crossing orbit.

The specific probability values presented in this DEIS are estimates and will likely differ from those presented in the more detailed FSAR being prepared by DOE for the New Horizons mission. Some probabilities will likely increase while others may decrease. However, NASA expects the overall probability of an accidental release of radioactive material will not vary substantially from the values presented in this DEIS.

4.1.4.5 Radiological Consequences

The radiological consequences of a given accident that results in a radiological release have been calculated in terms of maximum individual dose, collective dose, health effects, and land area contaminated at or above specified levels. The radiological consequences have been determined from atmospheric transport and dispersion simulations incorporating both launch-site specific and worldwide meteorological and population data. Biological effects models, based on methods prescribed by the National Council on Radiation Protection and Measurements (NCRP) and the

International Commission on Radiological Protection (ICRP), were applied to predict the number of health effects following a New Horizons launch accident that results in a release of PuO_2. Additional information on the behavior of plutonium in the environment (environmental transport and health impact mechanisms) can be found in Appendix B.

The maximum individual dose is the maximum dose delivered to a single individual for each accident case simulation. Collective dose is the sum of the radiation dose received by all individuals exposed to radiation from a given release in units of person-rem. Health effects represent statistically estimated incremental cancer fatalities induced by exposure to a release of radioactive material, and are determined by using ICRP-60 estimators[5] of $5x10^{-4}$ fatalities per person-rem for the general population and $4x10^{-4}$ fatalities per person-rem for workers (ICRP 1990). The health effects estimators are based on a linear, non-threshold model relating health effects and effective dose. This means that health effects occur as the dose increases from zero, rather than assuming a model in which health effects occur only at or above a threshold dose.

Table 4-4 presents a summary the DOE's risk assessment of radiological consequences for each of the mission phases. These consequence estimates represent the best available information at this time. Since the DOE's risk assessment for this DEIS was prepared in advance of the more detailed analysis being prepared for the FSAR, the information and results were developed based on consideration of risk assessments performed for past missions (e.g., Cassini and MER), and additional supplemental analyses where considered appropriate. The resulting approach for the risk assessment consists of a combination of scaling the results for past missions on a per curie inventory basis for specific accidents and accident environments, coupled with additional analyses required to make the risk assessment specific to the New Horizons mission.

The radiological consequences were estimated by mission phase in terms of both the mean and 99-th percentile values. The 99-th percentile radiological consequence is the value predicted to be exceeded 1 percent of the time for an accident with a release. In this context, the 99-th percentile value reflects the potential for higher radiological consequences to the exposed population at lower probabilities. For most accidents, the 99-th percentile consequences are a factor of 5 to 15 times the mean estimates reported in this EIS, but at probabilities a factor of 100 lower.

The radiological consequences summarized in Table 4-4 are generally proportional to the source terms listed in Table 4-3, except that the scaling factors vary with the type and nature of the release. Key factors include the particle size distribution of the release, release height, and energy of the release. Key results for the mean estimates are summarized below; the corresponding 99-th percentile estimates can be found in Table 4-4.

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[5] Another estimator addressing total health impacts (i.e., total detriment, as defined by ICRP-60) includes fatal cancers, non-fatal cancers, and hereditary effects. Total detriment is determined using estimators of $7.3x10^{-4}$ health impacts per person-rem for the general population and $5.6x10^{-4}$ health impacts per person-rem for workers (ICRP 1990).

TABLE 4-4. ESTIMATED RADIOLOGICAL CONSEQUENCES

Mission Phase (Ground Impact Configuration)	Total Probability of Release	Maximum Individual Dose, rem		Collective Dose, person-rem		Health Effects [a]		Land Contamination [b] km^2	
		Mean	99-th Percentile [d]	Mean	99-th Percentile [d]	Mean	99-th Percentile [d]	Mean	99-th Percentile [d]
0: Pre-Launch	2.2×10^{-8}	3.1	47.4	9,600	53,700	4.8	26.5	12.2	136.0
(Stage 3/SC)	(2.2×10^{-8})	(3.1)		(9,600)		(4.8)		(12.2)	
(Intact RTG)	(2.7×10^{-12})	(0.7)		(2,320)		(1.2)		(3.2)	
1: Early Launch	1.6×10^{-3}	0.3	7.1	718	10,500	0.4	5.2	1.8	10.7
(FSII)	(7.1×10^{-7})	(54.3)		(206,000)		(102.0)		(297.0)	
(Stage2/Stage3/SC)	(5.5×10^{-8})	(13.7)		(58,200)		(28.9)		(80.0)	
(Stage3/SC)	(8.7×10^{-8})	(46.3)		(183,000)		(90.6)		(269.0)	
(Intact SC)	(2.2×10^{-9})	(0.2)		(427)		(0.2)		(1.2)	
(Intact RTG)	(1.6×10^{-3})	(0.3)		(612)		(0.3)		(1.6)	
2: Late Launch	—	—	—	—	—	—	—	—	—
3: Pre-Orbit	7.9×10^{-4}	0.1	0.8	3	18	0.002	0.009	0.009	0.05
4: Orbit	9.4×10^{-4}	0.4	2.5	34	422	0.02	0.2	0.02	0.1
5: Escape	—	—	—	—	—	—	—	—	—
Overall Mission [c]	**3.3×10^{-3}**	**0.3**	**4.3**	**352**	**5,120**	**0.2**	**2.5**	**0.9**	**5.1**

Source: DOE 2005

(a) Based on ICRP-60 health effects estimators of 4×10^{-4} health effects per person-rem for workers and 5×10^{-4} health effects per person-rem for the general population.
(b) Land area contaminated above 0.2 μCi/m^2; 1 km^2 = 0.386 mi^2.
(c) Overall mission values weighted by total probability of release for each mission phase.
(d) 99-th percentile consequences were not estimated for the individual ground impact configurations which could occur during Phases 0 and 1.

Note: Differences in summations may be due to rounding.

- Phase 0 (Pre-Launch): The initiating failures that result in Phase 0 accident configurations have very low probabilities of occurrence. The overall probability of a release is 2.2×10^{-8} (or 1 in 45,000,000) during Phase 0. Most problems that arise during Phase 0 can be successfully mitigated by safety systems and procedures leading to safe hold or termination of the launch countdown.

  If an accident were to occur during Phase 0, however, there is a potential for measurable releases and off-site contamination. For Phase 0 accidents, there are no mechanisms which would ensure that the RTG becomes separated from the spacecraft and avoid large pieces of burning solid propellant. The mean maximum dose to an individual is estimated to be approximately 3 rem, about a factor of 9 higher than an individual might receive annually from natural background radiation[6]. This level is, however, significantly lower than that needed to result in short-term biological effects. It would increase the chance of a health effect for the exposed person by about 0.25 percent (from about 20–25 percent due to normal cancer incidence to about 20.25–25.25 percent with normal incidence plus radiation exposure). The mean collective dose is estimated to be 9,600 person-rem to the potentially exposed population.

  For Phase 0 accidents with a release (probability of 1 in 45,000,000), the mean area contaminated above 0.2 microcuries per square meter ($\mu Ci/m^2$) (see Section 4.1.4.7) is estimated to be about 12 square kilometers (km^2) (about 4.6 square miles (mi^2)). Detectable levels below 0.2 $\mu Ci/m^2$ would be expected over an even larger area. Assuming no mitigation actions, such as sheltering and exclusion of people from contaminated land areas, the potentially exposed population is predicted to inhale enough material to result in 4.8 mean health effects among the potentially exposed population.

- Phase 1 (Early Launch): Most initiating failures occurring in Phase 1 would lead to activation of the FTS. The elements of the FTS are highly redundant and very reliable[7]. As a result, the expected outcome of a Phase 1 accident is that the intact RTG or its components could fall free to the ground, where it would be subject to mechanical damage and potential exposure to burning solid propellant. The probability for this impact configuration with a release is 1.6×10^{-3} (or 1 in 620). A release could result in the spread of fine particles of PuO_2 over the area. The mean maximum individual dose is estimated to be 0.3 rem, equivalent to about 80 percent of the dose an individual might receive annually from natural background radiation. It would increase the exposed person's chance of a health effect by about 0.075 percent. The mean collective dose is estimated to be 718 person-rem to the potentially exposed population.

  The risk assessment indicates that less than 2 km^2 (less than 0.8 mi^2) might be contaminated above 0.2 $\mu Ci/m^2$. Assuming no mitigation action, such as

[6] An average of about 0.36 rem per year for an individual in the United States, including both natural sources and other sources such as medical X-rays; see Section 3.2.5 for further information.

[7] Range Safety specifies that for any launch vehicle FTS, the reliability goal shall be a minimum of 0.999 at the 95 percent confidence level (USAF 1997).

sheltering, the potentially exposed population is predicted to inhale enough material to result in 0.4 mean health effects among the potentially exposed population.

A much less likely outcome of a Phase 1 accident involves failure of some or all of the FTS elements to perform properly. This could lead to ground impact of the RTG while still attached to the spacecraft and, perhaps, other launch vehicle stages. Since this would require multiple failures of safety systems, such ground impact configurations leading to a release are extremely unlikely, ranging from 1 in 1.4 million to 1 in 18 million or less. However, because the RTG could impact the ground in very close proximity to the SRM and the SRBs, the potential for damage to the RTG is much greater. In the impact configurations leading to the largest estimated releases, such as the FSII and the Intact Stage 3/SC, less than 2 percent of the inventory might be released, potentially resulting in exposures as high as about 54 rem to the maximum exposed individual, and an estimate of nearly 300 km^2 (about 115 mi^2) might be contaminated above 0.2 μCi/m^2. Detectable levels below 0.2 μCi/m^2 would be expected over an even larger area. Assuming no mitigation action, such as sheltering, the potentially exposed population is predicted to inhale enough material to result in an estimated 102 mean health effects among the potentially exposed population.

- Phase 2 (Late Launch): No radiological consequences would be expected from an accident that could occur during Phase 2 since any accident during this mission phase would to lead to impact of debris in the Atlantic Ocean with no release of PuO_2 from the RTG.
- Phases 3 (Pre-Orbit): The total probability of a release in Phase 3 is estimated to be 7.9×10^{-4} (or 1 in 1,300). Mean consequences are estimated to be 0.1 rem for maximum individual dose, 3 person-rem for collective dose, and 0.002 health effects among the potentially exposed population.
- Phase 4 (Orbit): The total probability of a release in Phase 4 is estimated to be 9.4×10^{-4} (or 1 in 1,100). Mean consequences are estimated to be 0.4 rem for maximum individual dose, 34 person-rem for collective dose, and 0.02 health effects among the potentially exposed population.
- Phase 5 (Escape): No radiological consequences would be expected from an accident that could occur during Phase 5 since any accident during this mission phase would still lead to the spacecraft escaping the Earth's gravity field.

4.1.4.6 Discussion of the Results

Maximum Individual Doses

The maximum individual dose is the maximum dose delivered to a single individual for each accident based on the mean value results. During Phase 1, the predicted mean radiation dose to the maximally exposed individual ranges from very small, about 0.3 rem for the most probable result of a launch area accident, up to about 54 rem for an extremely unlikely FSII. No short-term radiological effects would be expected from any of these exposures. Each exposure would increase the statistical likelihood of a health effect. It should be noted that there are very large variations and uncertainties in the prediction of close-in doses due to the large variations and uncertainties in the locations of individuals, meteorological conditions, periods of exposure, and dispersion modeling.

Population Exposures

Impacts to off-site, downwind populations that might be exposed to releases following an accident are estimated by first calculating the collective dose to that population. This is simply the sum of the radiation dose received by all individuals exposed to radiation from a given release. These collective doses are assumed to result in the potential for health effects among the potentially exposed population following an accident. The health effects induced by releases are calculated using the methods described above in Section 4.1.4.5. The consequences discussed below have been estimated considering impacts on both the local population and the global population. Because of a variety of factors, principally involving meteorological conditions at the time of launch and the amount and particle size distribution of any PuO_2 released, not all persons in the affected regions would be exposed to a release.

Prior to launch, most problems that could potentially lead to an accident would be mitigated by safety systems and procedures that would lead to safe hold or termination of the launch countdown. After launch, most significant problems would lead to activation of the FTS, which would result in the destruction of all of the vehicle stages. This would lead to the RTG falling to the ground, where it could be subject to mechanical damage and potential exposure to burning solid propellant. The predicted release for this end state is estimated to be less than 0.01 percent of the inventory of the RTG. The probability for this scenario with a release is 1.6×10^{-3} (or 1 in 620). Assuming no interdiction, such as sheltering and exclusion of people from contaminated land areas, the potentially exposed population is predicted to inhale enough material to result in an additional 0.4 health effects among the exposed population over the long term.

For extremely unlikely launch area accidents, ranging in probability from 1 in 1.4 million to 1 in 18 million or less, slightly higher releases, approximately 2 percent of the RTG's inventory, might be expected with potentially higher consequences. Detectable levels below 0.2 $\mu Ci/m^2$ would be expected over a large area. Assuming no mitigation actions such as sheltering, the potentially exposed population for these extremely unlikely accidents with a release is predicted to inhale enough material to result in an estimated 90 to 100 health effects.

In the event of a launch area accident, it is unlikely that any given racial, ethnic, or socioeconomic group of the population would bear a disproportionate share of the consequences.

4.1.4.7 Impacts of Radiological Releases on the Environment

The environmental impacts of the postulated accidents include the potential for PuO_2 to be released to the environment, resulting in land and surface water contamination. The health and environmental impacts associated with plutonium-238 in the environment were addressed extensively in the EISs for previous NASA missions that used RTGs, including the Galileo, Ulysses, and Cassini missions (NASA 1989, NASA 1990, NASA 1995a, NASA 1997). The Ulysses EIS, for example, also identified the potential for launch area accidents contaminating comparable land areas. That EIS contained extensive evaluations of the potential impacts of PuO_2 releases on natural vegetation, wetlands, agricultural land, urban areas, inland water, the ocean, and other global areas. Based on these previous analyses, the potential impacts of plutonium releases from the launch area accidents on the environment are discussed in Appendix B and summarized here.

The affected environment, described in Section 3 of this EIS, includes the regional area near CCAFS and the global area. Launch area accidents (Phases 0 and 1) would initially release material into the regional area, defined in the EIS to be within 100 km (62 mi) of the launch pad. Since some of the accidents result in the release of very fine particles (less than a micron in diameter), a portion of such releases could be transported beyond 100 km (62 mi) and become well mixed in the troposphere, and have been assumed to potentially affect persons living within a latitude band from approximately 23° North to 30° North. Releases during Phase 3 could involve reentering aeroshell modules that could impact the ground in southern Africa. Releases during Phase 4 could impact anywhere between 28° North and 28° South latitude.

Potential environmental contamination was evaluated in terms of areas exceeding various screening levels (0.1 and 0.2 $\mu Ci/m^2$, and dose-rate related criteria (15, 25, and 100 millirem per year (mrem/yr))) considered by the U.S. Environmental Protection Agency (EPA), the Nuclear Regulatory Commission, and DOE in evaluating the need for land cleanup following radioactive contamination.

The risk assessment for this EIS uses the 0.2 $\mu Ci/m^2$ screening level (a screening level used in prior NASA environmental documentation (e.g., NASA 1989, NASA 1997, NASA 2003)) as an indicator of the extent of land area contaminated due to a release of PuO_2 from a potential launch accident. The results are summarized in Table 4-4. The area of land contaminated above the EPA lifetime-risk criterion, associated with an average annual dose rate criterion of 15 mrem/yr, could range from 3 to 6 times higher than the land area contaminated above the 0.2 $\mu Ci/m^2$ level in the first year following the release. This is due in part to the contribution of resuspension to dose. The 0.2 $\mu Ci/m^2$ screening level is used because following the first year after a release, the areas contaminated above the 15 mrem/yr criterion would be expected to decrease to values comparable to those associated with the 0.2 $\mu Ci/m^2$ level.

DOE's risk assessment indicates that for the most likely type of launch area accidents, the intentional destruction of all the vehicle stages freeing the RTG to fall back to the ground, would result in about 1.6 km^2 (about 0.6 mi^2) being contaminated above 0.2 $\mu Ci/m^2$. The risk assessment also indicates that in at least one extremely unlikely ground impact configuration, the FSII with a total probability of release of 7.1×10^{-7} (or 1 in 1.4 million), that nearly 300 km^2 (about 115 mi^2) might be contaminated above 0.2 $\mu Ci/m^2$. Detectable levels below 0.2 $\mu Ci/m^2$ would be expected over an even larger area.

Land areas contaminated at levels above 0.2 μCi/m^2 indicate areas potentially needing further action, such as monitoring or cleanup. Costs associated with these efforts, as well as continued monitoring activities, could vary widely depending upon the characteristics of the contaminated area. Potential cost estimating factors for decontamination of various land types are summarized in Table 4-5. These cost factors address a wide variety of possible actions, including land acquisition, off-site waste disposal, site restoration, and final surveys of remediated sites.

TABLE 4-5. POTENTIAL LAND DECONTAMINATION COST FACTORS

Land Type	Cost Factor in 2006 Dollars	
	Cost per km^2	Cost per mi^2
Farmlands	$95 million	$246 million
Rangeland	$93 million	$241 million
Forests	$170 million	$440 million
Mixed-Use Urban Areas	$520 million	$1.2 billion

Source: Adapted from Chanin et al. 1996

The Price-Anderson Act, as amended (42 U.S.C. 2210), governs liability and compensation in the event of a nuclear incident arising out of the activities of the DOE. The Price-Anderson Act is incorporated into the Atomic Energy Act, as amended (42 U.S.C. 2011 et seq.). A "nuclear incident" is defined under the Atomic Energy Act "as any occurrence, including an extraordinary nuclear occurrence, within the United States causing, within or outside the United States, bodily injury, sickness, disease, or death, or loss of or damage to property, or loss of use of property, arising out of or resulting from the radioactive, toxic, explosive, other hazardous properties of source, special nuclear or byproduct material…" (42 U.S.C. 2014 (q)). In the case of the New Horizons mission, DOE retains title to the RTG. The RTG would, therefore, be subject to Price-Anderson Act provisions. In the unlikely event that an accident were to occur resulting in release of PuO_2, affected property owners would be eligible for reimbursement for loss of property due to contamination.

In addition to the potential direct costs of radiological surveys, monitoring, and potential cleanup following an accident, there are potential secondary societal costs associated with the decontamination and mitigation activities with the extremely unlikely, potentially higher consequence, launch area accidents. Those costs could include, but may not be limited to:

- temporary or longer term relocation of residents;
- temporary or longer term loss of employment;
- destruction or quarantine of agricultural products, including citrus crops;
- land use restrictions (which could affect real estate values, tourism and recreational activities);

- restriction or bans on commercial fishing; and,
- public health effects and medical care.

4.1.4.8 Mission Risks

A summary of the mission risks is presented in Table 4-6. For the purpose of this EIS, risk is defined as the expectation of health effects in a statistical sense (i.e., the product of total probability times the mean health effects resulting from a release, and then summed over all conditions leading to a release). The risk of health effects in the potentially exposed populations is determined for each mission phase and the overall mission. Since the health effects resulting from a release equals the sum of the probability of a health effect for each individual in the exposed population, risk can also be interpreted as the total probability of one health effect given the mission. The overall radiological risk for the New Horizons mission is estimated to be 5.8×10^{-4}. Thus, the total probability of one health effect for the Proposed Action is about 1 in 1,700.

TABLE 4-6. SUMMARY OF HEALTH EFFECT MISSION RISKS

Mission Phase	Accident Probability	Conditional Probability of a Release	Total Probability of a Release	Mean Health Effects	Mission Risks
0: Pre-Launch	2.9×10^{-8}	0.78	2.2×10^{-8}	4.8	1.1×10^{-7}
1: Early Launch	6.4×10^{-3}	0.25	1.6×10^{-3}	0.4	5.6×10^{-4}
2: Late Launch	7.9×10^{-3}	—	—	—	—
3: Pre-Orbit	1.8×10^{-2}	0.04	7.9×10^{-4}	0.002	1.4×10^{-6}
4: Orbit	3.8×10^{-3}	0.25	9.4×10^{-4}	0.02	1.6×10^{-5}
5: Escape	2.5×10^{-2}	—	—	—	—
Overall Mission	$\mathbf{6.2 \times 10^{-2}}$	**0.05**	$\mathbf{3.3 \times 10^{-3}}$	**0.2**	$\mathbf{5.8 \times 10^{-4}}$

Source: DOE 2005

Note: Differences in summations may be due to rounding.

The risk contribution of Phase 1 accidents, 5.6×10^{-4} (or a probability of about 1 in 1,800 that a health effect will occur), represents 97 percent of the radiological risk for the New Horizons mission. The primary contributors to the Phase 1 risk are accidents leading to intact ground impact of the RTG in the vicinity of burning solid propellant from the SRBs and the third stage SRM. Phases 3 and 4 contribute most of the remainder of the overall mission risk, due primarily to releases associated with aeroshell modules impacting hard surfaces following sub-orbital or orbital reentry.

The contributions of risk to the local area (within 100 km (62 mi) of SLC-41) and the global area are summarized in Table 4-7. The launch area risk is about 33 percent of the overall mission risk, while the risk to global areas is about 67 percent. The launch area risks are due entirely from accidents during Phases 0 and 1. The global risks are due to accidents in all mission phases.

TABLE 4-7. HEALTH EFFECT MISSION RISK CONTRIBUTIONS BY AFFECTED REGION

Mission Phase	Mission Risks		
	Launch Area [(a)]	Global [(b)]	Total
0: Pre-Launch	$3.6x10^{-8}$	$7.0x10^{-8}$	$1.1x10^{-7}$
1: Early Launch	$1.9x10^{-4}$	$3.7x10^{-4}$	$5.6x10^{-4}$
2: Late Launch	—	—	—
3: Pre-Orbit	—	$1.4x10^{-6}$	$1.4x10^{-6}$
4: Orbit	—	$1.6x10^{-5}$	$1.6x10^{-5}$
5: Escape	—	—	—
Overall Mission	**$1.9x10^{-4}$**	**$3.9x10^{-4}$**	**$5.8x10^{-4}$**

Source: DOE 2005

(a) Phases 0 and 1: within 100 km (62 mi) of the launch pad.
(b) Phases 0, 1 and 2: within approximately 23° North and 30° North Latitude; Phase 3: southern Africa; Phase 4: land impacts between 28° North and 28° South Latitude.

Note: Differences in summations may be due to rounding.

Another descriptor used in characterizing risk is the average individual risk, presented in Table 4-8. The average individual risk, defined in this EIS as the risk divided by the number of persons potentially exposed, is estimated to be $5.1x10^{-10}$ (or a probability of about 1 in 2 billion that a health effect will occur for that individual) in the launch area and $4.3x10^{-13}$ (or a probability of about 1 in 2.3 trillion that a health effect will occur for that individual) globally. In estimating the average individual risks, the population at risk in each mission phase is taken to be those individuals receiving most of the collective dose, rather than the entire population in any given area of interest. All individuals within the exposed population (including the maximally exposed individual) face less than a one-in-a-million chance of a health effect due to the radiological consequences posed by the New Horizons mission.

These individual risk estimates are small compared to other risks. For example, the information presented in Table 2-5 indicates that in 2000 the average individual risk of accidental death in the United States was about 1 in 3,000 per year, while the average individual risk of death due to any disease, including cancer, was about 1 in 130.

4.1.4.9 Uncertainty

An uncertainty analysis to estimate uncertainties in probabilities, source terms, radiological consequences, and mission risks has not been performed as part of this report. Such an analysis will be performed in the Final Safety Analysis Report. Based on experience with uncertainty analyses in the preliminary risk assessment of previous missions (e.g., for the Cassini and MER missions), the uncertainty in the estimated mission risk for the New Horizons mission can be made. The best estimate of the New Horizons mission risk of $5.8x10^{-4}$ (or a probability of about 1 in 1,700 that a health effect will occur) can be treated as the median of the uncertainty probability distribution (i.e., it is equally probable that the mission risk could be higher or lower than this value). The mission risks at the 5 and 95 percent confidence levels are then estimated to be 2.3×10^{-5} (or a probability of about 1 in 44,000 that a health effect will occur) and 1.4×10^{-2} (or a probability of about 1 in 71 that a health effect will occur), respectively.

TABLE 4-8. AVERAGE INDIVIDUAL RISK BY AFFECTED REGION

Mission Phase	Launch Area [a]			Global [b]		
	Mission Risk	**Population at Risk [c]**	**Average Individual Risk [d]**	**Mission Risk**	**Population at Risk [c]**	**Average Individual Risk [d]**
0: Pre-Launch	3.6×10^{-8}	3.7×10^{5}	9.6×10^{-14}	7.0×10^{-8}	9.4×10^{8}	7.5×10^{-17}
1: Early Launch	1.9×10^{-4}	3.7×10^{5}	5.1×10^{-10}	3.7×10^{-4}	9.4×10^{8}	4.0×10^{-13}
2: Launch	—	—	—	—	—	—
3: Pre-Orbit	—	—	—	1.4×10^{-6}	1.0×10^{3}	1.4×10^{-9}
4: Orbit	—	—	—	1.6×10^{-5}	1.0×10^{4}	1.6×10^{-9}
5: Escape	—	—	—	—	—	—
Overall Mission	$\mathbf{1.9 \times 10^{-4}}$	$\mathbf{3.7 \times 10^{5}}$	$\mathbf{5.1 \times 10^{-10}}$	$\mathbf{3.9 \times 10^{-4}}$	$\mathbf{9.0 \times 10^{8}}$	$\mathbf{4.3 \times 10^{-13}}$

Source: DOE 2005

(a) Phases 0 and 1: within 100 km (62 mi) of the launch pad.
(b) Phases 0, 1 and 2: within approximately 23° North and 30° North Latitude;
Phase 3: southern Africa; Phase 4: land impacts between 28° North and 28° South Latitude.
(c) Number of persons exposed (order of magnitude estimate).
(d) Mission risk contribution divided by number of persons exposed.
Note: Differences in summations may be due to rounding.

4.1.5 Radiological Contingency Response Planning

Prior to launch of the New Horizons mission, a comprehensive set of plans would be developed by NASA to ensure that any launch accident could be met with a well-developed and tested response. NASA's plans would be developed in accordance with the National Response Plan (NRP) and the NRP Radiological Incident Annex with the combined efforts of the U.S. Department of Homeland Security (DHS), the DHS's Federal Emergency Management Agency, DOE, the U.S. Department of Defense (DOD), the U.S. Department of State (DOS), the EPA, the State of Florida, Brevard County, and local organizations involved in an emergency response.

The plans would be tested prior to launch in exercises designed to verify the response interfaces, command channels, and field responses to ensure that the various organizations would be prepared to respond in the unlikely event of a launch accident. NASA would be the Principal Technical Agency, working with the DHS to coordinate the entire federal response for launch accidents occurring within United States jurisdiction. Should a release of radioactive material occur in the launch area, the State of Florida, Brevard County, and local governments would determine an appropriate course of action for any off-site plans (such as sheltering in place, evacuation, exclusion of people from contaminated land areas, or no action required) and have full access to the

DHS-coordinated federal response. For accidents outside United States jurisdiction, NASA would assist the DOS in coordinating the United States' response via diplomatic channels and using federal resources as requested.

To manage the radiological contingency response, NASA would establish a Radiological Control Center (RADCC) at KSC prior to and during the mission launch. The RADCC would be where NASA's and DHS's coordination efforts would be managed. The RADCC would also be used to coordinate the initial federal response to a radiological contingency once the vehicle has left the launch site area until the New Horizons spacecraft has left Earth orbit. Participation in the RADCC would include NASA, DHS, DOE, DOD, DOS, the EPA, USAF, the National Oceanic and Atmospheric Administration, the State of Florida, and Brevard County. An additional off-site location would be established from which radiological monitoring and assessment could be conducted.

If impact occurs in the ocean, NASA would work with the DHS, the DHS's U.S. Coast Guard, the U.S. Navy, and DOE to initiate security measures and search and retrieval operations. Efforts to recover the RTG or its components would be based on technological feasibility and any potential health hazard presented to recovery personnel and the environment.

4.2 ENVIRONMENTAL IMPACTS OF THE NO ACTION ALTERNATIVE

Under the No Action Alternative, preparations for the proposed New Horizons mission would be discontinued and the mission would not be implemented. Environmental impacts associated with preparation of the proposed New Horizons spacecraft and the processing of the launch vehicle would not occur. There would be no local or global launch-related environmental impacts.

There would be no close reconnaissance of Pluto, Charon, or any objects within the Kuiper Belt. The proposed high-priority science to be performed at Pluto and Charon (see Section 1.2) is time-critical because of long-term seasonal changes in the surfaces and atmospheres of both bodies. Achieving objectives involving surface mapping and surface composition mapping would be significantly compromised if a spacecraft does not arrive at the Pluto-Charon system before this system recedes too far from the Sun. More of the surfaces of Pluto and Charon will be in permanent shadow each year until 2042. Furthermore, Pluto's withdrawal from perihelion is widely anticipated to result in substantial decline, if not complete collapse, of its atmosphere. Much of the atmospheric science would be lost if a spacecraft cannot arrive before the atmosphere significantly declines or completely collapses. Once that happens, fulfilling this science objective would have to wait until Pluto's next perihelion passage in 248 years. Canceling the New Horizons mission would create a significant gap in NASA's objectives for exploring the solar system.

4.3 CUMULATIVE IMPACTS

The potential cumulative impacts associated with use of the launch vehicle and facilities addressed within this DEIS have been assessed using currently available information.

Launch of the proposed New Horizons mission would not increase the number of Atlas V launches beyond the scope of previously approved programs from CCAFS (USAF 1998, USAF 2000).

Various components of the spacecraft and launch vehicle for the proposed New Horizons mission would be manufactured at different sites in the United States, with final integration of the components occurring at KSC and CCAFS. Each of these sites would be required to follow applicable Federal, State, and local regulations governing areas such as air pollution, noise ordinances, wastewater disposal, pollution prevention, disposal of hazardous waste, and worker safety and health (see Section 4.8). Spacecraft and launch vehicle manufacturing are specialized activities with only a limited number of units manufactured each year. While such activities could generate air pollutants, noise, and hazardous waste, any quantities would be small compared to major industrial activities and subject to the appropriate Federal, State, and local environmental laws and regulations pertinent to the individual manufacturing facilities.

The use of the facilities at KSC and CCAFS for processing the New Horizons spacecraft, launch vehicle components, and for launch of the mission would be consistent with existing land uses at each site. No new processing facilities for the New Horizons mission are anticipated at either KSC or CCAFS, and any impacts from their use are expected to be within the scope of previously approved programs (e.g., USAF 1998, USAF 2000, NASA 2002). Implementing the New Horizons mission would be unlikely to add new jobs to the workforce at either site.

Launching the New Horizons spacecraft would principally contribute to exhaust emission impacts on and near SLC-41 at CCAFS. The USAF has monitored numerous launches from CCAFS (USAF 1998). Launch of the Atlas V could result in scorched vegetation, and partially or completely defoliated trees near the launch complex from flame and acidic deposition. Deposition could also impact nearby bodies of water, resulting in temporary elevation of acidity levels. While these impacts may persist with continued use of SLC-41, they are probably not irreversible. At KSC, NASA found that in affected areas near the Space Shuttle launch pads, vegetation reestablished itself after the launches stopped (Schmalzer et. al. 1998).

On a short-term basis, the New Horizons launch would contribute negligible amounts of ozone-depleting chemical compounds to the stratosphere. The USAF has estimated that the total contribution from large expendable launch vehicles with SRBs to the average annual depletion of ozone would be small (approximately 0.014 percent per year). By comparison, a 3 percent to 7 percent annual decrease in ozone at mid-latitudes occurs as a result of the current accumulation of all ozone-depleting substances in the stratosphere (USAF 2000). However, the ozone depletion trail from a launch vehicle has been estimated to be largely temporary, and would be self-healing within a few hours of the vehicle's passage (AIAA 1991). Furthermore, because launches at CCAFS are always separated by at least a few days, combined impacts in the sense of holes in the ozone layer combining or reinforcing one another cannot occur (USAF 2000).

Rocket launches result in the emission of greenhouse gases (CO_2, trace emissions of nitrous oxides (NO_X) emitted by the SRBs, and water vapor). The exhaust cloud would also contain CO, most of which, under the high temperatures of the SRB's exhaust, would quickly react with oxygen in the atmosphere to form CO_2. Emissions from expendable launch vehicles have been previously estimated (USAF 1998, USAF 2000). These estimates indicate that the annual exhaust emissions from all launch vehicles analyzed would be a very small fraction (on the order of 10^{-5} percent) of the total net greenhouse gases emitted annually by the United States (about 6.2×10^{12} kg (1.3×10^{13} lb) CO_2 equivalent in 2002 (EPA 2004a)). Since the New Horizons mission would not increase the previously analyzed launch rates, launch of the mission would not be anticipated to contribute further to the accumulation of greenhouse gases from expendable launch vehicles.

Other activities on or near CCAFS that are not connected with the New Horizons mission that could occur during this timeframe includes the proposed development and construction of the International Space Research Park (ISRP) located on 160 hectares (400 acres) of KSC. These and other potential construction activities at and in the vicinity of CCAFS could potentially contribute to increases in noise, particulates and dust, solid waste disposal, and the potential for involving wetlands and endangered species. An EIS for the ISRP has been prepared. It is anticipated that, should NASA approve this project, phased construction would occur over the next 20 to 25 years.

No cumulative impacts would occur under the No Action Alternative.

4.4 ENVIRONMENTAL EFFECTS THAT CANNOT BE AVOIDED

At lift-off and during ascent, the Atlas V main engine and SRBs would produce Al_2O_3, CO, HCl, and relatively smaller amounts of CO_2, H_2, H_2O, N_2, Cl and NO_X. The exhaust cloud would be concentrated near the launch pad during the first moments of launch. Thereafter, the exhaust cloud would be transported downwind and upward, eventually dissipating to background concentrations.

Biota in the immediate vicinity of the SLC-41 launch pad could be damaged or killed by the intense heat and HCl deposition from the exhaust cloud. No long-term adverse effects to biota would be anticipated. Al_2O_3 particulates from the SRBs would also be deposited on soils and nearby surface waters at the launch site as the exhaust cloud travels downwind.

4.5 INCOMPLETE OR UNAVAILABLE INFORMATION

This EIS is being developed before final preparations are completed for the proposed New Horizons mission. The primary areas of either incomplete or unavailable information include the following items.

This EIS evaluates postulated launch accidents that could potentially result in a release of PuO_2 from the RTG. The risk assessment performed by DOE has made use of the results of risk analyses for previous NASA missions. The results from these prior missions have been scaled and combined with additional analysis to develop risk estimates for the New Horizon mission. A risk analysis that reflects the actual mission conditions, using procedures and techniques comparable to those used for earlier missions, has not yet been completed.

Several technical issues that could impact the results presented in this DEIS are under continuing evaluation. These issues could not be fully addressed in the risk assessment; best engineering judgment was used to address these issues and their impact on the risk estimate for the New Horizons mission. The important issues that were addressed in this manner and that are the subject of continuing evaluation include:

- the severity of the solid propellant fire environment and its potential effect on the release of PuO_2 from the RTG;
- the dispersal of solid propellant within the on-pad accident environment;
- the behavior of solid PuO_2 and PuO_2 vapor in the fire environment and the potential for PuO_2 vapor to permeate the graphite components in the RTG; and,
- the fragment environment associated with activation of the third stage SRM BUS and its potential impact on the RTG.

Under Presidential Directive/National Security Council Memorandum 25 (PD/NSC-25), a separate nuclear launch safety review of the New Horizons mission is being conducted by NASA and DOE. As part of this process DOE is preparing a Final Safety Analysis Report (FSAR) that will include a complete, detailed risk analysis. In preparing the FSAR, DOE is following procedures and using techniques similar to those used in the risk analyses performed for earlier NASA missions using radioisotope devices. An Interagency Nuclear Safety Review Panel (INSRP) has been formed for the New Horizons mission, and will review this safety analysis. Should the FSAR present risk estimates that differ significantly from those presented in this EIS, NASA would consider the new information, and determine the need for additional environmental documentation.

A detailed uncertainty analysis has not been performed as part of the risk assessment prepared for this DEIS. Based on uncertainty analyses performed for previous mission risk assessments (e.g., NASA 1997), parameter and model uncertainties associated with estimating radiological consequences could result in risk estimates that vary from one to two orders of magnitude at the 5 percent and 95 percent confidence levels. The FSAR would include the results of a formal uncertainty analysis based on the New Horizons risk analysis.

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

4.6.1 Short-Term Uses

The proposed New Horizons mission would be launched from CCAFS. The short-term affected environment would include this launch complex and surrounding areas. At CCAFS, short-term uses include commercial, NASA and USAF operations, urban communities, a fish and wildlife refuge, citrus groves, residential communities, and recreational areas. The proposed New Horizons mission would be conducted in accordance with past and ongoing NASA and USAF procedures for operations at CCAFS. Should an accident occur causing a radiological release, short-term uses of contaminated areas could be curtailed, pending mitigation.

4.6.2 Long-Term Productivity

No change to land use at CCAFS and the surrounding region is anticipated due to the Proposed Action. The region would continue to support human habitation and activities, wildlife habitats, citrus groves, grazing and agricultural land, and cultural, historic and archaeological areas. No long-term effects on these uses are anticipated because of the Proposed Action. However, should an accident cause a radiological release, the long-term productivity of contaminated land areas could be impacted, pending mitigation.

The successful completion of the proposed New Horizons mission would benefit science and the United States space program, which is important to the economic stability of the area. In addition to the localized economic benefits from the proactive small and small disadvantaged business plan, implementing this mission has broader socioeconomic benefits. These include technology spin-offs, such as low power digital receivers, to industry and other space missions, maintaining the unique capability of the United States to conduct complex outer planetary missions by a large number of scientists and engineers, and supporting the continued scientific development of graduate students in a number of universities and colleges. Furthermore, comprehensive formal and informal education programs would be conducted as education and public outreach efforts, and proactive small and small disadvantaged business plans would be available to small disadvantaged businesses. Data and images acquired by the New Horizons mission would be made available to the general public, schools, and other institutions via a broad variety of media, including the Internet.

4.7 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

An irretrievable resource commitment results when a spent resource cannot be replaced within a reasonable period of time. For the Proposed Action, quantities of various resources, including energy, fuels, and other materials, would be irreversibly and irretrievably committed. The use of these resources would be associated with the fabrication, launch, and operation of the proposed New Horizons mission.

4.7.1 Energy and Fuels

Fabrication of the New Horizons spacecraft and the Atlas V would use electrical and fossil-fuel energy. This use constitutes an irretrievable commitment of resources but would not impose any significant energy impacts. The launch and operation of the spacecraft would consume solid and liquid propellant and related fluids. The solid propellant ingredients would be ammonium perchlorate, aluminum powder, and HTPB binder. The liquid substances would include RP-1, hydrazine, LH_2, and LO_2. The quantities that would be used are discussed in Section 2.1.5.

4.7.2 Other Materials

The total quantities of other materials used in the proposed New Horizons mission that would be irreversibly and irretrievable committed are relatively minor. Typically, these materials include steel, aluminum, titanium, iron, molybdenum, plastic, glass, nickel, chromium, lead, zinc, and copper. Less common materials may include small quantities of silver, mercury, gold, rhodium, gallium, germanium, hafnium, niobium, platinum, iridium, plutonium and tantalum.

4.8 ENVIRONMENTAL COMPLIANCE AT CCAFS

This section presents an overview of environmental laws, regulations, reviews and consultation requirements applicable to operations at CCAFS, and includes permits, licenses, and approvals. The information presented is summarized from the *Final Environmental Impact Statement for the Evolved Expendable Launch Vehicle Program* (USAF 1998), the *Final Supplemental Environmental Impact Statement for the Evolved Expendable Launch Vehicle Program* (USAF 2000), and NASA's *Final Environmental Assessment for Launch of NASA Routine Payloads on Expendable Launch Vehicles from Cape Canaveral Air Force Station, Florida and Vandenberg Air Force Base, California* (NASA 2002). The referenced documents present the relevant discussions, analyses, potential environmental impacts and applicable mitigation plans within each topic of concern. Launch of the New Horizons mission from CCAFS would follow all applicable requirements, and no new permits, licenses, or approvals would be required.

Air Resources

Air permits are required for activities considered as stationary sources having the potential to release air pollutants such as launch support activities (e.g., vehicle preparation, assembly, propellant loading), but are not required for emissions from mobile sources such as launch vehicles during liftoff and ascent. Existing equipment and services would be used.

CCAFS currently operates under Title V (40 CFR 70) of the Clean Air Act, as amended (42 U.S.C. 7401 et seq.), as a single facility. Commercial launch service providers are required to obtain Title V permits for their operations.

Water Resources

The Clean Water Act, as amended (33 U.S.C. 1251 et seq.), provides regulatory guidelines for water quality.

Wastewater at CCAFS is discharged in accordance with the National Pollutant Discharge Elimination System permit conditions. Water used during launch would be discharged under a Florida Department of Environmental Protection permit or disposed by a certified contractor.

Floodplains and Wetlands

Executive Order (EO) 11988, *Floodplain Management*, and EO 11990, *Protection of Wetlands*, would be followed. The proposed New Horizons launch would not be anticipated to add impacts to floodplains and wetlands beyond those normally associated with any Atlas launch.

Hazardous Material Management

Hazardous materials are controlled through Federal regulations such as the Comprehensive Environmental Response, Compensation, and Liability Act, as amended (42 U.S.C. 9601 et seq.), the Toxic Substances Control Act, as amended (15 U.S.C. 2601 et seq.), and the Hazardous Material Transportation Act, as amended (49 U.S.C. 1803 et seq.). Air Force Instruction AFI 32-7086, *Hazardous Material Management*, provides guidance for managing hazardous materials.

Hazardous material would be procured and managed by the commercial launch service provider. The 45th Space Wing Operations Plan 32-3, *Hazardous Material Response Plan*, provides guidance for hazardous material spills.

Hazardous Waste Management

The Resource Conservation and Recovery Act, as amended (42 U.S.C. 6901 et seq.), provides regulatory guidance on managing hazardous wastes. Air Force Instruction AFI 32-7042, *Solid and Hazardous Waste Compliance*, provides guidance on managing hazardous waste. Hazardous wastes must be collected, labeled appropriately, and stored in hazardous waste collection areas prior to disposal.

Hazardous wastes would be managed by the commercial launch service provider or by NASA. The 45th Space Wing Operations Plan 19-14, *Petroleum Products and Hazardous Waste Management Plan* would be followed.

Pollution Prevention

The Pollution Prevention Act, as amended (42 U.S.C. 13101 et seq.), provides the regulatory framework. Department of Defense Directive 4210.15, *Hazardous Material Pollution Prevention*; USAF Policy Directive AFPD 32-70, *Environmental Quality*; and USAF Instruction AFI 32-7080, *Pollution Prevention Program*, provide pollution prevention guidelines. NASA participates in a partnership with the military services called the Joint Group on Pollution Prevention to reduce or eliminate hazardous material or processes.

Pollution prevention guidelines are provided by the 45th Space Wing *Pollution Prevention Program Guide and Pollution Prevention Management Action Plan*.

Spill Prevention

Hazardous material spills are addressed under the 45th Space Wing Operations Plan 32-3, *Hazardous Materials Response Plan*. The commercial launch service provider will, in most cases, be responsible for clean-up of any released hazardous material. When a spill of a Federally listed oil or petroleum occurs, as per the 45th Space Wing Operations Plan 19-4, *Hazardous Substance Pollution Contingency Plan*, the substance is collected and removed for disposal by a certified contractor.

Biological Resources

Federal mandates for the conservation of biological resources include, but are not limited to, the Endangered Species Act, as amended (16 U.S.C. 1531 et seq.) (ESA), the Marine Mammal Protection Act, as amended (16 U.S.C. 1361 et seq.), and the Migratory Bird Treaty Act, as amended (16 U.S.C. 703 et seq.), CCAFS has ESA-listed (endangered or threatened) species. USAF consultations with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service are in place or in process. Established standard practices (e.g., complying with the light management plan for nesting sea turtles and hatchlings) would be observed to minimize impacts to these resources.

Coastal Zone Management

The regulatory framework for coastal zone management is provided by the Federal Coastal Zone Management Act, as amended (16 U.S.C. 1451 et seq.), which establishes a national policy to preserve, protect, develop, restore, and enhance the resources of the nation's coastal zone. CCAFS would follow the State of Florida's requirements. No added impacts beyond those normally associated with launches would be anticipated.

Cultural Resources

Directives of Section 106 of the National Historic Preservation Act, as amended (16 U.S.C. 470 et seq.), would be followed. The State Historic Preservation Officer and the Federal Advisory Council on Historic Preservation would be consulted, if necessary, to determine if implementation of the New Horizons mission could adversely impact cultural resources within CCAFS, although no such adverse impacts are expected.

Noise

Regulations and guidelines prescribed by the Noise Control Act, as amended (42 U.S.C. 4901 et seq.), the Occupational Safety and Health Administration, and the National Institute of Occupational Safety and Health would be followed.

Worker and Public Safety and Health

OSHA regulations would be followed to ensure worker and public safety and health from excessive noise, exposure to hazardous materials and hazardous wastes, and ingestion of toxic fumes from operations such as fueling. The 45th Space Wing at CCAFS has the responsibility to follow Range Safety guidelines as outlined in EWR 127-1, *Eastern and Western Range Safety Requirements* (USAF 1997). RTG handling at the launch site would be performed following applicable regulations as outlined in KHB 1860.1, *KSC Ionizing Radiation Protection Program* (NASA 2001).

5 LIST OF PREPARERS

This Draft Environmental Impact Statement (DEIS) for the New Horizons Mission was prepared by the Science Mission Directorate, National Aeronautics and Space Administration (NASA). As a cooperating agency, the U.S. Department Energy (DOE) has contributed expertise in the preparation of this DEIS. The organizations and individuals listed below contributed to the overall effort in the preparation of this document.

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6 AGENCIES, ORGANIZATIONS AND INDIVIDUALS CONSULTED

This Draft Environmental Impact Statement (DEIS) for the New Horizons mission to Pluto is made available for review and comment by Federal, State, and local agencies and the public. The public review and comment period will close 45 days from the publication of the U.S. Environmental Protection Agency's (EPA) *Federal Register* notice of availability (NOA) or NASA's NOA, whichever is later. Timely comments will be considered during the preparation of the Final EIS. NASA has mailed copies of the DEIS directly to the agencies, organizations, and individuals, as listed below, who may have interest in environmental impacts and alternatives associated with the New Horizons mission.

Federal Agencies

Council on Environmental Quality
National Science Foundation
Office of Management and Budget
U.S. Department of Agriculture
U.S. Department of the Air Force
U.S. Department of Commerce
    National Oceanic and Atmospheric Administration
    National Marine Fisheries Service (NOAA Fisheries)
U.S. Department of Health and Human Services
    Centers for Disease Control and Prevention
    National Cancer Institute
U.S. Department of Homeland Security
    Federal Emergency Management Agency
    U.S. Coast Guard
U.S. Department of the Interior
    Fish and Wildlife Service
    National Park Service
U.S. Department of State
U.S. Department of Transportation
    Federal Aviation Administration
    Research and Special Programs Administration
U.S. Environmental Protection Agency
U.S. Nuclear Regulatory Commission

State Agencies

State of Florida, Office of the Governor
Florida State Clearinghouse
East Central Florida Regional Planning Council

County Agencies

Brevard County
    Board of County Commissioners

Natural Resources Management Office
Office of Emergency Management
Planning and Zoning Commission
Public Safety Department

Lake County
Orange County
Osceola County
Seminole County
Volusia County

Local Agencies

Canaveral Port Authority
City of Cape Canaveral
City of Cocoa
City of Cocoa Beach
City of Kissimmee
City of Melbourne
City of Merritt Island
City of New Smyrna Beach
City of Orlando
City of West Melbourne
City of St. Cloud
City of Titusville

Organizations

The American Association for the Advancement of Science
American Astronomical Society
American Institute of Aeronautics and Astronautics
American Society of Mechanical Engineers
Audubon of Florida
Economic Development Commission of Florida's Space Coast
Environmental Defense Fund
Federation of American Scientists
Friends of the Earth
Global Network Against Weapons and Nuclear Power in Space
Greenpeace
Indian River Audubon Society
National Space Society
National Wildlife Federation
Natural Resources Defense Council
The Planetary Society
Sierra Club
Union of Concerned Scientists

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