APPENDIX A
GLOSSARY OF TERMS

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APPENDIX A

GLOSSARY OF TERMS

99-th percentile—An expression of an outcome that would not occur in more than 1 percent of all statistical samples (that is, 1 percent of the outcomes would be greater than the 99-th percentile level); the 99-th percentile is derived from the distribution of outcomes on which the mean value is based.

accident environment—Conditions resulting from an accident, such as blast overpressure, fragments, and fire.

affected environment—A description of the existing environment that could be affected by the Proposed Action or its alternatives.

albedo—the ratio of the amount of solar radiation reflected from an object to the total amount incident upon it.

ambient air—The surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures. (It is not the air in the immediate proximity of an emission source.)

aphelion—The point on a planetary orbit farthest from the Sun.

astronomical unit (AU)—The average radius of Earth's nearly circular orbit around the Sun, about 149.6 million kilometers (93 million miles).

Atlas—A family of launch vehicles manufactured by the Lockheed Martin Space Systems Company.

attainment—An area is designated as being in attainment by the U.S. Environmental Protection Agency if it meets the **National Ambient Air Quality Standards (NAAQS)** for a given **criteria pollutant**. Nonattainment areas are areas in which any one of the NAAQS have been exceeded, maintenance areas are areas previously designated nonattainment and subsequently re-designated as attainment, and unclassifiable areas are areas that cannot be classified on the basis of available information as meeting or not meeting the NAAQS for any one criteria pollutant.

background radiation—Ionizing radiation present in the environment from cosmic rays and natural sources in the Earth; background radiation varies considerably with location.

conditional probability—Within the context of this Environmental Impact Statement, the probability that a release of radioactive material could occur given an initiating accident (that is, the accident has occurred).

confidence level—In statistics, the degree of desired trust or assurance in a given result. A confidence level is always associated with some assertion and measures the probability that a given assertion is true.

criteria pollutants—The Clean Air Act requires the U.S. Environmental Protection Agency to set air quality standards for common and widespread pollutants after preparing criteria documents summarizing scientific knowledge on their health effects. Currently, there are standards in effect for six criteria pollutants: sulfur dioxide (SO_2), carbon monoxide (CO), particulate matter equal to or less than 10 microns in diameter (PM_{10}), nitrogen dioxide (NO_2), ozone (O_3), and lead (Pb).

cultural resources—The prehistoric and historic districts, sites, buildings, objects, or any other physical activity considered important to a culture, subculture, or a community for scientific, traditional, religious, or any other reason.

cumulative impact—The impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes other such actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

curie (Ci)—A measure of the radioactivity level of a substance (that is, the number of unstable nuclei that are undergoing transformation in the process of radioactivity decay); one curie equals the disintegration of $3.7\text{x}10^{10}$ (37 billion) nuclei per second and is equal to the radioactivity of one gram of radium-226.

decibel—A logarithmic measurement unit that describes a particular sound pressure quantity compared to a standard reference value.

dose—The amount of energy deposited in the body by ionizing radiation per unit body mass.

essential fish habitat—The United States Congress defined essential fish habitat for Federally managed fish species as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity” (16 U.S.C. 1802(10)). The conservation of essential fish habitat is an important component of building and maintaining sustainable fisheries.

exposure to radiation—The incidence of radiation from either external or internal sources on living or inanimate material by accident or intent.

first stage—The launch vehicle stage that provides thrust at lift-off.

full stack intact impact (FSII)—For the purpose of this Environmental Impact Statement, a postulated accident in which the entire launch vehicle (that is, all stages, other vehicle elements, and the payload) impacts the ground in an intact configuration due to a failure at or very shortly after lift-off.

General Conformity Rule—The General Conformity Rule is applicable to non attainment or maintenance areas (see **attainment**) as designated by the U.S. Environmental Protection Agency (EPA), and ensures that Federal actions conform to each State Implementation Plan for air quality. These plans, approved by the EPA, are each State's individual plan to achieve the **NAAQS** as required by the Clean Air Act. The EPA is required to promulgate a Federal Implementation Plan if a State defaults on its implementation plan. A conformity requirement determination for the action is made from influencing factors, including, but not limited to, non attainment or maintenance status of the area, types of emissions and emission levels resulting from the action, and local impacts on air quality.

General Purpose Heat Source (GPHS)—A passive device that produces heat from the radioactive decay of plutonium (in a ceramic form called plutonium dioxide consisting mostly of plutonium-238, a non-weapons grade isotope). This heat can then be converted into usable electrical power.

gravitational perturbation—a disturbance to the regular path of a celestial body caused by an external gravitational force.

gravity assist (flyby or swingby)—A technique used to significantly alter a spacecraft's trajectory without requiring a large amount of onboard propellant. A gravity assist occurs when a spacecraft flies past a massive body (Venus, Earth, or Jupiter, for example). The spacecraft receives a change in speed and direction by the gravitational action of the body. The angle and distance at which the spacecraft approaches the body determine the amount of this change. The technique is used to allow greater spacecraft mass at launch, reduce overall mission flight time, or aim the spacecraft toward another body.

health effects—Within the context of this Environmental Impact Statement, health effects are defined as the number of additional **latent cancer fatalities** due to a radioactive release (that is, the number of cancer fatalities resulting from this release that are in excess of those cancer fatalities which the general population would normally experience from other causes).

hydrazine—A toxic, colorless liquid fuel that is hypergolic (able to burn spontaneously on contact) when mixed with an oxidizer such as nitrogen tetroxide (N_2O_4) or placed in contact with a catalyst. Vapors may form explosive mixtures with air.

infrared radiation—Electromagnetic radiation of wavelengths that lie in the range from 0.75 micron (the long-wavelength limit of visible red light) to 1,000 microns (the shortest microwaves).

initiating probability—The probability that an identified accident and associated adverse conditions (accident environments) will occur.

ionosphere—An upper atmospheric region where ionization of atmospheric gases occurs.

isotope—Any of two or more species of atoms of a chemical element with the same atomic number and nearly identical chemical behavior, but with different atomic mass (number of neutrons) or mass number and different physical properties.

latent cancer fatalities—Estimation of latent cancer fatalities assumes that 1) exposures to the radioactive material released to the environment occur over a

50-year period, and 2) the internal **dose** resulting from such exposure are 50-year committed doses, meaning that following inhalation or ingestion of the radioactive material, the resulting internal doses are based on tracking the material in the body for a 50-year period. The time period over which latent cancer fatalities occur is undefined, and could occur well after 50 years following the release.

maximally exposed individual—A hypothetical person that would receive the maximum predicted dose.

mean—The outcome (**source term**, **dose**, **health effects**, or land contamination as used in this Environmental Impact Statement) that would be anticipated if an accident which released radioactive material were to occur; the mean is a statistical expression of probability-weighted values (source terms or radiological consequences).

National Ambient Air Quality Standards (NAAQS)— Section 109 of the Clean Air Act requires the U.S. Environmental Protection Agency to set nationwide standards, the NAAQS, for widespread air pollutants. Currently, six pollutants are regulated by primary and secondary NAAQS (see **criteria pollutants**).

occultation—The period of time during which the ability to see a celestial body is blocked by another body (for example, when a spacecraft's view of the Earth or Sun is blocked by a planet during a flyby).

oxides of nitrogen (NO_X)—Gases formed primarily by fuel combustion, which contribute to the formation of acid rain. Hydrocarbons and oxides of nitrogen combine in the presence of sunlight to form ozone, a major constituent of smog.

parking orbit—A temporary low-altitude Earth orbit in which a spacecraft with its second or third launch vehicle stage waits until it is in the proper position to continue toward its next or final destination.

payload—The element(s) that a launch vehicle or spacecraft carries over and above what is necessary for the operation of the vehicle. For a launch vehicle, the spacecraft being launched is the payload; for a scientific spacecraft, the suite of science instruments is the payload.

payload fairing (PLF)—The protective shell on a launch vehicle that encapsulates the spacecraft through atmospheric ascent.

radiation—The emitted particles (alpha, beta, neutrons) or photons (X-rays, gamma rays) from the nuclei of unstable (radioactive) atoms as a result of radioactive decay. Some elements are naturally radioactive; others are induced to become radioactive by bombardment in a nuclear reactor or other particle accelerator. The characteristics of naturally occurring radiation are indistinguishable from those of induced radiation.

radiation dose—The amount of energy from ionizing radiation deposited within tissues of the body; it is a time-integrated measure of potential damage to tissues from exposure to radiation and as such is related to health-based consequences.

radioactive half-life—The time required for one half of the atoms in a radioactive substance to decay.

radioisotope thermoelectric generator (RTG)—A power source that converts the heat from the radioactive decay of plutonium (in a ceramic form called plutonium dioxide consisting mostly of plutonium-238, a non-weapons grade isotope) into usable electrical energy.

refractivity—a measure of the ability of a medium (for example, glass or a planet's atmosphere) to alter or distort the path of light.

rem—The unit dose representing the amount of ionizing radiation needed to produce the same biological effects as one roentgen of high-penetration X-rays (about 200,000 electron volts). The biological effects of 1 rem are presumed to be independent of the type of radiation.

risk—Within the context of this Environmental Impact Statement, risk is defined as the expectation of **health effects** in a statistical sense (that is, the product of total probability times the mean health effects resulting from a release of plutonium dioxide, and then summed over all conditions leading to a release).

second stage—The launch vehicle stage that continues to provide thrust during ascent after the vehicle's first stage has depleted its propellant and been jettisoned.

source term—The quantities of materials released during an accident to air or water pathways and the characteristics of the releases (for example, particle size distribution, release height and duration); used for determining accident consequences.

specific impulse—A performance parameter of a rocket propellant, expressed in seconds, defined as the rocket's thrust, in pounds-force, divided by the propellant flow rate, in pounds per second.

stratosphere—An upper portion of the atmosphere above the troposphere reaching a maximum height of 50 kilometers (31 miles) above the Earth's surface. The temperature is relatively constant in the lower stratosphere and gradually increases with altitude. The stratosphere is the Earth's main ozone producing region.

third stage—The launch vehicle stage that provides the final thrust required to place a launch vehicle's payload into its proper trajectory or orbit.

tropopause—The boundary between the troposphere and stratosphere, usually characterized by an abrupt change of lapse rate; the change is in the direction of increased atmospheric stability from regions below to regions above the tropopause; its height varies from 15 kilometers (9 miles) in the tropics to about 10 kilometers (6 miles) in polar regions.

troposphere—The portion of the atmosphere next to the Earth's surface in which the temperature rapidly decreases with altitude, clouds form, and convection is active. The troposphere begins at ground level and extends to an altitude of 10 to 12 kilometers (6 to 8 miles) above the Earth's surface.

unavoidable adverse effects—Effects that can not be avoided due to constraints in alternatives. These effects must be disclosed, discussed and mitigated, if practicable.

ultraviolet (UV) radiation—Electromagnetic radiation of wavelengths that lie in the range from 0.35 micron (the short-wavelength limit of violet light) to 0.05 micron (the longest X-rays).

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EFFECTS OF PLUTONIUM ON THE ENVIRONMENT

B.1 INTRODUCTION

This appendix addresses the potential impacts from a radioactive source containing plutonium (Pu)-238 released to the environment, which could occur in any of the low-probability accidents described in Chapter 4 of this Environmental Impact Statement (EIS). The health and environmental risks associated with Pu-238 were previously addressed in the National Aeronautics and Space Administration's (NASA) EISs for the Galileo, Ulysses, Cassini, and Mars Exploration Rovers missions (NASA 1989, NASA 1990, NASA 1995, NASA 1997, NASA 2002).

The New Horizons spacecraft carries one general purpose heat source radioisotope thermoelectric generator (RTG) containing approximately 10.9 kilograms (24 pounds) of plutonium dioxide (PuO_2) (consisting mostly of Pu-238), with a total activity of about 132,500 curies.

The purpose of this appendix is to describe qualitatively the factors that influence the movement of PuO_2 through the environment and into the human body, together with the subsequent health effects, in the event that there is an accidental release of PuO_2 from the spacecraft's RTG.

B.2 CHEMICAL AND PHYSICAL PROPERTIES THAT ARE IMPORTANT FOR BEHAVIOR IN THE ENVIRONMENT AND THE HUMAN BODY

In this section, the following important characteristics are discussed:

- Chemical form;
- Particle size distribution;
- Solubility;
- Half life; and
- Decay modes.

B.2.1 Chemical Form

In the RTG for the New Horizons mission, the Pu-238 is present as the dioxide. The predominant risk pathways are those in which this material is released as the result of ground impact and fire. It is therefore assumed that the Pu remains oxidized. This is important because the chemical form influences the solubility, which in turn strongly influences such factors as bioaccumulation and uptake in the human body.

B.2.2 Particle Size Distribution

It is also important to understand the physical form of the material, in particular the particle size distribution, which influences, among other things: whether the material will fall to the ground in the immediate vicinity of the accident or will be transported over long distances; the initial deposition and subsequent resuspension of particles in both air and water; solubility in water and in biological fluids; and whether or not the material can be inhaled and where it will be deposited and retained within the human respiratory system. Generally speaking, larger particles have less potential for suspension and resuspension; as the particle size decreases, particles are more easily kept in suspension.

The initial particle size distribution is a function of the conditions of the accident. For example, the launch area source terms could initially be in the form of vapor as a result of exposure to fire. The vapors would contain not only the radionuclides but also various structural materials. The radionuclides would tend to condense with and agglomerate with these other materials, which would then predominantly determine the characteristics of the aerosol. The potential for uptake of inhaled particles is critically dependent on the size of the particles (respirable particles are generally considered to be 10 microns or less, although larger sizes can be deposited in the upper respiratory tract).

B.2.3 Solubility

A number of factors affect the solubility of PuO_2 in water. Physical parameters most important to the solubility of PuO_2 are the reactive surface area and oxidation state of plutonium and the water chemistry, including pH, reduction/oxidation potential, and temperature. The mass to surface area ratios of particles affect the reactivity and solubility, with solubility being inversely related to particle size. In general, PuO_2 is insoluble.

Because PuO_2 is so insoluble, movement through the environment depends on physical processes. PuO_2 may be carried into the soil by a number of routes, including the percolation of rainfall and subsequent leaching of particles into the soil, animal burrowing activity, and plowing or other disturbance of the soil by humans. Migration of the PuO_2 into the soil column is of concern, primarily because of the potential for PuO_2 to reach groundwater aquifers used as drinking water supplies. Once deposited on soil, however, PuO_2 appears to be extremely stable. Soil profile studies have shown that generally more than 95 percent of the PuO_2 from nuclear weapons fallout remained in the top 5 cm (2 inches) of surface soil (in undisturbed areas) for 10 to 20 years following deposition (DOE 1987).

B.2.4 Half Life

The half-life of Pu-238 is 87.7 years. This half-life is particularly important for chronic exposure pathways. After a human lifetime (nominally 70 years), more than half of the Pu-238 will still be present.

B.2.5 Decay Modes

Pu-238 is an alpha particle emitter with decay energies of about 5 million electron volts. Its radioactive daughters are also alpha-emitters with about the same decay energy. These alpha particles are what predominantly determine the effects on the human body.

Pu-238 can also undergo spontaneous fission, but the branch probability is extremely small.

B.3 THE TRANSPORT OF PLUTONIUM OXIDES THROUGH THE ENVIRONMENT

Plutonium is one of the most widely studied elements in terms of chemistry and environmental behavior. Although its chemistry and oxidation states are quite diverse, the element's environmental mobility is very limited (INSRP 1989). The pathways and the generalized behavior of plutonium in the environment are described in the literature (e.g., Aarkrog 1977, Pinder and Doswell 1985, Pinder et al. 1987, Yang and Nelson 1984). The extent and magnitude of potential environmental impacts caused by PuO_2 releases depend on the mobility and availability of PuO_2 and are directly controlled by a number of physical and chemical parameters, including particle size, potential for suspension, deposition and resuspension, solubility, and oxidation state of any dissolved plutonium.

This Section discusses the various ways in which plutonium can be transported through the environment to the point at which it is taken into or irradiates the human body. The modeling for the New Horizons mission encompasses both short-term (during plume passage) and long-term (chronic exposure) pathways.

B.3.1 During Plume Passage

The predominant pathway during the passage of the airborne plume is inhalation. The important parameters in this calculation are the rate of dilution of the plume as it travels downwind, the deposition mechanisms that deplete the plume and leave radioactive material on the ground, and the rate of inhalation. All of these parameters and mechanisms are independent of the fact that the radionuclide in question is Pu-238. For example, the small particle sizes arising from agglomeration onto aluminum oxide particles (see Section B.1.2) mean that gravitational settling is not important. It is therefore appropriate to use a standard Gaussian model for the atmospheric dispersion. Similarly, the small particle size means that, once it is transported to a human receptor, it is inhaled. Work done for previous EISs shows that inhalation of the particles in the passing plume and of resuspended particles are the two most important contributors to the radiation dose accumulated by human receptors.

The other pathway that is potentially important during plume passage is cloudshine – the irradiation of the human body by neutrons and gamma rays emitted by the passing plume of radioactive material. However, because Pu-238 emits predominantly alpha particles, this irradiation pathway is not important for the New Horizons Mission.

B.3.2 Chronic Exposure Pathways

This section considers contributions due to resuspension, ingestion of vegetables, external exposure, seafood ingestion, and contamination of drinking water.

B.3.2.1 Resuspension

For launch area accidents, the resuspension model used in the analysis starts with an initial resuspension factor that decreases exponentially to a constant long term resuspension factor (Momeni et al. 1979, Strenge and Bander 1981). For materials deposited after traveling more than 100 km (62 mi) from the source of a release, or released high in the atmosphere, the resuspension factor is at all times typically similar to the long term resuspension factor (Bennett 1976, UNSCEAR 1982). The work done in previous EISs shows that resuspension is the most significant of the chronic exposure pathways and is comparable to or larger in its effects on humans than is the direct inhalation pathway.

B.3.2.2 Vegetable Ingestion

Parameters used for estimating the uptake from harvesting and consumption of agricultural products have been measured (Baes et al. 1984, Rupp 1980, Yang and Nelson 1984). These and similar agricultural and food consumption parameters and plutonium ingestion parameters (ICRP 1979) are used as the basis for estimating human doses via ingestion. For example, an analysis of Pu-238 contamination of orange trees shows that a total of only 1 percent of the plutonium actually aerially deposited on the plants would be transported on fruit from field to market during the 12 months following harvesting (Pinder et al. 1987). Most of this plutonium would adhere to the fruit’s peel and would be removed prior to ingestion; uptake to the orange itself would be extremely small or nonexistent.

Four mechanisms of vegetable ingestion were taken into account, as described below.

- *Initial deposition immediately following the accident* – the amount initially deposited per curie released depends on non-PuO_2 specific factors such as particle size distribution and characteristics of the vegetation. The predicted amount of radioactive material ingested by humans then depends on assumptions about physical mechanisms and vegetable distribution, such as: the removal half-life for leaf-deposited material, a leaf interception factor, and a vegetable density. Additionally, harvesting (continuous after the accident, delayed harvesting, crop destruction) and consumption assumptions would affect the predicted amount of radioactive material ingested by humans.

- *Continuous redeposition on the vegetables due to resuspension over the first 50 years following the accident* – the amount ingested by individuals is controlled by the resuspension mechanism (see above), the assumed dry deposition velocity and assumptions about harvesting and distribution.

- *Root uptake* – this mechanism is in principle highly radionuclide and vegetable specific and depends on such factors as solubility, radionuclide chemistry and vegetable chemistry. In general, PuO_2 is insoluble and is poorly transported in terrestrial environments. Most forms of plutonium, including PuO_2, are removed from biological pathways by processes such as fixation in soil. Only small amounts of material would be concentrated by biological accumulation into grazing animals, and vegetables.

- *Rain splashup* – this mechanism depends in part on the characteristics of the soil and the rainfall.

For Pu-238, radiation doses arising via these pathways are a small fraction of those arising from the inhalation pathways.

B.3.2.3 External Radiation

External radiation from material deposited on the ground and resuspended material is calculated using standard methods for cloudshine and groundshine. Because Pu-238 is predominantly an alpha emitter, this exposure pathway is relatively unimportant.

B.3.2.4 Seafood and Fish Pathway

Radiation doses can result from the bioaccumulation of plutonium deposited on the surfaces of inland waters or oceans. The predicted radiation doses arising from this pathway depend on a number of assumptions and physical and chemical processes, including how the deposited radionuclides are diluted in the water, how the radionuclides are partitioned between water and sediment, and how radionuclides are accumulated in different types of fish, crustaceans and mollusks.

In marine and aquatic systems, larger particles would quickly settle to the bottom sediments; smaller silt-size particles may remain in suspension within the water column for extended periods of time. Smaller particles may not even break the water surface (due to surface tension), forming a thin layer on the water surface that is subsequently transported to the shoreline by wind and wave action. Resuspension of smaller particles from the bottom could occur due to physical disturbance of the sediments by wave action and recreational uses of the water bodies (e.g., swimming, boating, and fishing), as well as by the feeding activity of various marine and aquatic species. Particles of PuO_2, as a component of the bottom sediments, may also be transported toward and along the shoreline by wave action and currents in near-shore environments (NASA 1990).

Studies have indicated that bioaccumulation in marine organisms can vary widely depending on the type and population densities of seafood species impacted (e.g., freshwater fish, saltwater fish, mollusks), the amount and particle size distribution of radioactive material released, and the deposition area.

PuO_2 entering into a water/sediment system would be preferentially taken out of solution and bound in saturated sediments in amounts on the order of 100,000 times greater than the amounts that would remain in the associated water column (NASA 1990).

Clays, organics, and other anionic constituents tend to bind most of the PuO_2 particles in the sediment column. The binding of PuO_2 usually occurs in the first few centimeters of sediment, greatly reducing the concentration of this constituent with depth.

Overall, the seafood pathway is insignificant for PuO_2. This is due to a combination of considerable dilution in the water, overwhelming partition into sediment, and small bioaccumulation factors.

B.3.2.5 Contamination of Drinking Water

It is possible that surface water runoff containing PuO_2 could directly contaminate drinking water supplies that originate from surface water bodies, because this type of contamination is primarily due to suspended PuO_2 particles and not from dissolved PuO_2. Filtering the surface water before chemical treatment would reduce the concentration of total plutonium to very low levels (NASA 1990).

B.4 TRANSPORT AND DEPOSITION OF RADIONUCLIDES IN THE HUMAN BODY

The International Commission on Radiological Protection (ICRP) has developed accepted models for the distribution of inhaled and ingested radionuclides in the body. The ultimate fate of these radionuclides depends on such factors as particle size distribution, solubility, and chemistry. The ICRP models requires knowledge of numerous parameters, most of which are obtained empirically (e.g., there is no theoretical model for determining what fraction of ingested plutonium (say) enters the bloodstream). The required parameters are obtained from animal experiments and, if available, from human studies concerning the effects of nuclear weapons and of nuclear fallout. Of the transuranium elements, plutonium is by far the most widely studied.

PuO_2 that enters the human body by inhalation or ingestion has many possible fates, all of which have been studied in detail (ICRP 1979; ICRP 1986). The inhalation route is found to be approximately 1,000 times as effective as ingestion in transporting plutonium to the blood, due to the short time of residency, the chemical properties of plutonium, and the physiological environment of the gastro-intestinal (GI) tract (ICRP 1979).

Ingested PuO_2 would quickly pass through the digestive system and be excreted with only a small quantity being absorbed via the mucosa into the bloodstream. The fractional absorption of PuO_2 is estimated to average about 1 part in 100,000 ingested (ICRP 1979; ICRP 1986) – that is, in ICRP terminology, the f_1 factor for ingestion is 10^{-5}. The fractional absorption is based on the average individual. Note that PuO_2 in the environment could become more soluble with time due to the use of fertilizers in gardening, chlorination in drinking water, and conversion to soluble forms in seawater. Dietary and physiological factors, such as fasting, dietary calcium deficiency, disease or intake of medications, may also change the fractional absorption (ICRP 1986).

Inhaled PuO_2 would be transported to one or more portions of the respiratory system depending on the particle size. Generally, most particles larger than 5 to 10 microns would be intercepted in the nasopharyngeal region and either expelled or swallowed to pass through the digestive tract; what is not absorbed, would then be excreted. Particles smaller than about 5 microns would be transported to and remain in the trachea, bronchi, or deep lung regions. Particles reaching the deep lung would be cleared from the body much more slowly than those not entering the lung. For example, approximate micrometer-size PuO_2 particles would typically be cleared from the pulmonary area of the lung at the rate of 40 percent in the first day, and the remaining 60 percent cleared in 500 days (ICRP 1979). Particles captured in the mucous lining of the upper respiratory tract would be moved more rapidly to the pharynx, where they would be swallowed. Once swallowed, they would behave as if ingested.

Plutonium dioxide remaining in the lung would continuously irradiate lung tissue, and a small fraction would be transported over time directly to the blood or to lymph nodes and then to the blood. The estimated fraction of plutonium transferred directly from pulmonary lung tissues to the blood would be about 1 percent of the amount retained in the lungs, depending on the size distribution of ultra-fine particles. Smaller particles are likely to form over time from larger particles due to the natural fragmentation processes associated with radioactive decay and may also be transferred to the blood. Over a period of years, approximately 15 percent of the PuO_2 initially deposited in the lungs would be transferred to the lymph nodes. Of that, up to 90 percent would likely be retained in the lymph node with a 1,000 day half-life before being transferred to the blood (ICRP 1986). Overall, the PuO_2 f_1 factor for inhalation is the same as that for ingestion, 10^{-5}.

Once PuO_2 has entered the blood via ingestion or inhalation, it would circulate and be deposited primarily in the liver and skeletal system. It is currently accepted that plutonium transported by the blood is distributed to the following organs: 45 percent in the liver, 45 percent in the skeletal system, 0.035 percent in the testes and 0.011 percent in ovaries with a non-measurable amount crossing the placenta and available for uptake by the fetus. The remaining 10 percent of the activity in the blood is excreted through the kidneys and colon or deposited in other tissues (ICRP 1979, ICRP 1986).

The estimated residence times in the liver, skeletal system, and gonads are quite long. Current estimates for 50 percent removal times for plutonium are 20 years for the liver, 50 years for the skeleton, and permanent retention for the gonads.

B.5 CANCER INDUCTION AND GENETIC EFFECTS

The relationship between dose received and the probability of cancer induction is described by the Linear, No-Threshold (LNT) model. For low-level doses such as those predicted for potential accidents involving the New Horizons mission, the LNT model states that for a collective dose of 10,000 person-rem accumulated by a given population, it is expected that 5 to 6 cancers will develop (EPA 2002). Equivalently, for low levels of radiation dose, the probability of cancer induction in an individual is 5×10^{-4}/rem to 6×10^{-4}/rem (where the radiation dose in question is the Effective Dose Equivalent (EDE) to the whole body) no matter how small the dose. LNT is frequently extrapolated to doses as low as one ten thousandth of those for which there is direct evidence of cancer induction by radiation (Cohen 2000).

The validity of the LNT model has been questioned by, among others, the Health Physics Society, which has issued a position statement (HPS 2001) that declares “In accordance with current radiation knowledge of health risks, the Health Physics Society recommends against quantitative estimation of health risks below an individual dose of 5 rem in one year or a lifetime dose of 10 rem in addition to background radiation. There is substantial and convincing evidence for health risks at high dose. Below 10 rem (which includes occupational and environmental exposures) risks of health effects are either too small to be observed or non-existent.”

In the past decade, there have been numerous studies worldwide on the effects of low dose radiation. One particularly comprehensive program has been initiated by the U.S. Department of Energy, the Low Dose Radiation Research Program (LDRRP), the goal of which is to support research that will help determine health risks from exposures to low levels of radiation. Progress in these areas is documented on the LDRRP web site at http://www.er.doe.gov/production/ober/lowdose.html. The LDRRP began in 1999 and is currently planned to last 10 years.

Some of the issues that need to be considered are as follows: a nearby cell may be affected in several ways by the ejection of an alpha particle from a decaying Pu-238 nucleus.

- The alpha particle entirely misses the cell and has no damaging effect.
- The alpha particle strikes the cell nucleus and kills it.
- The alpha particle strikes the cell nucleus, damaging the DNA, but the cell survives with one of the following results:
    - The damaged DNA is correctly repaired before cell division with no lasting effects.
    - The damaged DNA is not correctly repaired and the cell lives but does not reproduce and dies at the end of its life cycle (common for highly differentiated cells).
    - The damaged DNA is not correctly repaired and the cell lives to pass on defective genes to future generations of cells (common for undifferentiated stem cells).

Recent in vitro cellular-level irradiation studies have indicated that undifferentiated cells (including human epithelial cells of the type commonly involved in many cancers and leukemias) can survive intact not just single but also multiple alpha particle tracks (Nagasawa and Little 1992, Kadhim et al. 1992, Evans 1992, Kadhim et al. 1994, Hei et al. 1997, Little 1997, Riches et al. 1997, Pugliese et al. 1997, Miller et al. 1999). There is also evidence that low level radiation stimulates biological defense mechanisms. Cohen (2000) reviews the evidence for this, including reference to a report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR 1994).

Such biological defense mechanisms would tend to support the view that LNT is conservative. However, the latest research as documented on the above-referenced LDRRP web site suggests that it is premature to come to any definitive conclusion. For example, it is now possible to detect “bystander effects” in cells that do not have direct deposition of energy in them. These effects have been detected in model tissue systems by the Gray Laboratory. The past tendency has been to use localized dose to predict effects. However, this may not now be valid since there is a marked response in non-exposed cells and tissues. With bystander effects, especially for high-LET radiation, the use of dose as a common currency to predict risk may no longer be acceptable. The biological impact of such observations on radiation risk require a continuing reevaluation.

The use of gene chip technology makes it possible to look more deeply into the mechanisms of action of low dose radiation exposure. The influence of dose, dose rate, tissue type and time on the level of gene expression is creating some very interesting postulates about extrapolation from high doses to low doses. Such data demonstrate that different mechanisms may be involved in radiation-induced changes at high doses as compared to the actions of low doses.

In conclusion, it is premature to consider changes in the cancer induction risk relationships used in this EIS.

B.6 REFERENCES FOR APPENDIX B

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APPENDIX C
ENVIRONMENTAL JUSTICE ANALYSIS

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ENVIRONMENTAL JUSTICE ANALYSIS

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APPENDIX C
ENVIRONMENTAL JUSTICE ANALYSIS

C.1 INTRODUCTION

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, directs Federal agencies to identify and address, as appropriate, the disproportionately high and adverse health or environmental effects of their programs, policies, and activities on minority populations and low-income populations.

The Council on Environmental Quality (CEQ) has oversight responsibility for documentation prepared in compliance with the National Environmental Policy Act of 1969 (NEPA), as amended (42 U.S.C. 4321 et seq.). In December 1997, the CEQ released its guidance on environmental justice (CEQ 1997). The CEQ's guidance was adopted as the basis for the information provided in this Draft Environmental Impact Statement (DEIS).

This appendix provides data necessary to assess the potential for disproportionately high and adverse human health or environmental effects that may be associated with implementation of the New Horizons mission. The area examined in this appendix is the land area within 100 kilometers (km) (62 miles (mi)) of Space Launch Complex 41 (SLC-41) at Cape Canaveral Air Force Station (CCAFS), Florida.

C.2 DEFINITIONS AND APPROACH

C.2.1 Minority Populations

During the Census of 2000, the U.S. Bureau of the Census (USBC) collected population data in compliance with guidance adopted by the Office of Management and Budget (OMB) (62 FR 58782-58790). The OMB published its guidelines on aggregation of multiple race data in March 2000 (OMB 2000). Modifications to the definitions of minority individuals in the CEQ's guidance on environmental justice (CEQ 1997) were made in this analysis to comply with the OMB's guidelines issued in March 2000. The following definitions of minority individuals and population are used in this analysis of environmental justice:

Minority Individuals: Persons who are members of any of the following population groups: Hispanic or Latino of any race, American Indian or Alaska Native, Asian, Black or African-American, Native Hawaiian or Other Pacific Islander, or Multiracial (and at least one race which is a minority race under CEQ guidance of 1997).

Minority Population: The total number of minority individuals residing within a potentially affected area.

Persons self-designated as Hispanic or Latino are included in the Hispanic or Latino population regardless of race. For example, Asians self-designated as Hispanic or Latino are included in the Hispanic or Latino population and not included in the Asian Population. Data used to characterize minority populations in the year 2000 were extracted from Table P4 of Summary File 1 published by the USBC on their Internet web site (DOC 2001). Data used for the projection of minority populations in Florida for the year 2006 was projected from the USBC's 1990 (DOC 1992) and 2000 census data for the area surrounding CCAFS.

C.2.2 Low-Income Populations

Poverty thresholds are used to identify "low-income" individuals and populations (CEQ 1997). The following definitions of low-income individuals and population are used in this analysis:

Low-Income Individuals: Persons whose self-reported income is less than the poverty threshold for the year 2000.

Low-Income Population: The total number of low-income individuals residing within a potentially affected area.

C.2.3 Disproportionately High And Adverse Human Health Effects

Disproportionately high and adverse health effects are those that are significant (as employed by NEPA at 40 CFR Part 1580 Subpart 1508.27) or above generally accepted norms, and for which the risk of adverse impacts to minority populations or low-income populations appreciably exceeds the risk to the general population.

C.2.4 Disproportionately High And Adverse Environmental Effects

Disproportionately high and adverse environmental effects are those that are significant (as employed by NEPA), and that would adversely impact minority populations or low-income populations appreciably more than the general population.

Census 2000 data for low-income populations living in Florida are scheduled for publication by the USBC in mid-September 2002 (DOC 2002). Low-income data extracted from the 1990 Census will be used until the data from Census 2000 is available.

C.3 METHODOLOGY

C.3.1 Spatial Resolution

For the purposes of enumeration and analysis, the USBC has defined a variety of areal units (DOC 1992, DOC 2001). Areal units of concern in this document include (in order of increasing spatial resolution) states, counties, census tracts, block groups, and blocks. The block is the smallest of these entities and offers the finest spatial resolution. This term refers to a relatively small geographical area bounded on all sides by visible features such as streets and streams or by invisible boundaries such as city limits and property lines. During the 2000 census, the USBC subdivided the United States and its territories into 8,269,131 blocks. For comparison, the 2000 census used 3,232 counties, 66,304 census tracts, and 211,267 block groups. In the analysis below, block-level spatial resolution is used in the analysis of minority impacts (DOC 2001). Data that describes low-income status is not available at the block level. Therefore, block group spatial resolution is used in the analysis of low-income populations (DOC 2002).

C.3.2 Projections of Populations

Projections of population groups living in the area of interest surrounding SLC-41 in CCAFS for the year 2006 are shown in Table C-1. With three exceptions, populations living within distances of 10 km (6 mi), 20 km (12 km), and 100 km (62 mi) of SLC-41 in 2006 were obtained as linear projections of resident populations for the years 1990 and 2000.

The three exceptions are: the minority groups “Native Hawaiian or Other Pacific Islander” and “Multiracial Minority” and the non-minority group “White and Some Other Race”. No data for these groups are available from the 1990 Census. During the 1990 Census, the category “Native Hawaiian or Other Pacific Islander” was included in the single category “Asian or Pacific Islander”. The Native Hawaiian population surrounding SLC-41 in 2006 was estimated by assuming that the percent change in the Native Hawaiian population from 2000 to 2006 will be identical to the percent change in the Asian population in the same area for the same years. Similarly, the multiracial minority population surrounding SLC-41 in 2006 was obtained under the assumption that the percent change in the multiracial minority population from 2000 to 2006 will be identical to the percent change in the combined Asian, Native Hawaiian, Black or African American and American Indian or Alaska Native populations in the same area for the same years. The “White and Some Other Race” population surrounding SLC-41 in 2006 was obtained under the assumption that the percent change in that population from 2000 to 2006 will be identical to the percent change in the combined White population and “Some Other Race” population in the same area for the same years.

C.3.3 Environmental Justice Assessment

The purpose of this analysis is to (1) identify minority populations and low-income populations residing that would be potentially affected by implementation of the Proposed Action or Alternatives and (2) determine if implementation of the Proposed Action or Alternatives would result in disproportionately high and adverse effects on these populations. In the event that radiological or other human health risks resulting from the implementation of the Proposed Action or Alternatives are found to be significant, then the health risks to minority populations and low-income populations will be evaluated to determine if they are disproportionately high.

C.4 CHARACTERIZATION OF POTENTIALLY AFFECTED POPULATIONS

Figure C-1 shows the prominent features in the area within a distance of 100 km (62 mi) of the CCAFS boundary. The land area within 100 km (62 mi) of the CCAFS boundary includes approximately 18,000 square km (7,000 square mi) of central Florida’s eastern coast. Nearly 2.4 million persons lived within 100 km (62 mi) of SLC-41 in the year 2000 (Table C-1). Minorities comprised approximately 29 percent of the total population. By the year 2006, the total population is projected to increase to 6 million persons, and minorities are projected to comprise almost one-third of the total population.

As illustrated in Figures C-2 and C-3, approximately one-half of the total and minority populations lived in urban areas of Orange, Seminole and Volusia Counties. Ten percent of the minority population lived within 62 km (45 mi) of SLC-41, while ten percent of the non-minority population lived within 40 km (25 mi) of SLC-41.

Hispanic or Latino and Black or African-American American populations were the largest minority groups living within 100 km (62 mi) of SLC-41 in the year 2000. Moving outward from the CCAFS boundary, Blacks or African-Americans are the largest resident minority group until approximately the outskirts of the City of Orlando. Due to the relatively large concentration of Hispanics or Latinos in the Orlando Metropolitan Area, Hispanics or Latinos comprise the largest group of minority residents in the total area. Only 23 persons lived within 10 km (6 mi) of SLC-41 in 2000, although 21 (over 90 percent) were members of a minority group.

During the 1990 Census, eight to ten percent of the residents living within 100 km (62 mi) and 20 km (12 mi) of SLC-41 reported incomes below the 1990 poverty threshold (Table C-1). Data from Census 2000 (DOC 2002) shows that the low-income population living within 100 km (62 mi) of SLC-41 increased from 10.1 percent to 10.7 percent of the total population. At the same time, the percentage of the population living within 20 km (12 mi) of SLC-41 and reporting incomes below the poverty threshold declined from over eight percent to seven percent.

C.5 IMPACTS ON MINORITY AND LOW-INCOME POPULATIONS

As discussed in Chapter 4 of this DEIS, accidents during the New Horizons mission could result in human exposure to radioactive and other hazardous materials. Plutonium-238 is the primary radioactive material of concern. Potential radiological releases could affect populations residing both within and beyond 100 km (62 mi) of the launch site. As shown in Table 4-4 of Chapter 4, if the Proposed Action is implemented, and if an accidental release of radioactive material were to occur during any mission phase, on average no latent cancer facilities or other health impacts would be expected to occur.

Mission risks (consequences that would occur in the event of a radioactive release multiplied by the probability of a release) are also small. As shown in Table 4-3, the likelihood of an accident resulting in a release of radioactive material during the pre-launch and early launch phases combined is approximately 1 in 620. The corresponding risk to the local population (persons residing within 100 km (62 mi) of the launch facilities at CCAFS) and to the average local individual of a latent cancer fatality resulting from an accident in pre-launch or early launch is approximately 1 in 5,300 (population risk) and 1 in 2.2 billion (individual risk) (Table 4-7). The risk to the global population (persons residing more than 100 km (62 mi) from the launch site at CCAFS) and to the average individual of a latent cancer fatality resulting from an accident during the New Horizons mission is approximately 1 in 2,600 (population risk) and less than 1 in 2.3 trillion (individual risk) (Table 4-7).

As discussed in Section 4.1.3, non-radiological accidents also pose no significant risks to the public. Toxic effects that could result from a liquid propellant spill during fueling operations would not extend beyond the immediate vicinity of the launch pad. Members of the public are excluded from the area at risk during fueling operations. A fuel explosion on the launch pad or during the first few seconds of flight could temporarily increase carbon monoxide (CO), hydrochloric acid (HCl), and aluminum oxide (Al_2O_3) levels near the CCAFS boundary. One-hour average concentrations of hazardous emissions from such an explosion are less than the emergency response guidelines recommended by the American Industrial Hygiene Association and the National Research Council for the Department of Defense.

Thus, implementation of the Proposed Action would pose no significant radiological or non-radiological risks to the public, including minority and low-income groups within the potentially affected population.

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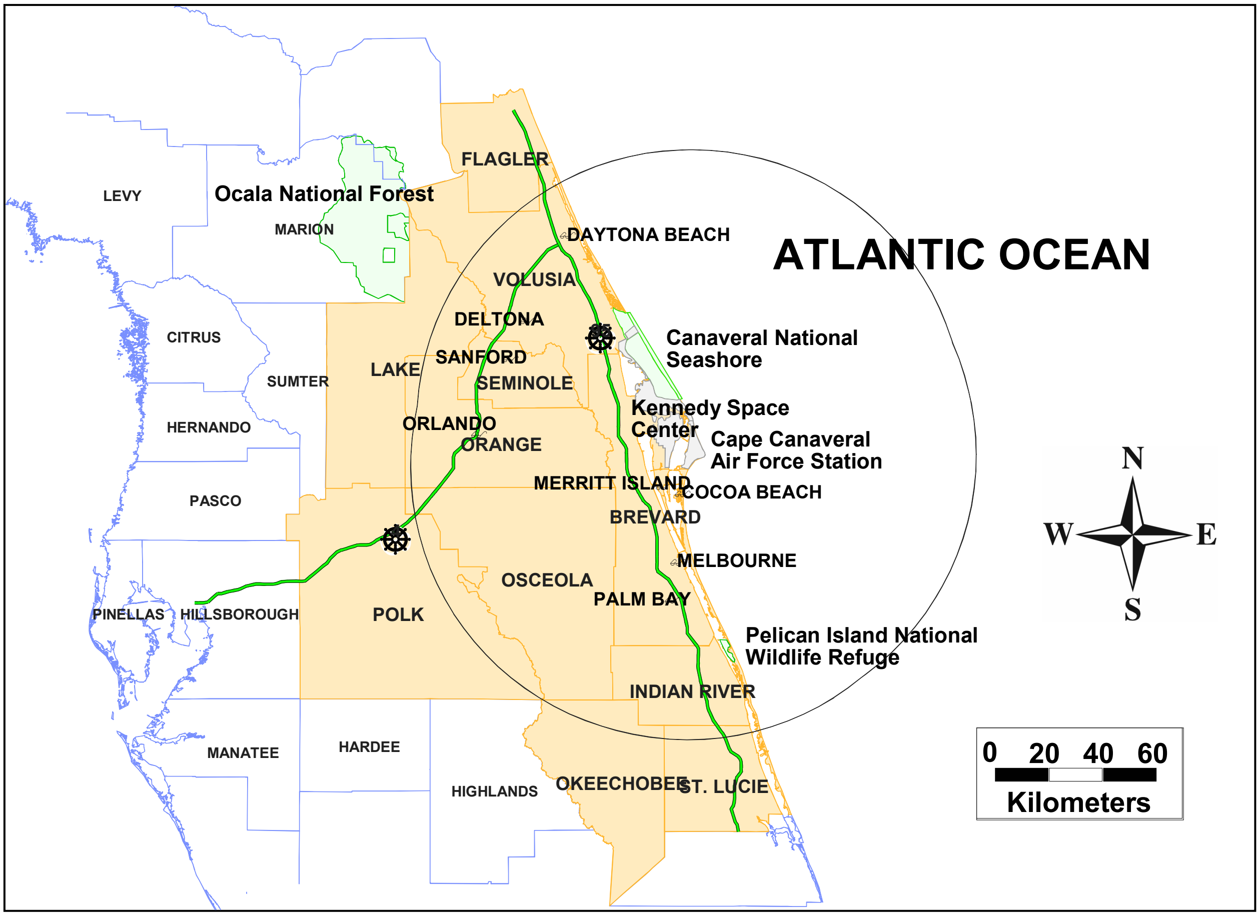

FIGURE C-1. THE AREA WITHIN 100 KM (62 MI) OF CCAFS

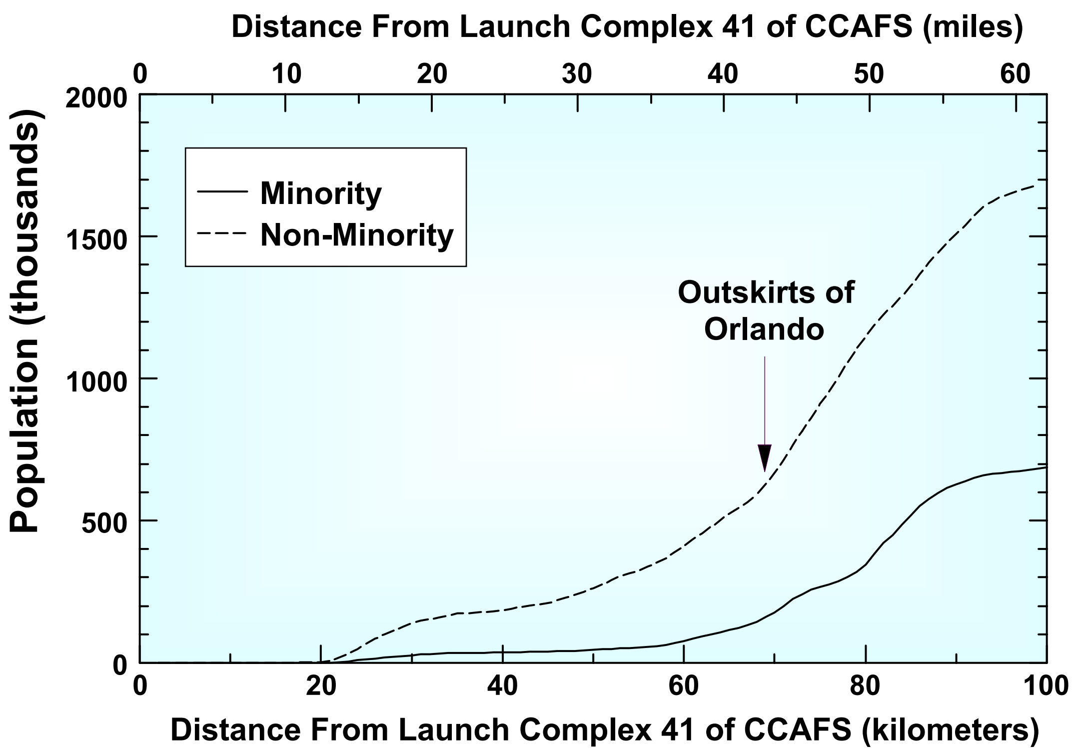

FIGURE C-2. MINORITY AND NON-MINORITY POPULATIONS LIVING WITHIN 100 KM (62 MI) OF SLC-41 OF CCAFS IN 2000

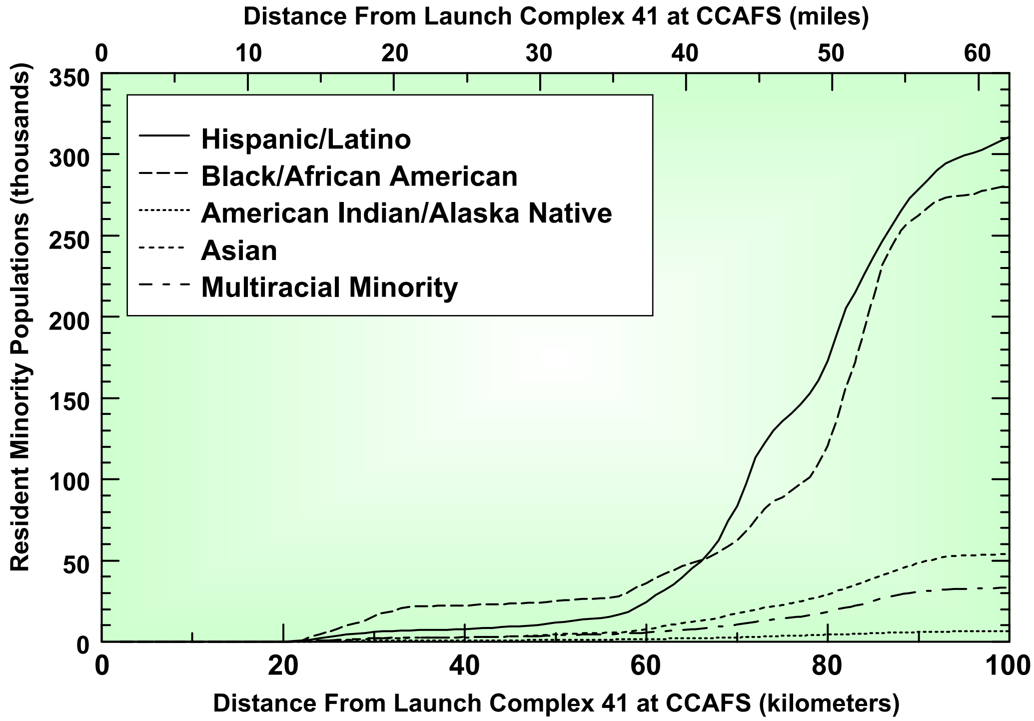

FIGURE C-3. MINORITY POPULATIONS LIVING WITHIN 100 KM (62 MI) OF SLC-41 OF CCAFS IN 2000

TABLE C-1. RACIAL AND ETHNIC COMPOSITION OF THE POPULATION AT VARYING DISTANCES FROM SLC-41 AT CCAFS FOR 1990, 2000, AND 2006

Population	100 km (62 mi)			20 km (12 mi)			10 km (6 mi)		
	1990	2000	2006 [a]	1990	2000	2006 [a]	1990	2000	2006 [a]
Asian	26,998	53,857	69,972	38	36	35	0	1	2
Native Hawaiian	No Data	1,355	1,760	No Data	3	3	No Data	0	0
Black/African American	192,622	281,143	334,256	36	74	97	0	11	18
American Indian/Alaska Native	6,183	6,507	6,701	26	18	13	0	0	0
Hispanic/Latino	118,831	310,636	425,719	67	121	153	0	7	11
Multiracial Minority	No Data	33,301	40,083	No Data	45	51	No Data	2	3
Some Other Race	1,187	5,382	7,899	1	3	4	0	0	0
White	1,508,431	1,678,429	1,780,428	2,944	3,101	3,195	0	2	3
White and Some Other Race	No Data	6,292	6,683	No Data	3	3	No Data	0	0
Minority	344,634	686,799	878,491	167	297	352	0	21	34
Total	**1,854,253**	**2,376,902**	**2,673,501**	**3,112**	**3,403**	**3,554**	**0**	**23**	**37**
Percent Minority	18.6%	28.9%	32.9%	5.4%	8.7%	9.9%	—	91.3%	91.9%
Percent Low Income	10.1%	10.7%	—	8.3%	7.0%	—	—	3.7%	—

(a) Projected population

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