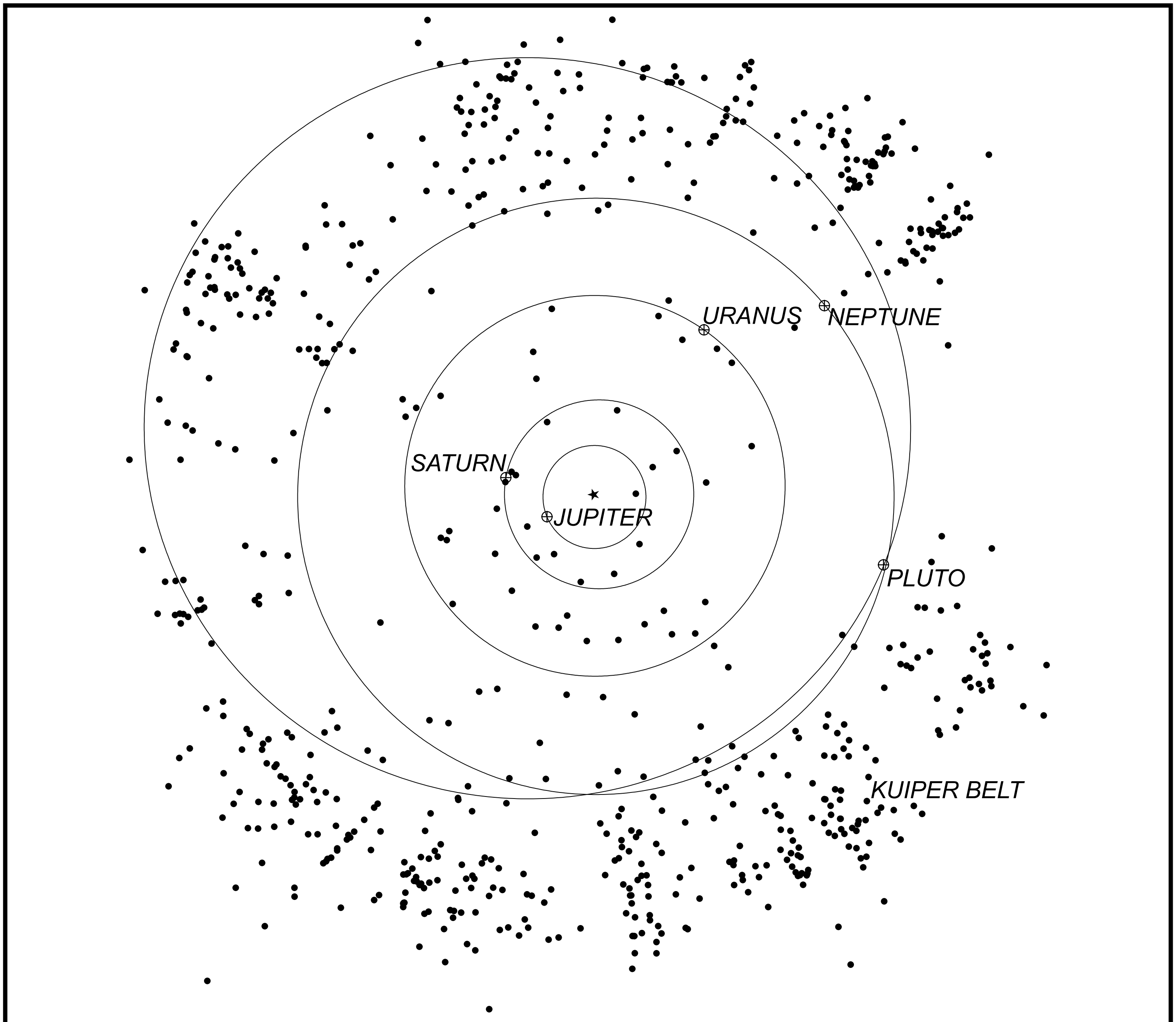
National Aeronautics and
Space Administration

February 2005

Draft Environmental Impact Statement for the New Horizons Mission



Cover graphic, *Map of the Outer Solar System*, courtesy of
Gareth V. Williams, Harvard-Smithsonian Center for Astrophysics.
Positions of the planets and Kuiper Belt Objects are shown as of June 2002.

DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE NEW HORIZONS MISSION

Science Mission Directorate
National Aeronautics and Space Administration
Washington, DC 20546

February 2005

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DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE NEW HORIZONS MISSION

ABSTRACT

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DATE:	February 2005

This Draft Environmental Impact Statement (DEIS) has been prepared by the National Aeronautics and Space Administration (NASA) in accordance with the National Environmental Policy Act (NEPA), as amended, to assist in the decisionmaking process for the New Horizons mission to Pluto.

The Proposed Action addressed in this DEIS is to continue preparations for and implement the New Horizons mission to explore Pluto and potentially the recently-discovered Kuiper Belt. The New Horizons spacecraft would be launched on an expendable launch vehicle in January – February 2006 from Cape Canaveral Air Force Station, Florida. With a launch in mid January 2006, the spacecraft would arrive at Pluto in 2015 to conduct scientific investigations of Pluto and its moon, Charon, as it flies past each body. After completing its investigations of Pluto and Charon, the spacecraft could continue into the Kuiper Belt on an extended mission to investigate one or more of the objects within the Kuiper Belt. The New Horizons mission would measure the fundamental physical and chemical properties of the Pluto-Charon system, and would make the first close observations of Kuiper Belt Objects, which are likely remnants of, and hold clues to, the early formation of the solar system.

This DEIS presents descriptions of the proposed New Horizons mission, spacecraft, and launch vehicle; an overview of the affected environment at and near the launch site; and the potential environmental consequences associated with the Proposed Action and the No Action Alternative.

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EXECUTIVE SUMMARY

This Draft Environmental Impact Statement (DEIS) for the New Horizons mission has been prepared in accordance with the National Environmental Policy Act of 1969 (NEPA), as amended (42 U.S.C. 4321 et seq.); Executive Order 12114, *Environmental Effects Abroad of Major Federal Actions*; the Council on Environmental Quality Regulations for Implementing the Procedural Provisions of NEPA (40 CFR parts 1500–1508); and the National Aeronautics and Space Administration's (NASA's) policy and procedures (14 CFR part 1216). The purpose of this DEIS is to assist in the decisionmaking process concerning the Proposed Action and the No Action Alternative for the New Horizons mission to Pluto.

The New Horizons mission is planned for launch in January – February 2006 from Cape Canaveral Air Force Station (CCAFS), Florida, on an expendable launch vehicle. With a launch in mid January 2006, the New Horizons spacecraft would receive a gravity assist from Jupiter in February 2007 and would arrive at Pluto as early as 2015. The spacecraft would conduct scientific investigations of Pluto and its moon, Charon, as it flies past these bodies. The spacecraft may then continue on an extended mission into the Kuiper Belt, where it would investigate one or more of the objects found there. The spacecraft would require electrical power for normal spacecraft operations and to operate the science instruments. One radioisotope thermoelectric generator (RTG) containing plutonium dioxide would be used for this purpose.

PURPOSE AND NEED FOR ACTION

The purpose of the action addressed in this DEIS is to further our knowledge of Pluto, the outermost known planet of our solar system, and its moon, Charon, and the Kuiper Belt. The goal of the New Horizons mission would be to measure the fundamental physical and chemical properties of Pluto and Charon. Specifically, the New Horizons mission would acquire data to address the following primary scientific objectives.

- Characterize the global geology and morphology of Pluto and Charon.
- Map the surface compositions of Pluto and Charon.
- Characterize the neutral (uncharged) atmosphere of Pluto and its rate of escape.

After the Pluto-Charon flyby and data playback is complete, the spacecraft could continue on an extended mission to encounter one or more objects within the Kuiper Belt. The remote science instrumentation planned for Pluto and Charon could also be used for investigations of the Kuiper Belt Objects (KBO).

Pluto is the only major body within our solar system that has not yet been visited by spacecraft. Many of the questions posed about Pluto and Charon can only be addressed by a spacecraft mission that brings advanced instruments close to the two bodies. Scientific knowledge of all other planets and their moons, and thus understanding of the nature of the solar system, has been increased enormously through visits by spacecraft.

The science to be performed at Pluto and Charon is time-critical because of long-term seasonal changes in the surfaces and atmospheres of both bodies. The objectives of surface mapping and surface composition mapping would be significantly compromised as Pluto and Charon recede from the Sun and their polar regions become increasingly hidden in shadow. Furthermore, as Pluto recedes from the Sun, substantial decline, if not complete collapse, of its atmosphere is widely anticipated.

The recent discovery of many objects beyond Neptune in the Kuiper Belt has opened another dimension for a mission of exploration. KBOs, in stable and well-defined orbits that have never taken them close to the Sun, are likely to be remnants of solar system formation and may hold clues to the birth of the planets. Knowledge gained from close examination of objects in the Kuiper Belt would be of great value in developing theoretical models of the evolution and destiny of the solar system.

ALTERNATIVES EVALUATED

This DEIS for the New Horizons mission evaluates the Proposed Action and the No Action Alternative.

- Proposed Action — NASA proposes to complete preparations for and implement the New Horizons mission to Pluto and its moon Charon, and the Kuiper Belt. NASA proposes to launch the New Horizons spacecraft from CCAFS, Florida, in January – February 2006 on board an Atlas V 551 expendable launch vehicle onto a trajectory towards Pluto. The New Horizons spacecraft would arrive at Pluto in 2015. The New Horizons spacecraft would remotely gather scientific data on Pluto, Charon, and one or more objects within the Kuiper Belt. A backup launch opportunity may exist in February 2007.
- No Action Alternative — Under this alternative, NASA would discontinue preparations for and not implement the New Horizons mission. There would be no reconnaissance of Pluto, Charon and KBOs during the timeframe of the Proposed Action. Potential science and data collection from the proposed mission would not be realized.

Alternatives to the Proposed Action that were considered but were not evaluated further include alternate power systems and alternate trajectories.

ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION AND THE NO ACTION ALTERNATIVE

For the New Horizons mission, the potentially affected environment includes the areas on or near the vicinity of the Atlas V launch site at CCAFS in Florida, and the global environment. The potential environmental consequences of the Atlas V launch vehicle have been addressed in prior U.S. Air Force (USAF) and NASA environmental documents, and are summarized below.

Environmental Impacts of the Mission

The environmental impacts of a normal launch of the New Horizons spacecraft for the Proposed Action would be associated principally with the exhaust emissions from the

Atlas V. These effects would include short-term impacts on air quality from the exhaust cloud at and near the launch pad, and the potential for acidic deposition on the vegetation and surface water bodies at and near the launch complex from the vehicle's solid rocket boosters. These effects would be transient and there would be no long-term impacts to the environment. Some short-term ozone degradation would occur along the flight path of the Atlas V as the vehicle passes through the stratosphere and deposits ozone-depleting chemicals (primarily hydrogen chloride) from its solid rocket boosters. These effects would be transient and no long-term impacts would be expected to the ozone layer (USAF 2000).

There would be no environmental impacts associated with the No Action Alternative.

Environmental Impacts of Potential Nonradiological Launch Accidents

Nonradiological accidents could occur during preparation for and launch of the New Horizons spacecraft at CCAFS. The two nonradiological accidents of principal concern would be a liquid propellant spill during fueling operations and a launch vehicle failure. Propellant spills or releases would be minimized through remotely operated actions that close applicable valves and safe the propellant loading system. Propellant loading would occur only shortly before launch, further minimizing the potential for accidents.

Range Safety at CCAFS uses models to predict launch hazards to the public and on-site personnel prior to a launch. These models calculate the risk of injury resulting from exposure to potentially toxic exhaust gases from normal launches, and from exposure to potentially toxic concentrations due to a failed launch. The launch could be postponed if the predicted collective risk of injury from exposure to toxic gases, blast overpressure or debris exceeds acceptable limits (USAF 1997).

A launch vehicle failure in or near the launch area during the first few seconds of flight could result in the release of the propellants onboard the Atlas V and the spacecraft. The resulting emissions from the combusted propellants would chemically resemble those from a normal launch. Debris would be expected to fall on or near the launch pad or into the Atlantic Ocean. Modeling of postulated accident consequences with meteorological parameters that would result in the greatest concentrations of emissions over land areas, reported in previous USAF environmental documentation (USAF 1998, USAF 2000), indicates that the emissions would not reach levels threatening public health.

Under the No Action Alternative, NASA would not complete preparations for and implement the New Horizons mission. The No Action Alternative would not involve any of the environmental impacts associated with potential launch-related accidents.

Environmental Impacts of Potential Radiological Launch Accidents

A principal concern associated with launch of the New Horizons spacecraft involves potential accidents that could result in release of some of the radioactive material onboard the spacecraft. The spacecraft would be electrically powered by one RTG containing plutonium dioxide (containing primarily plutonium-238).

The U.S. Department of Energy (DOE) prepared a nuclear risk assessment to support this DEIS. DOE's *Nuclear Risk Assessment for the New Horizons Mission*

Environmental Impact Statement (DOE 2005) was prepared in advance of the more detailed Final Safety Analysis Report (FSAR) being prepared in accordance with the formal launch approval process required by Presidential Directive/National Security Council Memorandum 25 (PD/NSC-25). The risk assessment is based on a combination of scaling the results of risk assessments for past missions (e.g., the Cassini and Mars Exploration Rover missions) on a per-curie inventory basis for specific accident configurations and environments, coupled with additional analyses where considered appropriate.

Several technical issues that could impact both the accident probabilities and consequences are under continuing evaluation as part of the FSAR. 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. Should the results to be reported in the FSAR differ significantly from those presented in this EIS, NASA would consider the new information and determine the need for additional environmental documentation.

The nuclear risk assessment for the New Horizons mission considers: (1) potential accidents associated with the launch, and their probabilities and accident environments; (2) the response of the RTG to such accidents in terms of the estimated amounts of radioactive material released (called source terms) and the release probabilities; and (3) the radiological consequences and risks associated with such releases.

Information on potential accidents and probabilities were developed by NASA based on information provided by the launch vehicle and third stage manufacturers and the spacecraft provider. DOE then assessed the response of the RTG to these accidents and estimated the amount of radioactive material that could be released. Finally, DOE determined the potential consequences of each release to the environment and to the potentially exposed population. Accidents were assessed over all mission launch phases, from pre-launch operations through Earth escape, and consequences were assessed for both the regional population near the launch site and the global population.

The risk assessment presented in this DEIS assumes a typical radioactive inventory of 132,500 curies. The plutonium dioxide 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 curies. A reduction in the assumed inventory from 132,500 curies would lead to an estimated proportional decrease in the reported results.

There are a range of accidents that have different probabilities of occurrence and consequences. For this summary, the following terminology has been adopted to categorize the range of probabilities of potential launch accidents that could lead to a release of plutonium dioxide:

- unlikely – probabilities ranging from 1 in 100 to 1 in 10 thousand;
- very unlikely – probabilities ranging from 1 in 10 thousand to 1 in 1 million; and,
- extremely unlikely – probabilities of less than 1 in 1 million.

Results of the risk assessment for this DEIS show that the most likely outcome of implementing the Proposed Action would be a successful launch with no release of radioactive materials. The risk assessment did, however, identify potential launch accidents that could result in a release of plutonium dioxide in the launch area, southern Africa following suborbital reentry, and other global locations following orbital reentry. However, in each of these regions an accident resulting in a release of plutonium dioxide is unlikely (i.e., the estimated probability of such an accident in each region ranges from 1 in 100 to 1 in 10 thousand, with the data and analysis of the risk assessment indicating mean probabilities on the order of 1 in several hundred for each region.) Accidents which could occur over the Atlantic Ocean or after the spacecraft escapes the Earth's gravity field would not result in a release of plutonium dioxide.

Very unlikely and extremely unlikely launch accidents were also assessed. These events were postulated for cases in which an accident occurs in the launch area and the safety systems fail to destroy the launch vehicle. Destruction of the vehicle by these safety systems would minimize potential damage to the RTG. Even though launch accidents in which these safety systems failed have not occurred in recent history, these types of extremely unlikely accidents (i.e., the estimated probability of an accident with a release is less than 1 in 1 million) are still being evaluated as a part of the detailed analysis for the FSAR. The mean probabilities of these events are estimated to range from 1 in 1.4 million to 1 in 18 million or less. These extremely unlikely accidents could, however, expose the RTG to severe accident environments, including mechanical damage, fragments, and solid propellant fires, which could result in greater damage to the RTG and potentially greater consequences.

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.

Discussion of Radiological Impacts

The radiological impacts or consequences for each postulated accident were calculated in terms of (1) impacts to individuals in terms of the maximum individual dose (the largest expected dose that any person could receive for a particular accident); (2) impacts to the exposed portion of the population in terms of the potential for additional latent cancer fatalities due to a radioactive release (i.e., cancer fatalities that are in excess of those latent cancer fatalities which the general population would normally experience from all causes over a long-term period following the release); and (3) impacts to the environment in terms of land area contaminated at or above specified levels.

Potential environmental contamination was evaluated in terms of areas exceeding various screening levels and dose-rate related criteria. For this EIS, land areas estimated to be contaminated above a screening level of 0.2 microcuries per square meter ($\mu Ci/m^2$) (used by NASA in the evaluations of previous missions) have been identified for the purpose of evaluating the need for potential characterization and cleanup. Costs associated with these efforts, should decontamination be required, could vary widely ($93 million to $520 million per square kilometer or about $241 million to $1.3 billion per square mile) depending upon the characteristics and size of the contaminated area.

These radiological consequences are described in terms of values indicative of a range represented by the mean and 99-percentile values derived from probability distributions. The 99-th percentile of the radiological consequences is the value predicted to be exceeded one 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.

The 99-th percentile consequences have been calculated for the group of accidents that could occur in and near the launch area; for those accidents that could occur beyond the launch area, during the pre-orbit and orbit portions of the mission; and for the overall mission. The estimated radiological consequences are summarized in Table ES-1 in terms of the mean and the 99-th percentile consequences.

TABLE ES-1. ESTIMATED RADIOLOGICAL CONSEQUENCES SUMMARIZED IN TERMS OF THE MEAN AND 99-TH PERCENTILE CONSEQUENCES

	Launch Area Accidents		**Accidents Beyond The Launch Area (Pre-Orbit)**		**Accidents Beyond The Launch Area (Orbit)**		**Overall Mission Accidents**	
	Mean	99-th	Mean	99-th	Mean	99-th	Mean	99-th
Probability of an Accident with a Release	1 in 620	1 in 62,000	1 in 1,300	1 in 130,000	1 in 1,100	1 in 110,000	1 in 300	1 in 30,000
Maximum Individual Dose, rem	0.7	7.1	0.1	0.8	0.4	2.5	0.3	4.3
Latent Cancer Fatalities	0.4	5.2	0.002	0.009	0.02	0.2	0.2	2.5
Land Contamination, square kilometers (square miles)	1.8 (0.7)	10.7 (4.1)	0.009 (0.003)	0.05 (0.02)	0.02 (0.008)	0.1 (0.04)	0.9 (0.3)	5.1 (2.0)

The launch area accident consequences are derived from a set of accident conditions that have a wide range of probabilities and consequences. The launch area accident mean consequences are dominated by an accident with releases in the unlikely probability category. Beyond the 99-th percentile consequence values reported above, there are other potential accidents with releases in the extremely unlikely category that could have higher consequences. The launch area accidents within these categories are discussed below.

Unlikely Launch Area Accidents

For most launch-related problems that could occur prior to launch, the most likely result would be a safe hold or termination of the launch countdown. After lift-off, most accidents would lead to activation of safety systems that would result in destruction of the launch vehicle. This would also include activation of the breakup system on the third stage solid rocket motor, resulting in the RTG or its components falling to the ground where they could be subject to mechanical damage and exposure to solid propellant fires. This unlikely situation, with an estimated probability of approximately 1 in 620, could result in a release of about 0.01 percent of the plutonium dioxide in the RTG (about 1 gram (0.035 ounce)).

The predicted radiological dose to the maximally exposed individual ranges from very small to less than 1 rem for the unlikely launch area accidents. No short-term radiological effects would be expected from any of these exposures. Each exposure would, however, increase the statistical likelihood of a cancer fatality over the long term.

Impact to a population group potentially exposed to a release (i.e., the exposed subset of the total population) following an accident is estimated by calculating the collective dose. Collective dose is the sum of the radiation dose received by all the individuals in the group exposed to a given release, and could lead to potential latent cancer fatalities among the group of exposed individuals following an accident. Any such cancer fatalities would not occur promptly upon exposure, but could occur over the long term.

For the unlikely accidents with a release which could occur in and near the launch area, as well as prior to and after the spacecraft achieves orbit, additional latent cancer fatalities would be small (i.e., a mean of 0.4) among the potentially exposed members of the local and global populations. This assumes no mitigation actions, such as sheltering and exclusion of people from contaminated land areas.

Results of the risk assessment indicate that the unlikely launch area accident, involving the intentional destruction of all launch vehicle stages freeing the RTG to fall to the ground, could result in less than two square kilometers (less than one square mile) potentially contaminated above the 0.2 $\mu Ci/m^2$ screening level.

Extremely Unlikely Launch Area Accidents

For extremely unlikely launch area accidents, the vehicle safety systems are assumed to fail. The probabilities of these types of accidents range from 1 in 1.4 million to 1 in 18 million or less, and could result in higher releases of plutonium dioxide (up to 2 percent of the RTG inventory) with the potential for higher consequences.

The maximally exposed individual could receive a dose of 10 to 50 rem following the more severe types of extremely unlikely accidents, such as ground impact of the entire launch vehicle. 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 dispersion modeling for such complicated accident situations. Assuming no mitigation actions, such as sheltering and exclusion of people from contaminated land areas, the potentially exposed members of the population could inhale enough material to result in about 100 additional cancer fatalities over the long term.

Results of the risk assessment also indicate that for the extremely unlikely accident that involves ground impact of the entire launch vehicle, nearly 300 square kilometers (about 115 square miles) of land area could be contaminated above the 0.2 $\mu Ci/m^2$ screening level. Contamination at this level could necessitate radiological surveys and potential mitigation and cleanup actions.

Considering both the unlikely and the extremely unlikely launch accidents assessed in this DEIS, both the maximally exposed member of the exposed population and the average individual within the exposed population face a less than 1 in 1 million chance of incurring a latent cancer due to a catastrophic failure of the New Horizons mission.

No Action Alternative

Under the No Action Alternative, NASA would not complete preparations for and implement the New Horizons mission. The No Action Alternative would not involve any of the radiological risks associated with potential launch accidents.

SCIENCE COMPARISON

The Proposed Action would complete NASA's reconnaissance of the known planets in our solar system, begun with Mariner 2 to Venus in 1962. The suite of instruments on the New Horizons spacecraft has been carefully selected to maximize collection of scientific data to meet the mission's objectives. Scientists would, for the first time, be able to closely examine the physical and chemical characteristics of Pluto, its moon Charon, and possibly other objects in the Kuiper Belt. These investigations of such primitive bodies could lead to fundamentally new insights into the formation and evolution of the solar system.

Under the No Action Alternative none of the science planned for the New Horizons mission to Pluto would be obtained.

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ABBREVIATIONS AND ACRONYMS

A

ac	acre(s)
AEC	U.S. Atomic Energy Commission
ADS	Automatic Destruct System
AIAA	American Institute of Aeronautics and Astronautics
AIHA	American Industrial Hygiene Association
Al_2O_3	aluminum oxide
ALICE	Ultraviolet (UV) Imaging Spectrometer
ALSEP	Apollo Lunar Surface Experiments Package
APL	Applied Physics Laboratory
Atlas V	Atlas V 551 Launch Vehicle
AU	astronomical unit(s)

B

BDM	biological defense mechanism
BEBR	Bureau of Economic and Business Research
BLS	U.S. Bureau of Labor and Statistics
BUS	Breakup System (third stage solid rocket motor)

C

$^{\circ}$C	degrees Celsius
C/A	closest approach
CAA	Clean Air Act
CADS	Centaur Automatic Destruct System
CAIB	Columbia Accident Investigation Board
CCAFS	Cape Canaveral Air Force Station
CDS	Command Destruct System
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
Ci	curie(s)
cm	centimeter(s)
Cm	curium
cm^3	cubic centimeter(s)
CO	carbon monoxide
CO_2	carbon dioxide
CSC	conical shaped charge

D

dBA	decibels (A-weighted)
DEIS	Draft Environmental Impact Statement
DHS	U.S. Department of Homeland Security
DOI	U.S. Department of the Interior
DOE	U.S. Department of Energy
DOD	U.S. Department of Defense
ΔV	Delta-V (change in velocity)
ΔVEGA	Delta-V Earth Gravity Assist

E

E	Endangered (species)
EA	Environmental Assessment
EFH	essential fish habitat
EIS	Environmental Impact Statement
EO	Executive Order
EPA	U.S. Environmental Protection Agency

F

°F	degrees Fahrenheit
FAA	Federal Aviation Administration
FDEP	Florida Department of Environmental Protection
FR	*Federal Register*
FSII	full stack intact impact
FSAR	Final Safety Analysis Report
ft	feet
ft/s	feet per second
FTS	Flight Termination System
FWS	U.S. Fish and Wildlife Service

G

g	gram(s)
gal	gallon(s)
GIS	graphite impact shell
GPHS	general purpose heat source
GSE	ground support equipment

H

H_2	hydrogen
H_2O	water
ha	hectare(s)
HCl	hydrogen chloride
HGA	high gain antenna
HHS	U.S. Department of Health and Human Services
HST	Hubble Space Telescope
HTPB	hydroxyl-terminated polybutadiene

I

IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
in	inch(s)
ISDS	Inadvertent Separation Destruct System
INSRP	Interagency Nuclear Safety Review Panel

J

JGA	Jupiter Gravity Assist

K

KBO	Kuiper Belt Object(s)
kg	kilogram(s)
km	kilometer(s)
km/hr	kilometers per hour
km^2	square kilometer(s)
KSC	Kennedy Space Center

L

l	liter(s)
lb	pound(s)
LDRRP	Low Dose Radiation Research Program
LEISA	Linear Etalon Imaging Spectral Array
LH_2	liquid hydrogen
LMMS	Lockheed Martin Missiles and Space
LNT	Linear, No-Threshold
LMILS	Lockheed Martin International Launch Services
LORRI	Long Range Reconnaissance Imager
LO_2	liquid oxygen

M

$\mu Ci/m^2$	microcurie(s) per square meter
$\mu g/m^3$	microgram(s) per cubic meter
m^3	cubic meter(s)
m	meter(s)
m/s	meters per second
MER	Mars Exploration Rovers

MFCO	Mission Flight Control Officer
mg/l	milligrams per liter
MHW	Multi-Hundred Watt
mi	mile(s)
MINWR	Merritt Island National Wildlife Refuge
MMRTG	Multi-Mission Radioisotope Thermoelectric Generator
mph	miles per hour
mrem	millirem(s)
mt	metric ton(s)
MVIC	Multispectral Visible Imaging Camera

N

N_2	nitrogen
N_2O	nitrous oxide
NA	not applicable
NAAQS	National Ambient Air Quality Standards
NASA	National Aeronautics and Space Administration
NCRP	National Council on Radiation Protection and Measurements
NEP	nuclear-electric propulsion
NEPA	National Environmental Policy Act
NLS	National Launch Services
NMFS	National Marine Fisheries Service
nmi	nautical mile(s)
NOAA	National Oceanic and Atmospheric Administration
NO_2	nitrogen dioxide
NO_X	oxides of nitrogen
NOA	Notice of Availability
NOI	Notice of Intent
NPS	National Park Service
NRC	National Research Council
NRHP	National Register of Historic Places
NRP	National Response Plan

O

O_3	ozone
oz	ounce(s)

P

PAF	payload attach fitting
PAFB	Patrick Air Force Base
Pb	lead
PEPSSI	Pluto Energetic Particle Spectrometer Science Investigation
PERSI	Pluto Exploration Remote Sensing Instrument
PHSF	Payload Hazardous Servicing Facility
PLF	payload fairing
$PM_{2.5}$	particulate matter less than 2.5 microns in diameter
PM_{10}	particulate matter less than 10 microns in diameter
ppm	parts per million
Pu	plutonium
PuO_2	plutonium dioxide

R

RADCC	Radiological Control Center
REX	Radio Science Experiment
RLSP	Request for Launch Services Proposal
RP-1	rocket propellant-1
RPS	radioisotope power system
RTG	radioisotope thermoelectric generator

S

S/A	Similarity of Appearance
s	second(s)

SC	spacecraft
SDC	Student Dust Counter
SEP	solar-electric propulsion
SFWMD	South Florida Water Management District
SJRWMD	St. Johns River Water Management District
SLC	space launch complex
SNAP	Systems for Nuclear Auxiliary Power
SO_2	sulfur dioxide
Sr	strontium
SRB	solid rocket booster
SRG	Stirling Radioisotope Generator
SRM	solid rocket motor
SSC	Species of Special Concern
Sv	sievert
SWAP	Solar Wind Around Pluto

T

T	time, mission elapsed; Threatened (species)

U

UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
USAF	U.S. Air Force
USBC	U.S. Bureau of the Census
U.S.C.	United States Code
UV	ultraviolet

V

VIF	Vertical Integration Facility

Y

yr	year

COMMON METRIC/BRITISH SYSTEM EQUIVALENTS

Length

1 centimeter (cm) = 0.3937 inch	1 inch = 2.54 cm
1 centimeter = 0.0328 foot (ft)	1 foot = 30.48 cm
1 meter (m) = 3.2808 feet	1 ft = 0.3048 m
1 meter = 0.0006 mile (mi)	1 mi = 1609.3440 m
1 kilometer (km) = 0.6214 mile	1 mi = 1.6093 km
1 kilometer = 0.53996 nautical mile (nmi)	1 nmi = 1.8520 km
	1 mi = 0.87 nmi
	1 nmi = 1.15 mi

Area

1 square centimeter (cm^2) = 0.1550 square inch (in^2)	1 in^2 = 6.4516 cm^2
1 square meter (m^2) = 10.7639 square feet (ft^2)	1 ft^2 = 0.09290 m^2
1 square kilometer (km^2) = 0.3861 square mile (mi^2)	1 mi^2 = 2.5900 km^2
1 hectare (ha) = 2.4710 acres (ac)	1 ac = 0.4047 ha
1 hectare (ha) = 10,000 square meters (m^2)	1 ft^2 = 0.000022957 ac

Volume

1 cubic centimeter (cm^3) = 0.0610 cubic inch (in^3)	1 in^3 = 16.3871 cm^3
1 cubic meter (m^3) = 35.3147 cubic feet (ft^3)	1 ft^3 = 0.0283 m^3
1 cubic meter (m^3) = 1.308 cubic yards (yd^3)	1 yd^3 = 0.76455 m^3
1 liter (l) = 1.0567 quarts (qt)	1 qt = 0.9463264 l
1 liter = 0.2642 gallon (gal)	1 gal = 3.7845 l
1 kiloliter (kl) = 264.2 gal	1 gal = 0.0038 kl

Weight

1 gram (g) = 0.0353 ounce (oz)	1 oz = 28.3495 g
1 kilogram (kg) = 2.2046 pounds (lb)	1 lb = 0.4536 kg
1 metric ton (mt) = 1.1023 tons	1 ton = 0.9072 metric ton

Energy

1 joule= 0.0009 British thermal unit (BTU)	1 BTU = 1054.18 joule
1 joule= 0.2392 gram-calorie (g-cal)	1 g-cal = 4.1819 joule

Pressure

1 newton/square meter (N/m^2) = 0.0208 pound/square foot (psf)	1 psf = 48 N/m^2

Force

1 newton (N) = 0.2248 pound-force (lbf)	1 lbf = 4.4478 N

Radiation

1 becquerel (Bq) = 2.703 x 10^{-11} curies (Ci)	1 Ci = 3.70 x 10^{10} Bq
1 sievert (Sv) = 100 rem	1 rem = 0.01 Sv

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1 PURPOSE AND NEED FOR THE ACTION

This Draft Environmental Impact Statement (DEIS) has been prepared by the National Aeronautics and Space Administration (NASA) to assist in the decisionmaking process as required by the National Environmental Policy Act of 1969 (NEPA), as amended (42 U.S.C. 4321 et seq.); Executive Order (EO) 12114, *Environmental Effects Abroad of Major Federal Actions*; Council on Environmental Quality Regulations (40 CFR parts 1500–1508); and NASA policies and procedures at 14 CFR part 1216. NASA solicited proposals for a Pluto-Kuiper Belt mission in an Announcement of Opportunity (AO 01-OSS-01) dated January 19, 2001. This DEIS provides information associated with potential environmental impacts of continuing preparations for and implementing the selected New Horizons mission, which would conduct scientific investigations of Pluto, its moon Charon, and possibly the Kuiper Belt. Launch of the New Horizons mission to Pluto is planned from Cape Canaveral Air Force Station (CCAFS), Florida, during the January – February 2006 opportunity, with a potential backup opportunity in February 2007. Chapter 2 of this DEIS evaluates the alternatives considered to achieve the New Horizons mission.

1.1 BACKGROUND

1.1.1 Pluto and Charon

Clyde W. Tombaugh discovered Pluto, the outermost known planet, in 1930, culminating a long photographic search. Many years previously, Percival Lowell had studied the slight differences between the observed and predicted motions of Uranus and Neptune, and had calculated where the unknown mass responsible for these effects might be found. Working at the Lowell Observatory in Arizona, Tombaugh located the elusive planet not very far from Lowell's predicted position.

Pluto differs drastically from the other four outer planets, which are gas giants. It is far smaller, made of a mixture of ice and rock, and orbits the Sun more slowly. Pluto's orbit is inclined by 17° to the plane of the other eight planets in the solar system (called the ecliptic plane). Its orbit is highly elliptical (elongated), with a perihelion (closest point to the Sun) of nearly 30 astronomical units[1] (AU) and aphelion (farthest point from the Sun) of nearly 50 AU. The uniqueness of its orbit, highly elliptical and not in the ecliptic plane, strongly suggests that Pluto was captured into its orbit at a later time than the other planets.

In 1978, James Christy of the U.S. Naval Observatory was studying photographic plates of Pluto, working on refining Pluto's orbit parameters. He noticed that Pluto appeared to have an irregularly shaped object attached to its side, and that the object seemed to move around Pluto. Charon, the moon of Pluto, was thus discovered and its existence confirmed when it was seen to eclipse Pluto every 6.4 days.

[1] One astronomical unit is the average radius of Earth's nearly circular orbit around the Sun, about 149.6 million kilometers (93 million miles).

During the period from 1985 through 1990, Pluto and Charon eclipsed each other on a daily basis as seen from Earth. These eclipses turned out to be very important, since observations of the eclipses led to the first accurate determination of Pluto's and Charon's sizes. As viewed from Earth, the brightness of the Pluto-Charon pair decreased during each eclipse because part of either Pluto or Charon is obscured. The larger the obscuring object, the longer the eclipse will last. From these observations it was determined that Charon is approximately 1,200 kilometers (745 miles) in diameter and Pluto is about 2,330 kilometers (1,448 miles). Thus, Charon is over half of Pluto's diameter, making it the largest satellite relative to its parent planet. The next closest pair in relative size is the Earth-Moon system.

Occasionally Pluto will cross in front of a reasonably bright star, an event called a stellar occultation. A significantly bright stellar occultation occurred in June 1988 and provided the first direct evidence of Pluto's atmosphere. For brief times at both the beginning and end of the occultation Pluto's atmosphere was backlit by the star. By carefully modeling the refractivity of the atmosphere (which depends on temperature and pressure), researchers determined that a large part of Pluto's middle atmosphere has a single temperature of about –173º Celsius (–280º Fahrenheit), and that there is either a temperature inversion or a haze layer near the surface (NRC 1998).

Recent images taken by the Hubble Space Telescope (HST) show Pluto to be an unusually complex object, with roughly 12 major regions, some bright and some dark. Earth is the only other object in the solar system that displays so much contrast. Topographic features such as basins or fresh impact craters may cause some of these variations. However, most of the surface features unveiled by HST, including the prominent northern polar cap, are likely produced by the complex distribution of frosts that are believed to migrate across Pluto's surface with its orbital and seasonal cycles, and photochemical by-products deposited out of Pluto's nitrogen-methane atmosphere. Dynamic changes in the atmosphere are believed to drive dynamic changes in surface appearance, particularly the size and distribution of bright and dark regions.

Earth-based observations show that Pluto's surface is covered with ices and relatively volatile (easily evaporated) compounds. Nitrogen is the dominant species with much less methane and a trace of carbon monoxide. Water has also been detected, but its relative abundance is currently unknown. Observations also indicate that considerable water is present on Charon; other volatile species are suspected but have not yet been detected.

1.1.2 The Kuiper Belt

Decades ago, Dutch astronomer Gerard Kuiper postulated that when the solar system formed from a vast dust cloud, a large collection of small pieces was left over. This "Kuiper Belt" of objects was believed to be largely confined within a few degrees of the ecliptic plane in a ring, or belt, lying beyond Neptune. The first Kuiper Belt Objects (KBO) were discovered in 1992 by D.C. Jewitt and J.X. Luu (NRC 1998). On the order of 1,000 objects have been discovered to date, about two-thirds of which have reliably determined orbits (Millis 2003). Tens of thousands of KBOs on the order of 100 kilometers (62 miles) in diameter, and millions to billions of smaller objects, are thought to exist in the radial zone extending outward from 30 AU (the orbit of Neptune) to at least 55 AU. KBOs are presently being discovered at a rate of 20 to 30 per month. Some KBOs have been observed within the orbit of Neptune; these are believed to have been deflected into highly elliptical planet-crossing orbits due to gravitational perturbations caused by Neptune.

Spectroscopic measurements of a small subset of KBOs show that they have diverse colors and, presumably, surface compositions. KBOs are believed to be a representative sample of the primordial material that condensed into the solar system (NRC 1998). Most if not all KBOs are believed to have spent their entire history far from the Sun in a deep freeze. Little or no opportunity has occurred for their lighter components to have been vaporized and driven off by the Sun's heat. Therefore, great interest exists in knowing their composition because it is believed to represent the starting composition from which the solar system evolved over the past 4 billion years.

1.2 PURPOSE OF THE ACTION

The purpose of the action addressed in this DEIS is to further our knowledge of Pluto, the outermost known planet of our solar system, and its moon, Charon. The goal of the proposed Pluto-Kuiper Belt mission would be to measure the fundamental physical and chemical properties of the Pluto-Charon system. Specifically, the Pluto-Kuiper Belt mission would acquire remote sensing and radio occultation data to address the following scientific objectives. The first three science objectives on this list were identified as having considerably higher priority than the remainder. The Announcement of Opportunity specified that any selected mission must address these three objectives as a minimum condition.

- Characterize the global geology and morphology of Pluto and Charon.
- Map the surface composition of Pluto and Charon.
- Characterize the neutral (uncharged) atmosphere of Pluto and its rate of escape.
- Characterize the time variability of Pluto's surface and atmosphere.
- Acquire stereo images of Pluto and Charon.
- Map the day/night terminators of Pluto and Charon with high resolution.
- Map the surface compositions of selected areas of Pluto and Charon with high resolution.
- Characterize Pluto's ionosphere and its interactions with the solar wind.
- Search for hydrogen, cyanide, other neutral chemical species, hydrocarbons, and nitriles in Pluto's upper atmosphere.
- Search for an atmosphere around Charon.
- Determine the albedos (reflected brightness) of Pluto and Charon.
- Map the surface temperatures of Pluto and Charon.
- Characterize the energetic particle environment of the Pluto-Charon system.

- Refine physical parameters such as radius, mass, and density of Pluto and Charon.
- Refine the orbit parameters of Pluto and Charon.
- Search for magnetic fields.
- Search for additional satellites and rings.

The suite of science instruments onboard the Pluto-Kuiper Belt spacecraft has been carefully selected to obtain measurements which will address these objectives.

After completion of the Pluto-Charon flyby and return of the collected science data, the spacecraft could continue on an extended mission to encounter and study one or more objects within the Kuiper Belt. The remote science instrumentation planned for Pluto and Charon would also be used for investigations of these objects.

In addition, scientists selected by NASA for participation in the Pluto-Kuiper Belt mission would actively contribute to NASA's goals for the improvement of science education and the public understanding of science.

1.3 NEED FOR THE ACTION

Orbiting at the outer edge of the solar system and just within the Kuiper Belt, Pluto and Charon hold chemical clues to the conditions at the boundary between the protoplanetary disk (the flat, spinning disk of gas and dust which condensed and aggregated into the planets) and the larger molecular cloud from which the disk formed. These chemical clues are likely to be at least partially preserved in the molecular composition of the ices on Pluto and Charon, which have never been exposed to the higher temperatures and solar radiation levels experienced by the other planets. Pluto's large size and brightness relative to other icy bodies has made it (barely) accessible to studies from Earth. Results of these studies indicate that it possesses a surface containing frosts of very volatile species that also occur in comets and are confirmed or suspected to be present in interstellar molecular clouds. The density of Pluto is consistent with a mixture of rock and ice that is close to the value predicted for primitive solar system material.

Pluto is known to have an atmosphere unique in the solar system. The atmosphere is thought to be transient and will collapse and condense on the surface as Pluto continues to retreat and cool from its 1989 closest approach to the Sun. Pluto's low gravity means that the atmosphere must be escaping the planet at a relatively rapid rate, making it intermediate in stability between the tenuous atmospheres (gaseous tails) of comets and the more stable atmospheres of larger planets.

What is known of Pluto is enough to make this smallest planet intriguing, but much remains unknown. How the ices are distributed across Pluto's surface or how impacts from collisions with smaller KBOs, for example, and geologic events have shaped its surface are unknown. Small amounts of many chemical species undoubtedly exist on the surface beyond those already detected. The nature of the dark material on Pluto is unknown, in particular whether it is simply silicates or organic material processed by cosmic rays or sunlight. The structure of the atmosphere is only inferentially understood, and available models only hint at its composition and dynamics. How the atmosphere will actually respond to the decrease in solar illumination as Pluto recedes from the Sun is unknown. Pluto is suspected to not have a significant magnetic field. Even a small magnetization would suffice to deflect the solar wind, which to some extent would help preserve the atmosphere. However, if such a magnetic field is not present, the inferred rates at which the atmosphere is escaping suggest a comet-like interaction with the solar wind, an interaction that would be unique for a planet in the solar system.

Far less is known about Charon, including its origin, surface appearance, compositional relationship to Pluto. The surfaces of both Pluto and Charon might show the scars of their early history in terms of craters and tectonics induced by impacts or tides, but we cannot tell without high resolution imagery. The close correspondence in the sizes of Pluto and Charon is also a mystery. There are large and scientifically tantalizing differences between these two objects orbiting each other in close proximity. Charon appears to have no measurable atmosphere, no methane or carbon monoxide, but much more water than Pluto.

Many of the questions posed about Pluto and Charon can only be addressed by a spacecraft mission that brings advanced instruments close to the two bodies. Scientific knowledge of all other planets and their moons, and thus understanding of the nature of the solar system, has been increased enormously through visits by spacecraft. The Pluto-Charon system remains the last unvisited planetary sized set of objects in the solar system.

The science to be performed at Pluto and Charon is time-critical because of long-term seasonal changes in the surfaces and atmospheres of both bodies. The objectives of surface mapping and surface composition mapping would be significantly compromised if the spacecraft does not arrive at the Pluto-Charon system before this system recedes too far from the Sun. As one polar region on each object becomes increasingly hidden in shadow, these polar regions would be lost to imaging and spectroscopic measurements, thus limiting the amount of global geology and composition mapping that could be achieved. 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 could be lost if the atmosphere collapses or significantly declines before the spacecraft's arrival. The search for an atmosphere around Charon would also be adversely affected, or completely lost, as would the opportunity to detect and study any atmospheric transfer between Pluto and Charon, a phenomenon which could be unique in the solar system (NRC 2003).

The recent discovery of the Kuiper Belt beyond Neptune has opened another dimension for a mission of exploration. KBOs, in stable and well-defined orbits that have never taken them close to the Sun, are likely to be remnants of solar system formation and hold many clues to the birth of the planets. A mission extension beyond Pluto to visit one or more of these objects would be an extraordinary complement to a Pluto-Charon flyby, such that the whole suite of outermost primitive bodies from comet-sized objects to planets will have been visited and studied by remote sensing instruments. It may be possible to conduct a systematic search and inventory of KBOs near the spacecraft's flight path to count and characterize bodies smaller than those that can be observed from Earth. Knowledge of the size and mass distribution of objects in the Kuiper Belt would be of great value in developing theoretical models of the evolution and destiny of the solar system.

1.4 NEPA PLANNING AND SCOPING ACTIVITIES

On October 7, 1998, NASA published a Notice of Intent (NOI) in the *Federal Register* (63 FR 53938) to prepare an Environmental Impact Statement and conduct scoping for the Pluto-Kuiper Express mission. The scoping period closed on November 23, 1998 but was reopened and extended until December 18, 1998. Comments were solicited from Federal, State and local organizations, and interested parties on the scope of the EIS. Scoping comments were received from one Federal Agency, one Florida County Agency, one private organization, and ten individuals.

Since publication of the NOI, NASA prepared further evaluations of the mission design, including the alternatives indicated in the NOI. These evaluations have resulted in refinement of NASA's original baseline plan for the mission, specifically with respect to details such as specific launch dates, launch vehicle options, and the possible use of a new radioisotope power system (RPS) for spacecraft power.

An Information Update was published in the *Federal Register* on June 10, 2002 (67 FR 39748) to keep the public informed of the evolving planning for a science mission to Pluto and the Kuiper Belt. The New Horizons mission, selected through a competitive process, is now proposed for launch in January – February 2006. The spacecraft would be launched on an expendable launch vehicle from Cape Canaveral Air Force Station, Florida. NASA's original baseline plan was modified to propose the use of a conventional radioisotope thermoelectric generator (RTG) instead of the RPS originally envisioned. The earlier Pluto-Kuiper Express mission also included several radioisotope heater units to maintain the temperature within the spacecraft. A conventional RTG would generate a greater amount of heat than a RPS. A combination of excess heat from the RTG, heat generated from electronics, heat from electrical heaters, and insulation would be utilized to maintain the thermal environment of the New Horizons spacecraft and would eliminate the need to carry radioisotope heater units, as originally envisioned.

The Information Update also reopened the scoping period, which closed on July 25, 2002. Comments were solicited from Federal, State and local organizations, and interested parties on the scope of the EIS. Scoping comments were received from 12 private organizations and 67 individuals. One of these organizations and three of these individuals had submitted comments in response to the original scoping period. Issues raised in the scoping comments included: (1) concern with the use of radioactive material for the spacecraft electrical power source; (2) use of alternative (radioactive and non- radioactive) sources for electrical power; (3) impacts to air quality due to launch vehicle exhaust; (4) global impacts in the event of a launch accident; and (5) concerns with the manufacturing and handling of the RTG.

Issues 1, 2, 3, and 4 are addressed in this DEIS. Issues 1, 3, and 4 are summarized in Chapter 2 and discussed more thoroughly in Chapter 4. Issue 2 is addressed in Chapter 2. Comments associated with issue 5 have been addressed in existing environmental documentation prepared by the U.S. Department of Energy (DOE 1991, DOE 1999, DOE 2002b), which is responsible for the manufacturing and handling of RTGs.

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