Draft

Programmatic Environmental Assessment of Launches Involving Radioisotope Heater Units (RHUs)

Prepared for

National Aeronautics and Space Administration
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Contents

Appendixes

Tables

Figures

Acronyms and Abbreviations

45 SW	45th Space Wing
AFI	Air Force Instruction
AFMAN	Air Force Manual
AFSPC	Air Force Space Command
CCAFS	Cape Canaveral Air Force Station
CEQ	Council on Environmental Quality
CFR	*Code of Federal Regulations*
CNS	Cape Canaveral National Seashore
CZMA	Coastal Zone Management Act
DHS	U.S. Department of Homeland Security
DOE	U.S. Department of Energy
DSA	Documented Safety Analysis
EA	environmental assessment
EELV	evolved expendable launch vehicle
EIS	environmental impact statement
EO	Executive Order
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FAA	Federal Aviation Administration
FDEP	Florida Department of Environmental Protection
FONSI	finding of no significant impact
HPO	Historic Preservation Officer
IAEA	International Atomic Energy Agency
ICRMP	Integrated Cultural Resource Management Plan
ICRP	International Commission on Radiological Protection
INL	Idaho National Laboratory
ISCORS	Interagency Steering Committee on Radiation Standards
JPL	Jet Propulsion Laboratory
km	kilometer(s)
KSC	Kennedy Space Center
LC	launch complex
LSP	Launch Services Program
LWRHU	light-weight radioisotope heater unit
MBTA	Migratory Bird Treaty Act
MER	Mars Exploration Rover
MINWR	Merritt Island National Wildlife Refuge
MSL	Mars Science Laboratory
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NLSA	Nuclear Launch Safety Approval
NMFS	National Marine Fisheries Service
No.	number
NPD	NASA Policy Directive
NPR	NASA Procedural Requirement
NPS	National Park Service
NRA	nuclear risk assessment

NRC	Nuclear Regulatory Commission
NRHP	National Register of Historic Places
NSC	National Security Council
PEA	programmatic environmental assessment
Pu	plutonium
RADCC	Radiological Control Center
REC	Record of Environmental Consideration
rem	Roentgen Equivalent Man
RHU	radioisotope heater unit
ROD	record of decision
RPS	radioisotope power system
RTG	radioisotope thermoelectric generator
SHPO	State Historic Preservation Office
SMD	Science Mission Directorate
U	uranium
U.S.	United States
U.S.C.	United States Code
USAF	U.S. Air Force
USFWS	U.S. Fish and Wildlife Service
VAFB	Vandenburg Air Force Base

SECTION 1

Purpose and Need for the Proposed Action

1.1 Introduction

The National Aeronautics and Space Administration (NASA) is proposing to programmatically address the use of radioisotope heater units (RHUs) in spacecraft launched from Kennedy Space Center (KSC) and Cape Canaveral Air Force Station (CCAFS) in Brevard County, Florida. The need for RHUs in NASA missions is expected to increase as NASA expands its missions to the Moon and Mars. Consequently, NASA is pursuing a programmatic approach to RHU analysis, which provides a principal assessment compliant with the National Environmental Policy Act (NEPA) and could be applied each time an RHU is used in a space mission, if certain parameters are met. This approach is being taken in response to the Council on Environmental Quality's (CEQ's) Regulations for Implementing the Procedural Provisions of NEPA, specifically, Title 40 *Code of Federal Regulation*s (CFR) Section 1500.4(i) and 40 CFR Section 1501.4(c).

> **40 CFR 1500.4(i) requires agencies to find efficiencies in producing NEPA documents.**
> (i) Using program, policy, or plan environmental impact statements and tiering from statements of broad scope to those of narrower scope, to eliminate repetitive discussions of the same issues.
>
> **40 CFR 1501.4(c) directs agencies to consider the use of an environmental assessment to determine whether there is a significant impact associated with a proposed action and whether an environmental impact statement (EIS) is warranted.**
> (c) Based on the environmental assessment make its determination whether to prepare an environmental impact statement.

NASA is the lead federal agency for this action, while the U.S. Department of Energy (DOE), the U.S. Air Force (USAF), and the Federal Aviation Administration (FAA) are cooperating agencies on this Programmatic Environmental Assessment (PEA). The DOE's cooperating agency role stems from its responsibility in developing and producing special nuclear material and nuclear power systems, including RHUs, used by NASA. The USAF is a cooperating agency because it manages the launch facilities at CCAFS and has expertise in launches using RHUs. The FAA is serving as a cooperating agency based on their special expertise with respect to environmental issues for space launch and reentry vehicle operations and because of the potential for commercial space vehicle operators to apply for a license for launches or reentries involving RHUs[1]. The FAA's Office of Commercial Space Transportation regulates the U.S. commercial space transportation industry and is required to analyze the potential environmental impacts of proposed licensed and permitted actions, including the licensing of launch and reentry activities, the operation of the launch and reentry sites, and the issuing of permits for suborbital reusable rockets. At this time, FAA-licensed commercial missions using RHUs are not anticipated; however, if that changes in the future, the FAA could tier from this PEA[2].

1.2 Background

Radioisotope heater units have been used in U.S. space missions since 1961. Missions into deep space and extended missions to distant planetary surfaces use RHUs for heat due to the functional limitations of solar heat and the limited life capabilities of electrical heat from batteries. The U.S. has launched hundreds of RHUs in support of missions spanning over 50 years. Accordingly, RHU technology is established in the space industry and has been refined based on decades of experience and demonstrated successes.

A few notable space missions that used RHUs, include the following:

[1] https://www.faa.gov/about/office_org/headquarters_offices/ast/licenses_permits/launch_reentry/

[2] 40 CFR 1502.20 and 1508.28; Paragraph 3-2, FAA Order 1050.1F, *Environmental Impacts: Policies and Procedures*.

- The Cassini mission sent a probe to study Saturn and its system, including its rings and moons. After 20 years of exploration, Cassini exhausted its liquid propellant fuel supply.
- The Mars Pathfinder Sojourner Rover was designed to demonstrate the technology necessary to deliver a lander and robotic rover to the surface of Mars. The lander and the rover both greatly exceeded their design lives and returned more than 2.3 trillion bits of information about Mars to Earth, including thousands of photographs.
- The Galileo mission studied Jupiter and its moons. The Galileo mission made notable discoveries, including evidence of a saltwater ocean on the moon Europa. It also was the first spacecraft to visit an asteroid.
- The Mars Exploration Rovers (MER),Spirit and Opportunity, explored and collected data on the surface of Mars including evidence of past water activity. Both rovers exceeded their planned 90-day mission lifetimes by many years. Spirit's mission ended in 2010 and Opportunity in 2018.

NASA's Science Mission Directorate (SMD) is responsible for providing a broad portfolio of mission capabilities, including RHUs, for NASA to achieve its current and future mission needs. Under SMD's Planetary Science Division, the Radioisotope Power System (RPS) Program Office collaborates with the DOE on nuclear technologies that maintain NASA's current space science capabilities and aid in future space exploration missions.

When employing RHUs on a spacecraft, the current strategy is to:

- Design and build safety into the RHU application at the outset.
- Demonstrate the safety of the RHU application through rigorous analysis.
- Assess the level of risk for each proposed RHU application for use in decision making and approval processes.
- Accomplish this approach through the Nuclear Launch Safety Approval (NLSA) process, per NASA Procedural Requirement (NPR) 8715.3 (NASA, 2017a).

1.3 Purpose and Need for the Proposed Action

The National Aeronautics and Space Act of 1958 establishes a mandate to conduct activities in space that contribute substantially to the expansion of human knowledge of the Earth and phenomena in the atmosphere and space and to preserve the role of the United States as a leader in aeronautical and space science and technology. In response to this mandate, NASA's mission is to 1) lead an innovative and sustainable program of exploration to enable human expansion across the solar system and bring new knowledge and opportunities back to Earth, 2) support the growth of the Nation's economy in space and aeronautics, 3) increase our understanding of the universe and our place in it, 4) work with industry to improve America's aerospace technologies, and 5) advance American leadership (NASA, 2018a). To meet its mission and the mandates of the National Aeronautics and Space Act, NASA must be able to launch spacecraft into the Earth's orbit, near Earth, and deep space.

One of the most important technical challenges in space exploration is efficiently keeping spacecraft warm in environments that are far away, or blocked, from the heat of the Sun. Some spacecraft can use solar energy to keep their structures, systems, and instruments warm and running effectively. However, when spacecraft are operating in the hardest to reach, darkest, and coldest locations in our solar system, solar power is not an option. For example, solar heating is ineffective when operating at an extreme distance from the Sun or in locations with extreme temperatures and intense radiation; high amounts of clouds or dust; or long durations of shadows or lack of sunlight, such as the surface of the Moon, a subsurface ocean, or in a cave on a rocky body. Also, depending on the specific mission need, solar power may not be adequate to meet all needs. For these reasons, an alternate heat source is needed for spacecraft operating in these conditions. The heat from the natural decay of radionuclides is a well-tested and efficient technology for keeping spacecraft structures, systems, and instruments, at the necessary operating temperatures in deep space, independent of solar availability. Consequently, NASA needs to be able to use radioisotope heating technology, otherwise known as RHUs, in its exploration missions.

As noted in Section 1.1, the FAA has a potential action of issuing launch or reentry licenses involving RHUs to commercial space vehicle operators. The FAA's purpose of issuing licenses is to fulfill the FAA's responsibilities as authorized by chapter 509 of Title 51 of the U.S. Code for oversight of commercial space launch activities, including licensing launch activities. The need for FAA's action results from the statutory direction from Congress under the U.S. Commercial Space Launch Competitiveness Act of 2015 to, in part, "promote commercial space launches and reentries by the private sector; facilitate Government, State, and private sector involvement in enhancing U.S. launch sites and facilities; and protect public health and safety, safety of property, national security interests, and foreign policy interests of the United States." Pub. L. 114-90, § 113(b). Additionally, Congress has determined the Federal Government is to "facilitate the strengthening and expansion of the United States space transportation infrastructure, including the enhancement of United States launch sites and launch-site support facilities, and development of reentry sites, with Government, State, and private sector involvement, to support the full range of United States space-related activities." 51 U.S.C. § 50901(b)(4). Since the FAA has jurisdiction over commercial space activities and licensing, the FAA has a need to environmentally analyze the use of RHUs in commercial space activities.

1.4 Use and Organization of this PEA

This PEA was prepared in compliance with NASA's obligations under NEPA, the CEQ's Regulations for Implementing the Procedural Provisions of NEPA (40 CFR Parts 1500 through 1508), the procedures for NASA to implement NEPA and CEQ regulations (14 CFR Section 1216.3), and FAA Order 1050.1F, *Environmental Impacts: Policies and Procedures*. To reduce unnecessary paperwork, CEQ NEPA regulations encourage federal agencies to analyze the potential environmental impacts of similar actions in a single programmatic document (40 CFR Section 1500.4). A programmatic document is a type of general, broad NEPA review from which subsequent NEPA documents can be tiered, focusing on the issues specific to the subsequent action. Programmatic NEPA documents may be prepared for broad federal actions, such as a proposed program, policy, plan, or suite of projects, which address actions occurring over large areas or systems and may include groupings of similar actions or repeating actions over longer periods of time than other NEPA reviews. In response to this directive, NASA has prepared this PEA to provide an efficient analysis under NEPA for the application of RHU technology in future space flights.

To apply this PEA to a future action, the activity must fall within the bounds described in Section 2.1, *Proposed Action*. It is the responsibility of the program executive to ensure that the mission is within the bounds of this PEA. If a future mission is determined to be within these requirements, the finding would be documented in a Record of Environmental Consideration (REC), citing this PEA in accordance with NEPA's procedures and guidance for NASA (14 CFR Section 1216.3). The REC will show that the mission meets the parameters outlined in Section 2.1. The RECs will be published on the NASA NEPA website to maintain NASA's commitment to inform the public of NEPA decisions. Cooperating agencies may tier from this PEA utilizing their agency-specific NEPA documentation procedures. For future missions requiring FAA review, if a mission is determined to be within these requirements, the finding would be documented in a project-specific environmental document, written re-evaluation or supplemental EA, as appropriate according to FAA Order 1501.1F.

If a future mission is found to be outside the prescribed bounds described herein, additional analysis and/or NEPA documentation would be necessary for that action. Because a NEPA analysis is conducted very early in mission planning, the number of RHUs needed for a mission could change after the REC is prepared. If the number of RHUs were to increase beyond the parameters set within this PEA, additional analysis and/or NEPA documentation would be conducted.

This PEA does not supersede previous NEPA documents. Furthermore, this PEA will be subject to periodic review to remain current with relevant rules, regulations, scientific findings, space technologies, available launch vehicles and sites, and the evolving requirements of NASA's space research program. If substantial changes are necessary, either a supplemental document or a new PEA will be issued.

1.4.1 Organization of the PEA

This PEA is organized as follows:

- **Section 1: Purpose and Need for the Proposed Action**, provides background information about the Proposed Action, the purpose and need for the Proposed Action, and a brief description of how the document is organized.
- **Section 2: Description of the Proposed Action and Alternatives**, presents detailed descriptions of the Proposed Action and the No Action Alternative.
- **Section 3: Affected Environment and Environmental Consequences**, provides a description of the existing conditions of the environmental resources potentially affected by the No Action Alternative and the Proposed Action and presents an analysis of potential direct, indirect, and cumulative impacts to environmental resources resulting from the No Action Alternative and the Proposed Action.
- **Section 4: Summary of Impacts**, describes the potential impacts associated with the Proposed Action and the measures that would be implemented to avoid or minimize those impacts.
- **Section 5: Consultation and Coordination**, provides a list of agencies and individuals who were contacted for information in the preparation of this document and to whom the PEA will be distributed.
- **Section 6: List of Preparers**, provides a list of the names and qualifications of the document preparers.
- **Section 7: References**, lists the references used in preparing this PEA.

1.4.2 Public Outreach and Involvement

The Notice of Availability of the Draft PEA was advertised in the *Florida Today* newspaper on September 8, 2019. Public comments will be accepted through October 9, 2019. Copies of the Draft PEA were also provided to the public at the following library locations:

- Central Brevard Library and Reference Center, 308 Forrest Ave, Cocoa, FL 32922
- Cocoa Beach Public Library, 550 N Brevard Ave, Cocoa Beach, FL 32931
- Melbourne Library, 540 E Fee Ave, Melbourne, FL 32901
- Merritt Island Public Library, 1195 N Courtenay Pkwy, Merritt Island, FL 32953
- Port St John Public Library, 6500 Carole Ave, Cocoa, FL 32927
- Titusville Public Library, 2121 S Hopkins Ave, Titusville, FL 32780
- Satellite Beach Public Library 751 Jamaica Blvd, Satellite Beach, FL 32937

The Notice of Availability and PEA will also be posted on the NASA NEPA Library on the public portal maintained by the NASA Environmental Management Division at NASA Headquarters (https://www.nasa.gov/content/public-reviews).

SECTION 2

Description of the Proposed Action and Alternatives

This section identifies and describes the Proposed Action and No Action Alternative.

2.1 Proposed Action

Under the Proposed Action, NASA would continue to use RHUs in its space missions when the use of solar or other technologies would be infeasible or when the use of an RHU would enhance the ability of a mission to meet its science goals. For a mission to fall under the scope of this PEA, it must fall within the following parameters. If a future mission falls outside these parameters, an additional analysis and/or NEPA documentation would be required.

- Only RHUs are included in this analysis. Other space nuclear power systems, such as radioisotope thermoelectric generators (RTGs), are not included. The current RHU configuration is described in detail in Section 2.1.1, *RHU Technology Description*.
- This PEA covers missions using up to 130 RHUs or 351 grams of Pu-238 oxide (further referred to as Pu-238) per launch. The rationale for this limitation is explained in Section 2.1.2, *Number of RHUs*.
- Only the CCAFS and KSC launch complexes (LCs) may be used. Historically, spacecraft containing RHUs have launched from these facilities, and the facilities have the capabilities and infrastructure in place to respond to potential incidents. These launch locations are described in detail in Section 2.1.3, *Launch Locations*.
- Only launch vehicles that have been fully analyzed through the NASA NEPA process and have undergone the NASA launch approval process per NASA Policy Directives (NPDs) 8610.7D, 8610.23C, and 8610.24C and NPR 8705.4 are included in this analysis. Future launch vehicles that meet NEPA and launch approval requirements would also be covered in this analysis. These requirements are described in Section 2.1.4, *Launch Vehicles and Approval.*
- All potential NASA near-Earth and deep space missions meeting the preceding requirements are included in this PEA. These activities are further defined in Section 2.1.5, *Mission Types.*

As mentioned in Section 1.1, the FAA may have a future proposed action of issuing launch or reentry licenses involving RHUs to commercial space vehicle operators. At this time, there are no pending license applications for commercial missions using RHU currently being reviewed by FAA for license applications; however, if that changes in the future, the FAA could tier from this PEA.

2.1.1 RHU Technology Description

RHUs are small devices that use the natural decay of Pu-238 to provide thermal energy, which is used to heat electronics. RHUs are generally placed close to the equipment needing heat, though more sophisticated thermal designs based on pipes and thermal conductors that transfer heat by conduction may also be employed. The heat is transferred to spacecraft structures, systems, and instruments by direct radiant energy, without moving parts or electronic components. Consequently, RHUs are among the simplest of space nuclear devices.

By using RHUs, the spacecraft designer can allocate critical electrical power to the spacecraft's systems and instruments instead of heating. RHUs also provide the benefit of reducing electromagnetic interference with instruments or electronics that might be generated by electrical current heating systems.

RHUs have the following characteristics (NASA, 2014a):

- Highly reliable, continuous, and predictable output of heat
- No moving parts
- Compact structure
- Resistant to radiation and meteorite damage
- Heat produced is independent of the distance from the Sun

The current generation of RHUs are referred to as light-weight radioisotope heating units (LWRHUs) and have heated deep space missions since the 1980s; though RHUs in other forms have been used since the 1960s[3]. A LWRHU contains a fuel pellet, about the size of a pencil eraser, which consists of 2.7 grams of Pu-238 oxide. The entire LWRHU is approximately the size of a C-cell battery (Figure 2-1) and outputs about 1 watt of heat.

Figure 2-1. Components of an RHU

LWRHUs were designed to withstand the potential accidents of a wide range of space missions without the release of Pu-238 by including multiple layers of protection. The outer-most layer of protection is composed of fine-weave, pierced fabric carbon-carbon composite material. This material provides the primary protection to the metal capsule against impacts or overpressures resulting from explosions or accidental reentry. Three layers of pyrolytic graphitic insulators provide thermal protection that limits the heating of the metal capsule containing the fuel pellet in events such as fires and accidental reentry.

The inner-most level of protection is the platinum-rhodium metal encapsulation. The completely welded capsule serves to minimize the dispersal of the fuel pellet or pieces of the fuel pellet in an impact accident. The platinum-rhodium alloy is a high temperature, oxidation-resistant alloy that is intended to deform but not fail during extreme impact accidents.

Finally, the hot-pressed ceramic fuel pellet ensures the Pu-238 is in its most stable form to meet application needs and to minimize risk in the event of an accident. The fuel pellet has the highest melting point of all the materials used in the LWRHU. It is resistant to fracture and breaks into pieces instead of a fine dust during extreme impacts, thereby limiting the potential airborne release of Pu-238 (Tate, 1982). The design also includes a vent feature that allows helium gas released from the fuel pellet to escape during thermal events.

2.1.2 Number of RHUs

The number of RHUs used in a mission depends on the purpose and destination of the spacecraft. Previous RHU requirements have ranged from 2 to 120 RHUs. RHUs have flown on NASA missions since the 1960s, including the following missions (NASA, 2018b):

- Apollo 11 – two RHUs
- Pioneer 10 and 11 – 12 RHUs each
- Voyager 1 and 2 – nine RHUs each
- Galileo – 120 LWRHUs (103 on orbiter, 17 on atmospheric probe)
- Mars Pathfinder Sojourner Rover – three LWRHUs

[3] RHUs for the Apollo, Pioneer, and Voyager missions predate the current LWRHU configurations; these RHUs were considerably larger than LWRHUs (approximately 15 times the heat output).

- Cassini – 117 LWRHUs (82 on orbiter, 35 on Huygens Titan probe)
- MER Spirit and Opportunity Rovers – eight LWRHUs each

The environmental analysis provided in Section 3, *Affected Environment and Environmental Consequences*, examines the use of up to 130 RHUs or 351 grams of Pu-238 oxide in a single mission. This threshold was chosen based on NASA's projected future needs and decades of safety analyses performed for the RHU-enabled missions (Appendix A). The mass of Pu-238 oxide is included as part of this PEA as to not limit the use of RHUs to the current LWRHU design.

2.1.3 Launch Locations

KSC and CCAFS are located on the east coast of Florida (Figure 2-2) in Brevard County. KSC and CCAFS are adjacent facilities on Merritt Island, which is situated approximately 242 kilometers (km) (150 miles) south of Jacksonville and 64 km (40 miles) due east of Orlando.

These two installations were chosen because historically, handling and integrating RHUs into spacecraft have been performed at KSC and launches have been performed at CCAFS. Consequently, KSC and CCAFS have the trained personnel and the contingency requirements in place to appropriately approve, conduct, and respond to missions using RHUs. As other NASA and USAF facilities gain this capability, they could become candidate locations from which to launch RHUs; however, additional site-specific NEPA documentation would be required.

2.1.3.1 Description of KSC

KSC is NASA's main space launch location and is home to NASA's Launch Services Program (LSP). Its core competencies are rooted in its 50-year history in space flight and include the following:

- Acquisition and management of launch services and commercial crew development.
- Launch vehicle and spacecraft processing, launching, landing and recovery, operations, and sustainment.
- Payload and flight science experiment processing, integration, and testing.
- Designing, developing, operating, and sustaining flight and ground systems and infrastructure.
- Developing, testing, and demonstrating advanced flight systems and transformational technologies.
- Developing technology to advance exploration and space systems.
- Producing the Launch Vehicle Databooks used by DOE in their Nuclear Risk Assessments (NRA), which supported previous NEPA documents.

KSC has two active LCs: LC-39B and LC-39A. As of 2013, the former Shuttle Landing Facility, now the Launch and Landing Facility, has been transferred over to Space Florida for non-government use under a property agreement with NASA. Commercial aerospace companies frequently use KSC's and CCAFS's LCs for launches.

KSC is bordered on the west by the Indian River (a brackish water lagoon) and on the east by the Atlantic Ocean and CCAFS. The northernmost end of the Banana River (another brackish-water lagoon) lies between Merritt Island and CCAFS and is included as part of KSC submerged lands. The southern boundary of KSC runs east-west along the Merritt Island Barge Canal, which connects the Indian River with the Banana River and Port Canaveral at the southern tip of Cape Canaveral. The northern border lies in Volusia County near Oak Hill across Mosquito Lagoon. The Indian River, Banana River, and the Mosquito Lagoon collectively make up the Indian River Lagoon system. A portion of the seashore on the eastern edge of the KSC is available for public recreational purposes on a non-interference basis (NASA, 2016).

KSC is a major central Florida tourist destination and is an approximately 1-hour drive from the Orlando area. The Visitor Complex offers public tours of the center and CCAFS. Because much of the installation is a restricted area and only 9 percent of the land is developed, the site also serves as an important wildlife sanctuary. The Indian River Lagoon, Merritt Island National Wildlife Refuge, and Canaveral National Seashore are other natural features of the area. KSC workers and the visiting public can encounter bald eagles, American alligators, wild boars, eastern diamondback rattlesnakes, bobcats, and Florida manatees, among other wildlife (NASA, 2016).

2.1.3.2 Description of CCAFS

CCAFS is managed by the USAF 45th Space Wing (45 SW) at Patrick Air Force Base, which is located 24 km (15 miles) to the south of CCAFS proper (Figure 2-2). The 45 SW provides launch facilities and services to support NASA and is responsible for overseeing the preparation and launching of U.S. Government, civil, and commercial spacecraft from CCAFS. The 45 SW also operates the Eastern Range for Air Force Space Command (AFSPC). The Eastern Range Operations provide the resources and activities for safe flight, airspace restrictions, range instrumentation, infrastructure, and schedule to support space launches. The Eastern Range consists of tracking stations at CCAFS, mainland annexes, and down-range tracking stations on islands in the Caribbean Sea and South Atlantic Ocean. All launch countdown activities and many NASA operations use Eastern Range Operations.

CCAFS consists of 16,198 acres; its northern boundary abuts KSC and its southern boundary abuts the city of Port Canaveral, a growing and active tourist port. CCAFS is bordered to the east by the Atlantic Ocean and to the west by the Indian River Lagoon. These water bodies serve as natural buffers to the installation. Natural areas near CCAFS include the Merritt Island National Wildlife Refuge and Canaveral National Seashore, both of which contain biological and cultural resources (USAF, 2015a).

CCAFS has 51 LCs, though only the following 4 are currently active: LC-37, LC-40, LC-41, and LC-46. LC-36 is currently under construction. The remaining LCs are either deactivated or inactive (USAF, 2018). CCAFS has one landing site, referred to as LC-13 (Landing Zone-1 and Landing Zone-2), which is now leased to SpaceX specifically for landing their reusable boosters.

The land uses within CCAFS include open fields, an airfield, LCs, supporting infrastructure, and areas of native habitat, including scrub habitat and coastal dunes. Several LCs lie just inland of the beach dune community on CCAFS, but most of the LCs are not active and are abandoned in place (USAF, 2015a).

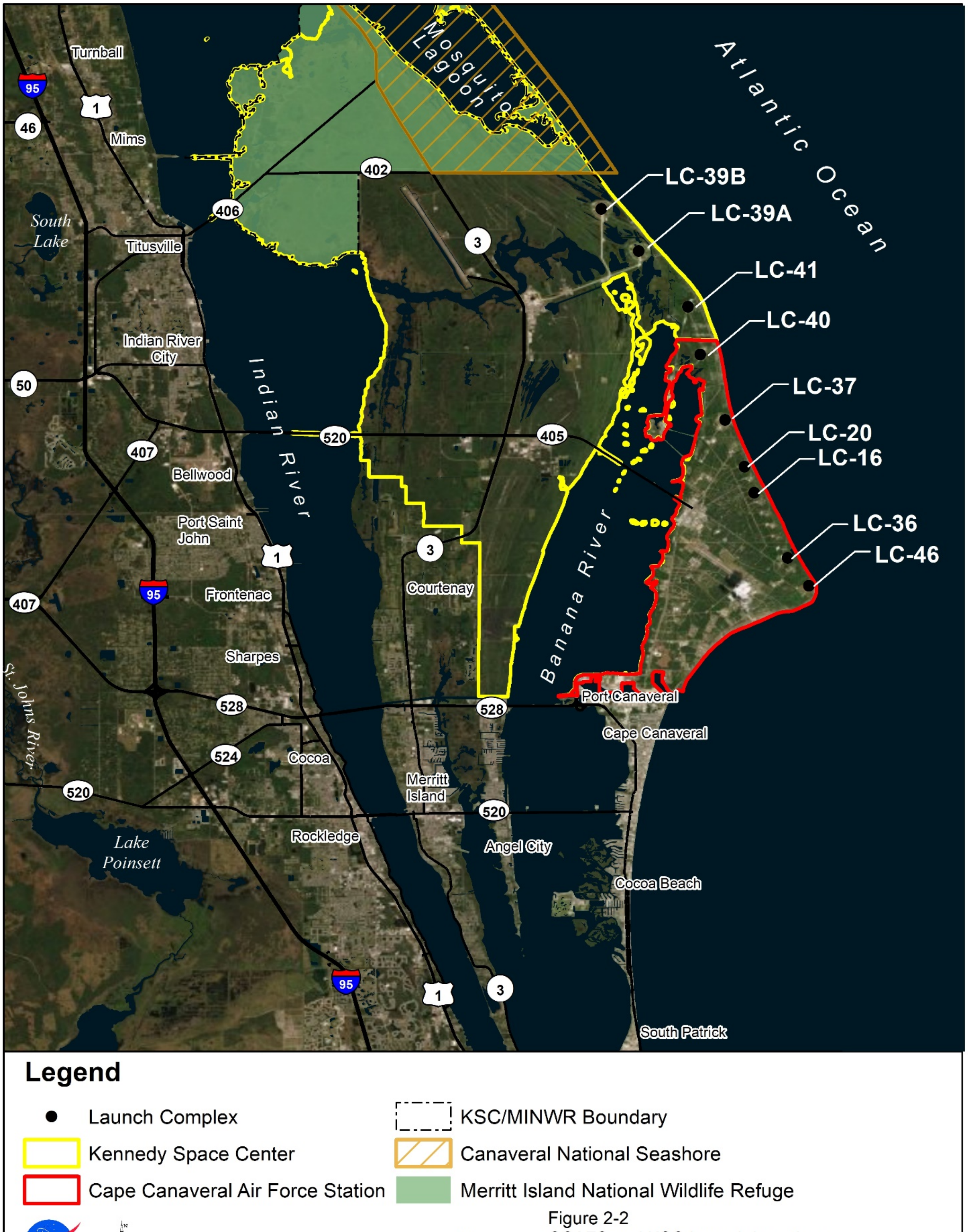

Figure 2-2
CCAFS and KSC Launch Locations
Programmatic Environmental Assessment for RHUs

2.1.4 Launch Vehicles and Approval

A launch vehicle, also known as a rocket, provides the lift and velocity needed for a spacecraft to achieve the desired trajectory. RHUs covered by this PEA would only be launched using U.S. domestic launch vehicles that have been examined through the NEPA and NASA launch approval processes, as discussed in Section 2.1.4.2.

2.1.4.1 Launch Vehicles Analyzed Through NEPA

A new launch vehicle is analyzed under the NEPA process prior to being approved for launch. Appendix A provides a detailed list of the NEPA documentation for existing launch vehicles. The environmental effects associated with the use of launch vehicles are addressed in these documents; therefore, those impacts are not addressed in this PEA.

Additional and future launch vehicles could be covered under this PEA, if they meet at least one of the following parameters:

1. NASA has completed the NEPA process for the specific launch vehicle at KSC or CCAFS.
2. NASA has been a cooperating agency with the U.S. Department of Defense or FAA for a specific launch vehicle at CCAFS or KSC and a finding of no significant impact (FONSI) or record of decision (ROD) has been issued by NASA.
3. NASA has adopted another agency's NEPA compliance document for a specific launch vehicle at CCAFS or KSC and a FONSI or ROD has been issued by NASA.

2.1.4.2 NASA Launch Approval Process

Under the existing process, NASA uses a structured pre-launch review process, to assess and certify the flight readiness of launch vehicles, readiness of payload support hardware and software, and readiness of the launch site infrastructure prior to a launch. NASA's LSP conducts a pre-launch review process for all NASA missions and assures launch system flight readiness for NASA payloads and/or missions. The launch approval process is currently governed by the following requirements. These requirements are continuously updated. NASA, USAF, DOE, and FAA will comply with any revised requirements governing RHU approval.

- NPD 8610.7D, *Launch Services Risk Mitigation Policy for NASA-Owned and/or NASA-Sponsored Payloads/Missions* – Provides guidance for assigning categories of risk to launch vehicles (high risk, medium risk, and low risk) and required mitigation of the risk through a launch vehicle certification process. This document sets forth the requirement that even a launch vehicle with a low priority non-nuclear payload must show reliability of a least 89 percent. High priority payloads must show a reliability of 95 percent (NASA, 2018b).
- NPD 8610.23C, *Launch Vehicle Technical Oversight Policy* – Provides approval and requirements for the technical oversight of launch services provided by commercial launch service providers. NASA remains accountable for the success of its missions launched with commercially provided launch services, because launch remains an element affecting mission success (NASA, 2017b).
- NPD 8610.24C, *Launch Services Program Pre-Launch Readiness Reviews* – Provides NASA management guidelines to assess and certify the flight readiness of launch vehicles, readiness of payload support hardware and software, and readiness of the launch site infrastructure prior to launch through a structured pre-launch review process (NASA, 2015).
- NPR 8705.4, *Risk Classification for NASA Payloads* – Establishes baseline criteria that enable a user to define the risk classification level for NASA payloads on human- or nonhuman-rated launch systems or carrier vehicles and the design and test philosophy and the common assurance practices applicable to each level. The establishment of the risk level early in programs and projects provides the basis for program and project managers to develop and implement appropriate mission

assurance and risk management strategies and requirements and to effectively communicate the acceptable level of risk (NASA, 2004).

Additional launch approval requirements are mandated for payloads that contain RHUs. The key requirements currently governing RHU approval are as follows:

- Presidential Memorandum on Launch of Spacecraft Containing Space Nuclear Systems-20 – Provides guidance regarding the approval of launches containing nuclear material (White House, 2019).
- NPR 8715.3D, *Chapter 6, Nuclear Safety for Launching of Radioactive Materials* – Provides NASA procedural requirements for characterizing and reporting potential risks associated with a planned launch of radioactive materials into space on launch vehicles and spacecraft during normal or abnormal flight conditions (NASA, 2017a).
- Air Force Manual (AFMAN) 91-110, *Nuclear Safety Review and Launch Approval for Space or Missile Use of Radioactive Material and Nuclear Systems* (*currently being updated*) – Implements related policy and establishes the nuclear safety review and launch approval procedures for radioactive materials intended for space or missile use (USAF, 2019).
- AFSPC Manual 91-710 , *Range Use Launch Safety Requirements* – Implements appropriate safety policies and procedures by highlighting requirements associated with flight safety; launch vehicle, payload, and ground support systems; flight termination systems; facilities and structures; ground and launch personnel, equipment, systems, and materials operations (USAF, 2017b).

2.1.5 Mission Types

Under the Proposed Action, RHUs would be incorporated as part of a mission payload and launched using an approved launch vehicle from either CCAFS or KSC. The RHUs would then serve as a heat source during the operation phase of the mission. RHUs could be used on any future NASA space mission, which typically include the following:

- Crewed missions: spacecraft with human crew aboard.
- Low-Earth orbiting missions: these missions include, but are not limited to, communication, navigation, and military spacecraft. Objects in low-Earth orbit maintain an altitude of 160 to 2,000 km (99 to 1,200 miles) above the Earth's surface. This scenario includes crewed and uncrewed missions.
- Earth-escape trajectories: these missions require escaping the Earth's gravitational influence and reaching a solar orbit for interplanetary missions.
- Earth-reentry: purposefully returning a launched vehicle and its payload to Earth. The Earth-reentry could occur outside the boundaries of the United States and its territories.
- Earth gravity assist maneuvers: use of relative movement (e.g., orbit around the Sun) and gravity of the Earth to alter the path and speed of spacecraft, typically to save propellant and reduce expense.
- Non-Earth planetary flybys: a spacecraft follows a continuous solar orbit or escape trajectory, never to be captured into a planetary orbit.
- Non-Earth planetary soft landings: spacecraft are designed to enter and land intact on the surface of a planetary body. NASA has previously used soft landings for Moon, Mars, and Venus missions.
- Non-Earth planetary orbits: spacecraft enter and stay in orbit around a planetary body. An orbiter spacecraft is designed to travel to a distant planetary body and enter orbit. The spacecraft must carry a substantial propulsive capability to decelerate at the right moment to achieve orbit insertion.

2.2 Description of the No Action Alternative

Under the No Action Alternative, NASA would continue to use RHUs in major missions through the completion of mission-specific NEPA documents. However, the use of RHUs in smaller scale missions would be substantially disincentivized due to the considerable requirements associated with performing mission-specific NEPA documentation for nuclear-enabled missions. The No Action Alternative does not meet the purpose and need of the Proposed Action, as it would limit NASA's ability to efficiently use RHUs in space missions and hinder compliance with the requirements to reduce paperwork in the CEQ NEPA implementing regulations (40 CFR Section 1500.4).

2.3 Resources Analyzed

Resources have been divided into two groups: (1) resources studied in detail, and (2) resources eliminated from further analysis.

2.3.1 Resources Studied in Detail

This PEA evaluates the potential impacts to the following environmental resources in Section 3, *Affected Environment and Environmental Consequences*:

- Health and Safety
- Land Use (including Farmlands)
- Water Resources
- Biological Resources
- Hazardous Materials
- Cultural Resources

2.3.2 Resource Areas Eliminated from Further Analysis

In accordance with the CEQ directives to focus the analyses on environmental resource areas where there is a potential for significant impact and where the analyses are expected to provide useful information to the decision maker (40 CFR Section 1502.2), some common resource areas have been eliminated from detailed study. The rationale for their elimination is summarized as follows:

- **Visual Resources:** The use of RHUs in a mission would not alter any of the visual characteristics of KSC or CCAFS.
- **Noise and Noise-Compatible Land Use**: The noise associated with launches has been analyzed in NEPA documentation for the individual launch vehicles. See Appendix A, *Existing NEPA Documentation*, for a full list and summary of these documents. The use of RHUs in a mission would not alter the noise environment associated with a launch or result in an incremental impact.
- **Utilities and Infrastructure (including Natural Resources and Energy Supply)**: There would be no changes to existing utilities, building infrastructure, natural resources[4], or energy supply under the Proposed Action. The use of RHUs would not result in additional natural resource or utility demands.
- **Environmental Justice and Children's Environmental Health and Safety Risks**: Executive Order (EO) 12898, *Federal Actions to Address Environmental Justice in Minority and Low-income Populations*, requires federal agencies to consider disproportionate risk to minority and low-income communities. Using the U.S. Environmental Protection Agency's (EPA's) Environmental Justice Screening and Mapping Tool, a 16-km (10-mile) buffer area surrounding the KSC and CCAFS boundary did not contain a disproportionate percentage of minority and low-income populations (EPA, 2018). Although minority and low-income individuals are within the buffer area, the Proposed Action will not disproportionately impact these individuals; consequently, there is no likelihood for a

[4] In this context, natural resources are resources such as asphalt, aggregate, wood, etc.

disproportionately high and adverse effect to minority and low-income populations resulting from the Proposed Action. The potential environmental effects associated with the production of RHUs has been addressed in existing DOE NEPA documentation (DOE 2008, 2013).

Similarly, EO 13045*, Protection of Children from Environmental Health Risks and Safety Risks*, directs federal agencies to identify and assess environmental health risks and safety risks that may disproportionately affect children. There are no concentrations of children near any of the launch complexes at KSC and CCAFS. Therefore, the Proposed Action would not disproportionately affect children. The potential for disproportionate health effects to children from exposure to Pu-238 is considered in Section 3.1, *Health and Safety.*

- **Ambient Air Quality and Climate:** KSC and CCAFS are in full attainment of National Ambient Air Quality Standards criteria pollutants under the Clean Air Act. Previous NEPA documents have analyzed the impacts of launches on air quality and climate. See Appendix A, *Existing NEPA Documentation*, for a full list and summary of these documents. The Proposed Action of using RHUs on future missions will not result in changes to the current Clean Air Act criteria pollutants at KSC or CCAFS and will not result in an increase in greenhouse gas emissions. Furthermore, the Proposed Action will also be in full compliance with KSC and CCAFS's Title V Operating Permits (KSC, 2015; CCAFS, 2014). Therefore, no new impacts to air quality or climate are expected from the Proposed Action. Impacts associated with an airborne release of Pu-238 are discussed in detail in Section 3.1, *Health and Safety*.
- **Socioeconomics:** The Proposed Action would have no appreciable effect on the socioeconomic conditions of Brevard County. No additional onsite personnel would be hired to implement the Proposed Action and no population growth is expected. Therefore, there would be no effects to socioeconomics under the Proposed Action. Potential impacts to land use including farm land and recreational areas are discussed in Section 3.2, *Land Use.*
- **Transportation:** The potential environmental effects associated with the transportation of RHUs have been addressed in existing DOE NEPA documentation (DOE 1993, 2000, 2008, 2013). The emergency evacuation protocols to be implemented after a mission mishap would be the same as the protocols for non-RHU missions; therefore, there would be no unique impacts to transportation from the Proposed Action.
- **Geology and Soils:** In the extremely unlikely event of a release of Pu-238 during a launch accident, the depth of potential soil cleanup would be approximately 2 inches (NASA, 2014b), which would be too shallow to affect geology. There are also no soil resources or farmland located within the potentially affected areas (see Section 3.2, *Land Use*); therefore, there would be only negligible impacts to soil.
- **Coastal Zones:** The Coastal Zone Management Act (CZMA) establishes a national policy to preserve, protect, develop, restore, and enhance the resources of the nation's coastal zone. Federal agencies are responsible for making consistency determinations within coastal zone areas. The entire state of Florida is considered a coastal zone area. However, the Proposed Action would have no effect on coastal zone resources in Florida and would be consistent with the Florida Coastal Management Program.

SECTION 3

Affected Environment and Environmental Consequences

Affected Environment

This section provides an overview of the existing natural and cultural conditions within the Proposed Action area. In compliance with NEPA, the description of the affected environment focuses on those resources and conditions potentially impacted by the Proposed Action.

This section is organized by resource type and includes a description of the existing environment and the region of influence for each resource. The region of influence is defined as the area in which project-related environmental impacts could occur. For most resources, the region of influence is limited to the KSC and CCAFS installation boundaries, as shown on Figure 2-2. However, for some resources, the potential effects of the project must be considered within the context of the surrounding vicinity. For example, the evaluation of land use also includes the surrounding areas. Resources that occur across a broader area were considered on a regional scale.

Environmental Consequences

The purpose of NEPA is to inform decision makers and the public of the likely environmental consequences of the Proposed Action and its alternatives. Consistent with these requirements, this section identifies the anticipated effects of the Proposed Action on each resource. The analysis of resource impacts focuses on environmental issues in proportion to the degree of impact within the region of influence. Under NEPA (40 CFR Section 1508.27), a determination of significance requires consideration of context and intensity. Accordingly, impacts described in this PEA are evaluated in terms of type (beneficial or negative), context (local or regional), intensity (none, negligible, minor, moderate, or significant), and duration (temporary or permanent). These terms are further defined in Table 3-1.

Table 3-1. Impact Threshold Definitions

Impact Intensity	Intensity Description
Negligible	An environmental effect that is so small, it would be difficult to observe, and its effect to human health, cultural resources or the environment would be considered inconsequential.
Minor	An environmental effect that is observable, yet it is unlikely to noticeably affect human health, cultural resources, or the environment.
Moderate	An environmental effect that is observable and may noticeably affect human health, cultural resources, or the environment, yet it is below regulatory, industry, and commonly accepted thresholds for significance. The relevant thresholds are described for each resource in the following resource sections.
Significant	An environmental effect that is observable and could cause a major and lasting impact to human health, cultural resources, or the environment. If significant impacts are identified, an environmental impact statement (EIS) would need to be completed prior to implementing the Proposed Action.

Duration: Temporary – the effects of the impact disappear over time

Permanent – the effects of the impact will remain in the environment indefinitely.

Mitigation measures or best management practices that would be implemented to avoid or minimize potential impacts are also identified, where relevant. As required under NEPA, the environmental effects of the No Action Alternative were also evaluated.

3.1 Health and Safety

The only relevant health and safety concern for the Proposed Action is the potential for radiation exposure from RHUs in spacecraft during a mission mishap. Other health and safety concerns, such as exposure to extreme noise during a launch, have been addressed in the NEPA documents listed in Appendix A. The following analysis considers radiation exposure impacts resulting from the maximum individual dose after a mission mishap. The consideration of the maximally exposed individual (MEI) is the DOE and NRC standard for calculating dose limits (DOE Order 458.1).

3.1.1 Affected Environment

The following subsections provide a definition of radiation, an explanation of the health concerns associated with radiation exposure, and a description of the current radiological conditions at CCAFS and KSC.

3.1.1.1 Radiation and Plutonium-238

Nuclear radiation is defined as energy in the form of particles or electromagnetic waves that is emitted when the nucleus of an unstable isotope or radionuclide[5] decays. The particles or waves are referred to as ionizing radiation if they contain enough energy to separate electrons from their atoms. The process of an unstable isotope undergoing spontaneous change is called radioactive decay. Heat is generated during radioactive decay through the interaction of emitted particles or waves with nearby atoms. Half-life is the time it takes for half of a group of unstable isotopes to decay and is inversely proportional to the rate of decay (expressed as Curies). An unstable isotope decays through one or more nuclear transitions into a stable isotope and potentially a new element.

RHUs function through the release of heat from the radioactive decay of Pu-238 (an isotope of the element plutonium). The isotope Pu-238 has a half-life of 87.7 years and emits alpha particles[6] and neutrons. Each atom of Pu-238 decays into an atom of Uranium (U)-234, a radioactive isotope of uranium with a half-life of 246,000 years, and an atom of stable helium. Eventually, the subsequent decays of radioactive progeny radionuclides end with the creation of a stable atom of lead (Knolls, 2010).

3.1.1.2 Health Effects from Radiation Exposure

Humans are constantly exposed to natural ionizing radiation from various sources, including cosmic radiation (from outer space) and terrestrial radiation (from Earth's rocks and soils). These types of radiation are commonly referred to as background radiation. Man-made sources of radiation also exist; for example, smoke detectors, cigarette smoke, and certain coatings on camera lenses emit small doses of radiation. Because living cells are constantly exposed to ionizing radiation, they have developed biochemical mechanisms to repair damage from this exposure. However, when delivered in enough quantity, ionizing radiation can overwhelm repair mechanisms and cause significant health effects such as cancer. External exposure to alpha radiation is not harmful because the outer dead layer of skin serves as a natural barrier and prevents penetration to more sensitive cells. However, if alpha-emitting radionuclides such as Pu-238 are introduced into the body by inhalation (or breathing), they can deposit in internal organs and deliver a radiation dose to tissues.

The ICRP has studied the movement of Pu-238 within the human body. The inhalation of small particles, less than 5 microns in diameter, poses the greatest potential health effect. Breathing is approximately 1,000 times more effective than eating for transporting plutonium to the sensitive tissues in the human body. Ingested (or eaten) Pu-238 would quickly pass through the digestive system and be excreted, with only a minute fraction being absorbed into the bloodstream. Inhaled Pu-238 could be transported to the

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[5] An unstable isotope or radionuclide is defined as an atom where the number of neutrons is too large or too small to create a stable nucleus.

[6] Alpha particles consist of two protons and two neutrons and are the heaviest type of ionizing radiation. Alpha particles lose their energy when they collide with anything, such as the skin's surface or a sheet of paper.

deep portions of the lungs, depending on the particle size. Generally, particles larger than 5 microns would be intercepted in the nose or throat, swallowed, and passed through the digestive tract and excreted. Particles smaller than 5 microns could accumulate in the deep lung regions. Most health effects would result from Pu-238 accumulating in the deep lungs and then migrating into the blood stream, which transports it to body tissues. Once Pu-238 has entered the blood stream, it would be deposited primarily in the liver and skeletal system, creating a potential for cancer if the radiation dose is sufficiently large (ICRP, 1986; National Research Council, 2006). Therefore, most of the radiological health risks associated with mission mishaps are attributed to the potential release of Pu-238 in a respirable form. Mishap scenarios that do not result in a release Pu-238 or that result in a release of Pu-238 in solid fragments are a relatively minor component of the overall risk spectrum.

The unit of radiation dose measurement is called a Roentgen Equivalent Man (rem). Radiation dose is a measurement of the amount and type of ionizing radiation energy adsorbed per unit mass of body tissue and the relative biological effect of that absorbed radiation. An average person in the U.S. is exposed to approximately 0.62 rem per year from background and man-made sources of radiation. This yearly dose has not been shown to cause harm to humans, including children and other sensitive populations (NRC, 2018a).

3.1.1.3 Existing Conditions

Florida receives less exposure from cosmic radiation compared to most parts of the country because of its low elevation resulting in a thicker atmosphere, which allows cosmic radiation to be absorbed. Assessments performed by the U.S. Geological Survey and EPA indicate that KSC, CCAFS, and adjacent areas have a low potential for geological radon (terrestrial radiation). In other categories of medical or background radiation exposure, Florida is consistent with the national average (NASA, 2014b).

3.1.1.4 Established Nuclear Safety Procedures

Regional Safety

CCAFS, KSC, the City of Cape Canaveral, and Brevard County have a mutual-aid agreement in the event of emergencies. During launch activities, CCAFS remains in communication with KSC, Brevard County Emergency Management, the Florida Marine Patrol, the U.S. Coast Guard, and Florida Division of Emergency Management. CCAFS' Range Safety monitors launch areas to ensure that risks to people, aircraft, and surface vessels are within acceptable limits. Control areas and airspace are closed to the public during launches (USAF, 1998; NASA, 2014b).

Prior to launch approval of a mission using RHUs, a comprehensive set of plans are developed by NASA to ensure that any launch accident could be met with a well-developed and tested response. NASA's plans are developed in accordance with the National Response Framework (U.S. Department of Homeland Security [DHS], 2016b) and the National Response Framework Nuclear/Radiological Incident Annex (DHS, 2016a) in coordination with the DOE, the USAF, other federal agencies, the state of Florida, Brevard County, and local governmental organizations. These organizations and agencies, as needed, could be involved in response to a radiological emergency (Scott et al., 2012).

Onsite Safety

The Radiological Control Center (RADCC) at KSC coordinates all radiological contingency planning and initial response activities. The RADCC is equipped with extensive communication and computing systems. The main functions of RADCC are field data monitoring, data assessment, formulation of recommendations (onsite or offsite), coordination with response organizations, and delivery of information to the public (Scott et al., 2012).

The RADCC uses ground monitoring teams, dispersion modeling, and Environmental Continuous Air Monitors to collect data during launches. The Environmental Continuous Air Monitors provide near real-time radiological air concentration measurements and correlations with wind speed and directions

(Scott et al., 2012). Prior to each NASA launch, a joint NASA/USAF contingency response group is formed and prepared to coordinate an emergency response in the event of a mission mishap (Scott et al, 2012).

International Response

For incidents that occur post-launch and outside the jurisdiction of the United States, DOE and NASA would assist the Department of State in coordinating the United States' response via diplomatic channels and deploying federal resources as requested. If an impact occurs in the ocean following an accident, NASA and the DOE coordinate with the DHS, the U.S. Coast Guard, and the U.S. Navy, to initiate security measures and assess the feasibility of search and retrieval operations. Efforts to recover RHUs are based on an assessment of technical feasibility, potential risks to recovery personnel, and potential environmental impacts.

3.1.2 Environmental Consequences

This section identifies potential direct and indirect impacts to health and safety that may result from implementing the Proposed Action and the No Action Alternative.

3.1.2.1 Proposed Action

NASA has assessed the potential impacts to health and safety from launch accidents involving the release of Pu-238 through the EISs detailed in Appendix A. The most likely outcome of implementing the Proposed Action is the successful launch of future missions; this scenario represents the normal operating conditions. However, in the unlikely[7] event of an accident, the most probable outcome is still an accident without the release of Pu-238, as the RHU has been designed to withstand most launch mishaps and Earth reentry without releasing Pu-238. RHU safety features are designed to withstand many energetic accident conditions, thereby preventing or minimizing the release of the Pu-238 oxide fuel. However, certain low probability accident scenarios could involve sequential mechanical insults to the RHUs or worst-case accident configurations (e.g., RHUs or fuel in direct contact with, or very close proximity to, burning solid propellant). While previous analyses have generally shown the likelihood of such accidents to be extremely unlikely[8], they typically represent the upper bound of a potential release. For a potential health effect to occur, multiple failures would have to happen and the RHU would have to be exposed to an extreme amount of heat, long enough for the Pu-238 pellet to vaporize into a respirable form. In the history of using RHUs in spacecraft, there have been no such releases of Pu-238 involving an RHU. However, failure scenarios have been postulated and the following scenarios represent the highest risk events during a launch mishap:

- RHU safety mechanisms are designed to withstand most explosion scenarios, but a sustained exposure to burning solid fuel or a liquid propellant fire could result in the release of a measurable amount of respirable Pu-238 during an incident on or near the launch pad. This scenario represents the upward boundary of a potential release. The likelihood of its occurrence is extremely unlikely, as it would require burning fuel to land on or very close to the RHUs. NASA designs its missions to avoid this potential.
- A suborbital (below Earth's orbit) space vehicle mishap could occur along the vehicle flight path, which could result in the RHU(s) unintentionally returning to Earth beyond the launch area. The RHUs are designed to withstand the reentry environment and would be able to withstand most suborbital accidents. Rocket boosters, which contain the rocket fuel, are jettisoned relatively early in the flight sequence. This greatly lowers the potential and quantity of released Pu-238, as proximity to burning fuel represents the upward bounds of potential release scenarios. Therefore, the

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[7] The use of the term "unlikely" is based on DOE guidelines for risk (DOE Standard 3009) and represents a 1 in 100 to a 1 in 10,000 chance of occurrence.

[8] The use of the term "extremely unlikely" is based on DOE guidelines for risk (DOE Standard 3009) and represents a 1 in 10,000 to a 1 in 1,000,000 chance of occurrence.

potential of a Pu-238 release is extremely unlikely in this scenario and efforts would be taken to retrieve the RHU.

Risk Assessment associated with an Extremely Unlikely Release

DOE has estimated potential radiological dose consequences associated with the use of RHUs in NASA space missions (INL, 2019). These estimates were based on extensive launch related analysis performed for previous NASA missions in which RHUs were considered. A sensitivity analysis was also conducted to determine the effect of key parameters, such as distance from the incident and meteorological conditions, on the potential dose (Table 3-2). This sensitivity analysis is relevant because after a substantial mishap the Pu-238 would be distributed as a passing cloud that would dissipate over a distance. Therefore, the radiation dose that a person might receive from the passing cloud depends on wind speed, wind direction, distance traveled and similar factors.

Table 3-2. Sensitivity Analysis – Receptor Location and Wind Speed

Distance from Incident	Distance Reference	Wind Speed 2.3 mph	Wind Speed 10.0 mph
10 miles	Representative distance from launch site to western federal property boundary	0.141 rem	0.005 rem
8.7 miles	Representative distance from launch site to southern federal property boundary	0.167 rem	0.006 rem
7.5 miles	Representative distance from launch site to KSC Visitor Center	0.202 rem	0.008 rem
2.5 miles	Representative distance from launch site to invited visitor location	0.847 rem	0.039 rem
1.25 miles	Representative distance from launch site to nearest worker	2.253 rem	0.113 rem

Source: INL, 2019

It should be noted that the estimates shown in Table 3-2 assume no mitigation measures are in place (e.g. sheltering), even though these mitigations are standard protocols for any launch at KSC or CCAFS. It also does not consider the established safety procedures described in Section 3.1.1.4, *Established Nuclear Safety Procedure*s. These mitigation measures would lessen the potential consequences to the public after a release of radioactive materials in an accident scenario. Therefore, the estimates in Table 3-2 demonstrate the maximum planning basis exposure; in an actual launch accident environment, it is doubtful that the exposure to any individual would reach these levels.

The highest potential dose consequences shown in Table 3-2 were compared against known exposure limits and established safety standards to determine the significance of the potential impact. The potential public exposure level[9] is beneath the typical annual exposure rates of 0.62 rem per year from background and man-made sources of radiation. This yearly dose has not been shown to cause harm to humans, including children and other sensitive populations (NRC, 2018a). In addition, according to the EPA it is very difficult to determine individual health effects below 10 rem (EPA, 2019a). Finally, the calculated dose is significantly below the evaluation guideline of 25 rem for an extremely unlikely event involving consequences to the public at a nonreactor nuclear facility incident. The 25 rem threshold is deemed appropriate as an evaluation tool for accident assessments, as it is generally accepted to be indictive of low risk for health effects from an isolated incident (DOE, 2014)

[9] Defined as potential receptors beyond 7.5 miles from the incident

The potential health and safety effects associated with the use of RHUs are considered minor and temporary, because the estimated maximum dose is below established radiation exposure thresholds, including limits for children and other sensitive populations. This impact designation was chosen because the radiation exposure after a mission mishap may be measurable, but health effects have not been reliably demonstrated at the estimated maximum exposure level. The potential for a health effect from the maximum rem exposure to an individual after an incident is beyond extremely unlikely[10].

3.1.2.2 No Action Alternative

Under the No Action Alternative, environmental impacts would be evaluated on a mission-specific basis through project-specific NEPA documentation. The No Action Alternative would also have a very unlikely minor temporary impact to health and safety.

3.2 Land Use

3.2.1 Affected Environment

The following subsections describe land resources at CCAFS and KSC, including administrative and natural areas. The region of influence for land use is KSC, CCAFS, and the surrounding areas, as shown on Figure 3-1.

3.2.1.1 KSC

Land use at KSC is planned and managed to support space missions and to maximize protection of the environment. Essential safety zones, clearance areas, lines-of-sight, and similar elements have been incorporated into land use planning (NASA, 2014c).

KSC is located on the northern part of Merritt Island adjacent to CCAFS and consists of approximately 139,490 acres of land and lagoon waters (Figure 3-1). The majority (95 percent) of KSC is identified as undeveloped area, which includes uplands, wetlands, mosquito control impoundments, and open water areas. Nearly 40 percent of the undeveloped areas are open water areas of the Indian River Lagoon system, which includes portions of the Indian River, Banana River, Mosquito Lagoon, and Banana Creek (NASA, 2013). The remaining 5 percent (approximately 4,415 acres) is identified as NASA's operational area and includes both developed and undeveloped areas. The developed operational areas are primarily used for ground processing, launch, and landing activities and include facilities and associated infrastructure such as roads, parking areas, and maintained rights-of way. Developed operational areas also include the two launch complexes, LC-39A and LC-39B. Undeveloped lands within the operational areas are dedicated safety zones or are reserved for planned and future expansion.

Management of the remaining areas within KSC's boundaries that are not directly used for NASA operations has been delegated to the U.S. Fish and Wildlife Service (USFWS) at the Merritt Island National Wildlife Refuge (MINWR) and the National Park Service (NPS) at the Canaveral National Seashore (CNS). The NPS administers 6,644 acres of the CNS, while the USFWS administers 50,945 acres of the CNS and the 75,383 acres of the MINWR (NASA, 2013).

MINWR and CNS provide a buffer between NASA operations and the surrounding communities. The USFWS and NPS also exercise management control over recreational and environmental programs within MINWR and CNS. All zoning and land use planning at MINWR and CNS are under NASA directive. Therefore, USFWS and NPS management is subject to operational requirements defined by NASA, such as temporary closures for launch and landing-related activities (NASA, 2014c).

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[10] The use of the term "beyond extremely unlikely" is based on DOE guidelines for risk (DOE Standard 3009) and represents a greater than 1 in 1,000,000 chance of occurrence.

3.2.1.2 CCAFS

CCAFS includes approximately 16,198 acres that support multiple land use types (Figure 3-1). Some of the land uses within CCAFS include launch operations, launch and range support, airfield, port operations, station support area, and open space. The launch operations land use category is present along the Atlantic Ocean shoreline and includes the active and inactive launch sites and support facilities. Other CCAFS operational land uses are primarily in the central and southern portions of the facility. Open space includes areas managed for natural resources and is the largest land use category at CCAFS. All land uses at CCAFS are under operational control of the USAF 45 SW at Patrick Air Force Base (NASA, 2013). The beaches along CCAFS are used for launch operations and are restricted from public use (USAF, 2015a).

3.2.1.3 Surrounding Land Use (including Farmland)

Land use surrounding KSC and CCAFS includes an active seaport; residential, recreation, and wildlife management areas; and agricultural uses that include citrus and other crops and pasture (Figure 3-1). Port Canaveral to the south of CCAFS has several cruise ship and commercial terminals. Security personnel regularly patrol the Port waters to ensure unauthorized personnel do not access CCAFS via the Port (USAF, 2015a). There is an abundance of public recreational opportunities in the area, including beaches, waterways, lakes, open land, and parks. The coastal beaches and supporting facilities that are a part of the CNS or MINWR are classified as operational buffer/public use; therefore, these areas are open to the public but are closed during some launch operations at the discretion of USAF (USAF, 2015a). Other surrounding land use types include farmland. Brevard County has a total of 771 acres of citrus groves, primarily oranges and grapefruit.

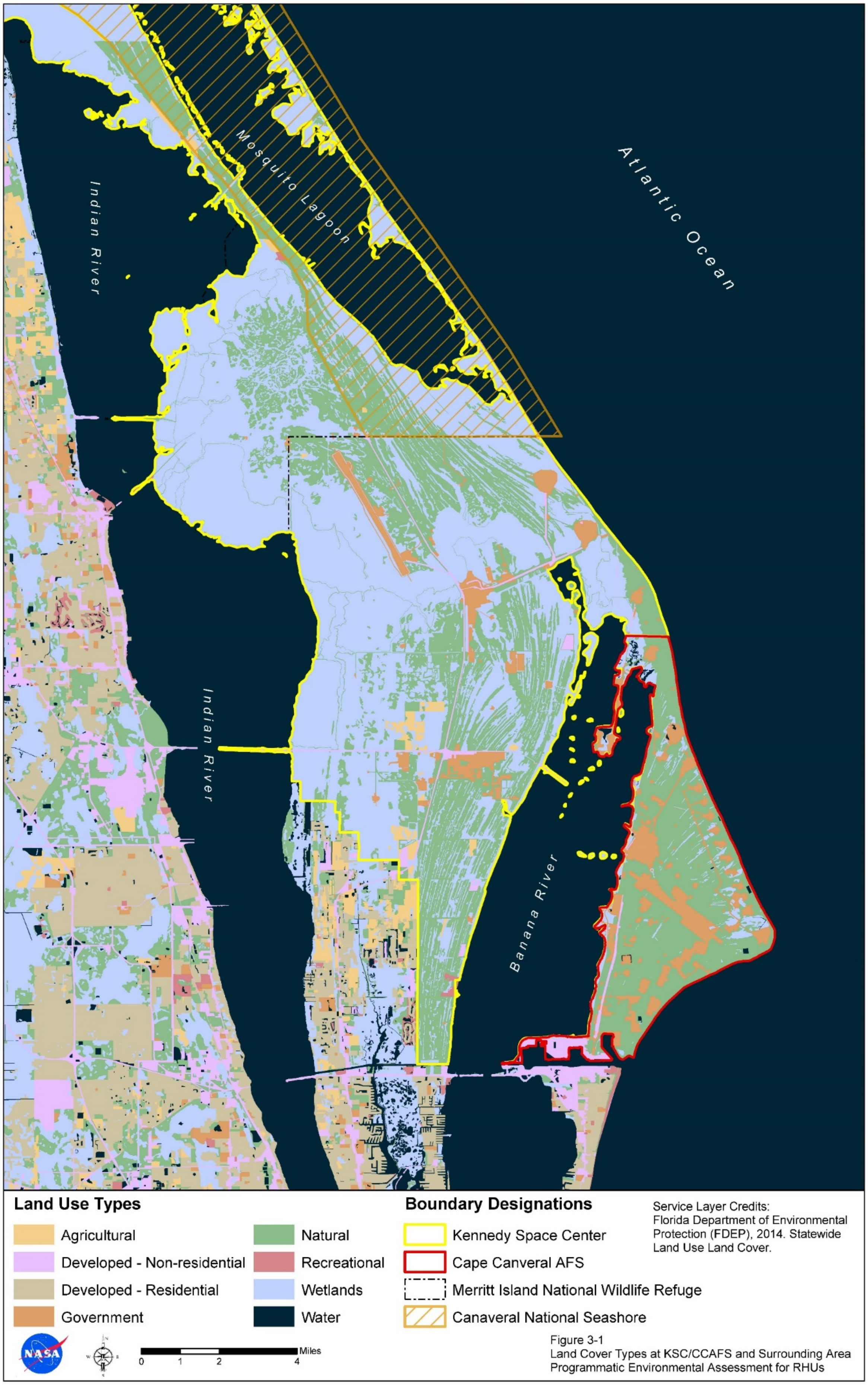

Figure 3-1
Land Cover Types at KSC/CCAFS and Surrounding Area
Programmatic Environmental Assessment for RHUs

3.2.2 Environmental Consequences

3.2.2.1 Proposed Action

Under normal operating conditions, there would be no impacts to land use from the use of RHUs. Land uses, including recreation, wildlife areas, and agricultural land would remain the same. Any impacts from the use of existing facilities are expected to be within the scope of the previously approved programs (USAF, 1998, 2000; NASA, 2002, 2011).

Radiological Deposition

There is a potential for Pu-238 to be released into the environment under an extremely unlikely release scenario, as described in Section 3.1, *Health and Safety*. Such a release could result in the deposition of radiological materials on the ground. In a launch pad accident involving the release of Pu-238, the potential area of deposition would most likely remain within the boundaries of KSC and CCAFS (NASA, 1997, 2002, 2014b); therefore, there is little potential for an impact to valued land uses such as recreational areas, archeological sites, or agricultural/farmland areas (Figure 3-1) as a result of the Proposed Action.

There is a beyond extremely unlikely potential for radiological materials to be deposited outside KSC or CCAFS. If this was to happen, NASA and DOE would coordinate response activities per the National Response Framework (DHS, 2016a). The public may be required to undertake certain actions (e.g. shelter in place) in the event that an accident occurs with the release of Pu-238. NASA with its federal, state and local partners, would undertake the appropriate radiological screening and other necessary response actions, in accordance with previously developed contingency plans. The area would return to normal use after radiation concerns are addressed.

Land use impacts associated with an accidental release of Pu-238 from the use of RHUs would be temporary and minor. This determination was made based on the remote likelihood of a mishap, the high probability that the affected area remains within KSC and CCAFS boundaries, and the mitigation measures currently in place.

U.S. Department of Transportation Act Section 4(f)

The FAA, a cooperating agency on this PEA, is required to consider impacts to unique land use categories per Section 4(f) of the U.S. Department of Transportation Act. A Section 4(f) evaluation is required when a transportation project uses a Section 4(f) resource, defined as significant publicly owned parks, recreational areas, wildlife and waterfowl refuges, and public and private historic sites. A “use” is defined as the occurrence of one of the following on a 4(f) resource:

- When land is permanently incorporated into the transportation facility
- When there is a temporary occupancy of land that is adverse in terms of the statute’s preservationist purposes
- When proximity impacts of the transportation project are so great that the protected activities, features, or attributes that qualify the property for 4(f) protection are substantially impaired (this is known as a “constructive use”)

A *de minimis* impact involves the use of Section 4(f) property that is generally minor in nature. A *de minimis* impact is one that, after considering avoidance, minimization, mitigation, and enhancement measures, results in one of the following:

- Determination that the project would not adversely affect the activities, features, or attributes of qualifying a park, recreational area, or refuge for protection under Section 4(f).
- National Historic Preservation Act Section 106 finding of no adverse effect or no historic properties affected.

The following Section 4(f) resources could be affected by the Proposed Action (Figure 3-1):

- Cultural properties (see Section 3.5, *Cultural Resources,* for a detailed explanation)
- MINWR
- CNS

There would be no permanent or constructive use of these Section 4(f) resources. The safeguards developed through compliance with the requirements defined in Section 3.1.1.4, *Established Nuclear Safety Procedures*, would also lessen the potential for land impacts. Potential impacts to cultural resources are discussed in Section 3.5, *Cultural Resources*. Because a release on these sites is extremely unlikely to result in an adverse effect under Section 106 of the National Historic Preservation Act, there would be no permanent or constructive use of a Section 4(f) resource. If, on the off chance, a cultural site is affected by radiological materials, NASA and DOE would coordinate any land cleanup efforts or temporary closures with the Florida State Historic Preservation Office (SHPO). If a cultural site were affected by radiological materials, it would most likely result in a *de minimis* impact, and efforts would be made to bring the site back to its original use or state after response.

3.2.2.2 No Action Alternative

Under the No Action Alternative, impacts to land use would be evaluated on a mission-specific basis through project-specific NEPA documentation. The No Action Alternative would also have a very unlikely minor temporary impact to land use, as the potential for impacts are expected to be similar as those described for the Proposed Action.

3.3 Water Resources

3.3.1 Affected Environment

The following subsections describe water resources at CCAFS and KSC, including surface water, groundwater, potable water supply, and wetlands. The region of influence for water resources is the Upper St. Johns River and Cape Canaveral watersheds (Florida Department of Environmental Protection [FDEP], 2018), as well as the aquifers beneath the watersheds.

3.3.1.1 Surface Water

KSC is located on a barrier island. It is bounded by Mosquito Lagoon to the north and the Atlantic Ocean and Banana River to the east, and it is separated from the mainland by the Indian River to the west (Figure 3-2). CCAFS is east of KSC and is bounded by the Banana River on the west and the Atlantic Ocean to the east. Where most of the launch pads are located, surface drainage flows to the west into the Banana River. South of CCAFS is the Port Canaveral channel, which connects the Banana River to the Atlantic Ocean.

The FDEP assigns a classification system to surface waters of Florida based on their potential use and value. The Banana River, Mosquito Lagoon, and Indian River are classified as Class II surface waters that are suitable for shellfish propagation and harvesting under Florida Administrative Code 62-302.

Waters within the Merritt Island National Wildlife Refuge and Canaveral National Seashore have been designated as an Outstanding Floridian Water by the FDEP, which supersedes other classifications and has the highest water quality standards under Florida Administrative Code 62-302.

3.3.1.2 Groundwater

Three aquifers are located within the region of influence. These aquifer layers are not uniform in thickness and the depths below the ground surface vary throughout the region. The top layer is the surficial aquifer, which is composed of sand, silt and clay and ranges from approximately 75 to 175 feet (23 to 53 meters) in thickness and depth. The surficial aquifer begins at the land surface. Underneath the surficial aquifer is the intermediate aquifer, which is composed of clay with thin water bearing zones of sand, shell, and limestone. The intermediate aquifer ranges from 0 to 500 feet (0 to 152 meters) in thickness and disappears in a small area near the St. Johns River and west of KSC. The intermediate aquifer begins 75 to 175 feet (23 to 53 meters) below land surface. Underneath the intermediate aquifer is the Floridian aquifer, which is composed of limestone and dolomite. The top plane of the Floridian aquifer ranges from 75 to 500 feet (23 to 152 meters) below land surface. These aquifers are recharged primarily through rainfall infiltration (St. Johns River Water Management District, 1990).

3.3.1.3 Potable Water Supply

CCAFS and KSC and much of Brevard County obtain drinking water from the City of Cocoa’s Claude H. Dyal Water Treatment Plant, which treats and distributes water obtained from the Taylor Creek Reservoir and 34 Floridian aquifer wells approximately 400 to 600 feet (122 to 183 meters) deep and 14 wells in the intermediate aquifer (City of Cocoa, 2009). The reservoir and wells are located more than 15 miles (24 km) west of KSC and CCAFS. The tributary streams that drain into the reservoir are even farther west. Water supplies from ground and surface water sources are treated to EPA drinking water standards before distribution. Also, numerous private well owners obtain their potable water from all three aquifers.

3.3.1.4 Wetlands

Wetlands are areas where the frequent and prolonged presence of water at or near the soil surface drives the natural system, including the kinds of soil that form, the plants that grow, and the fish and/or wildlife communities that use the habitat (EPA, 2019b). Wetland locations for the region of influence were obtained from the National Wetlands Inventory database (USFWS, 2019a) and are shown on Figure 3-1 in Section 3.2, *Land Use*.

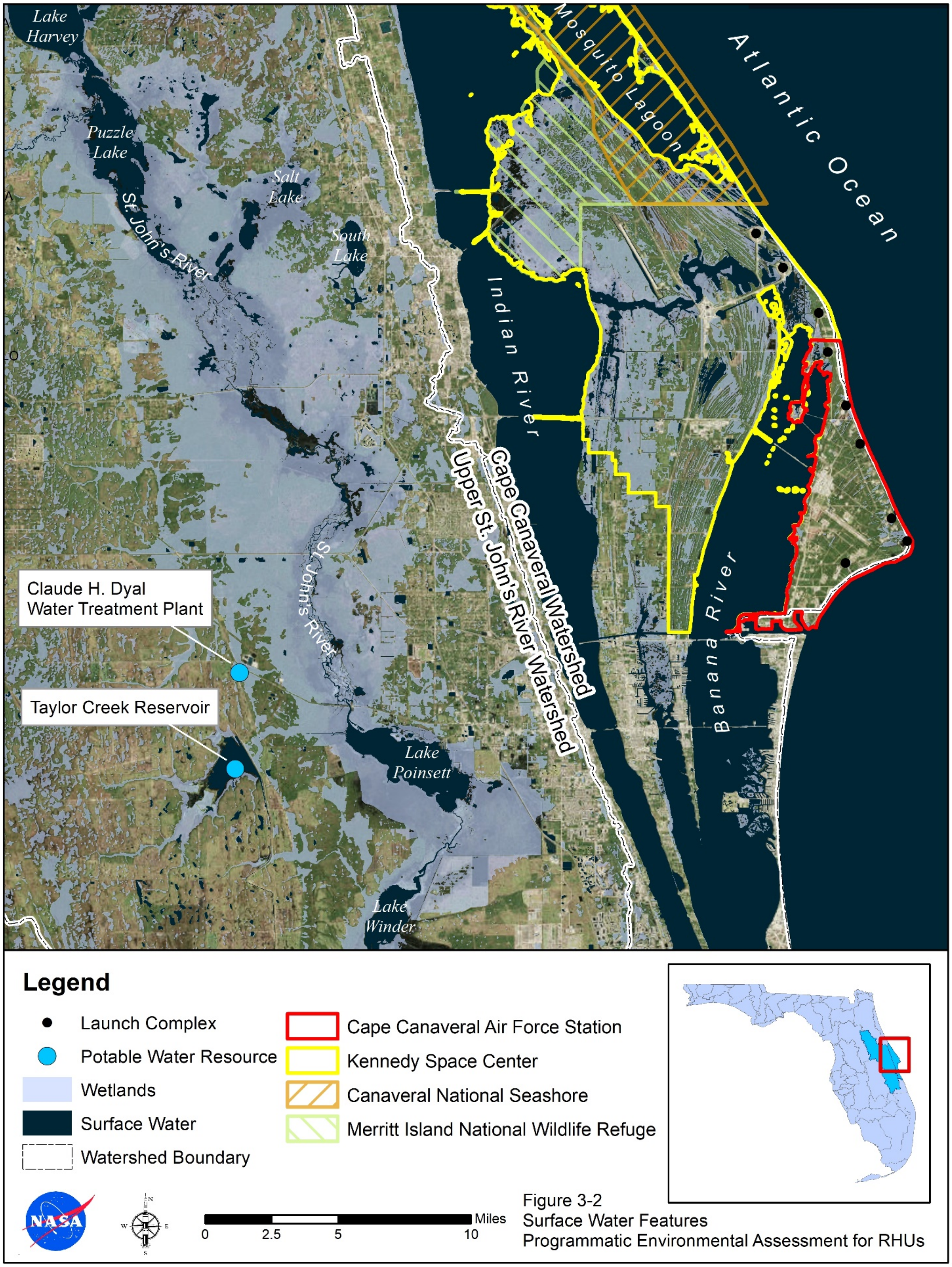

Figure 3-2
Surface Water Features
Programmatic Environmental Assessment for RHUs

3.3.2 Environmental Consequences

This section identifies potential impacts to water resources that may result from implementing the Proposed Action and the No Action Alternative.

3.3.2.1 Proposed Action

Under normal operating conditions of the Proposed Action, there would be no impacts to water resources from the use of RHUs. The following impacts are evaluated only for the extremely unlikely event that Pu-238 is released during a launch accident as described in Section 3.1, *Health and Safety*.

Surface Water

For surface water to be affected by the Proposed Action, a mission mishap would have to deposit portions of a Pu-238 pellet in a waterway or a plume of airborne Pu-238 would have to spread over a waterway. In these scenarios, the Pu-238 would be released as an oxide that has low solubility; therefore, in the extremely unlikely event portions of a Pu-238 pellet came in contact with water, the pellet fragments would sink to the sediment. If an airborne plume extended over a water body, the Pu-238 would condense or attach to particulates, sink to the bottom, and bind with saturated sediments. The insoluble nature of the Pu-238 oxide and its tendency to bind with solid sediments makes ingestion (eating) of the compound the most likely exposure pathway for humans and aquatic species. As explained in Section 3.1.1.2, *Health Effects from Radiation Exposure*, ingestion does not represent a substantial risk, as Pu-238 would most likely be expelled during the digestive process before a health effect could be realized. Given the insoluble nature of Pu-238 oxide and the limited potential for an adverse health effect for humans and aquatic species, the potential impacts to surface water are considered negligible.

Groundwater

Water supply from the three aquifers is extremely unlikely to be impacted by the Proposed Action. Because Pu-238 oxide is insoluble, there is no direct mechanism for transport into groundwater. Soil studies have shown that more than 95 percent of Pu-238 oxide remains in the top 2 inches of undisturbed surface soil after deposition. The remaining 5 percent may be pushed beyond the top 2 inches by percolation of rainfall or animal burrowing activity, or unintentionally by human activities such as plowing (DOE, 1987). However, DOE and NASA would be committed to performing radiological response in accordance with the National Response Framework (DHS, 2016a); therefore, the likelihood of groundwater contact is extremely remote, and the impacts are considered negligible.

Potable Water

The Taylor Creek Reservoir is more than 15 miles west of the KSC and CCAFS and is far removed from the potential effected area (Figure 3-2). In the highly improbable event that debris containing an RHU from a suborbital mishap is carried far enough to reach the reservoir or tributary streams, then it is possible that suspended Pu-238 oxide particles could be introduced into the treatment plant. However, the Claude H. Dyal Water Treatment Plant process is designed to comply with the EPA drinking water standards (40 CFR Part 141) and monitors for radiation. The treatment process includes sand and anthracite coal filters (City of Cocoa, 2019), which are effective in removing Pu-238 (NASA, 1990). The impact from Pu-238 exposure from drinking water is negligible due to the insolubility of Pu-238 oxide, the distance of the Taylor Creek Reservoir from the launch pads, the low probability that ingested Pu-238 will remain in human body, and existing infrastructure that meets EPA drinking water standards.

Wetlands

In the extremely unlikely event that Pu-238 is released in a launch accident, site response would be conducted per the National Response Framework (DHS, 2016a) (Figure 3-2). Any dredge and fill activities would be coordinated through the U.S. Army Corps of Engineers and state agencies if wetlands or waters of the US/State could be affected after an accidental release of Pu-238. Impacts to wetlands are expected to be negligible, because the potential for an impact is extremely unlikely and because NASA would coordinate potential wetland impacts with the U.S. Army Corps of Engineers and develop agreed-upon mitigation.

3.3.2.2 No Action Alternative

Under the No Action Alternative, environmental impacts would be evaluated on a mission-specific basis through project-specific NEPA documentation. The effects on water resources also would be expected to result in negligible impacts.

3.4 Biological Resources

3.4.1 Affected Environment

The following subsections describe biological resources at CCAFS and KSC, including the ecological setting, vegetation, fish and wildlife, and protected species. The region of influence for biological resources consists of CCAFS, KSC, the adjacent Atlantic Ocean, and three major inland water bodies, including the Banana River, the Indian River, and Mosquito Lagoon.

3.4.1.1 Ecological Setting

CCAFS and KSC occupy a coastal habitat on a barrier island complex that parallels Florida’s mid-Atlantic coast. The Merritt Island National Wildlife Refuge and Canaveral National Seashore are located north of KSC and CCAFS. Most land adjacent to the KSC/CCAFS barrier island complex is developed.

3.4.1.2 Vegetation

Natural vegetative communities at KSC and CCAFS are dominated by forests and wetlands. This includes upland scrub and pine flatwoods (coastal strand, oak scrub, palmetto scrub, pine flatwoods), upland forest (upland coniferous forest, upland hardwood forest, cabbage palm, hardwood hammock), and wetlands (mangrove wetlands, salt marshes, freshwater wetlands, and estuaries) (NASA, 2016).

3.4.1.3 Fish and Wildlife

The water bodies and natural areas provide for a variety of habitats and resources for aquatic and terrestrial wildlife at KSC and CCAFS. Common animals occurring at KSC and CCAFS include frogs, turtles, lizards, snakes, birds, mammals, fish, and invertebrates (USAF, 2015a). Adjacent areas of water, including the Atlantic Ocean and three major inland water bodies, support over 140 species of freshwater fish, saltwater fish, and aquatic mammals (USAF, 2015a).

3.4.1.4 Protected Species

Threatened and endangered species are federally protected plants and animals that are in danger of becoming extinct within the foreseeable future throughout all or a significant portion of the species’ range. The Endangered Species Act (ESA) requires federal agencies to ensure their actions do not jeopardize the continued existence of any federally listed endangered or threatened species or adversely modify any critical habit of such species. CCAFS and KSC contain 17 federally listed wildlife species; there are no federally listed plant species on CCAFS or KSC (Table 3-3).

The Marine Mammal Protection Act prohibits, with certain exceptions, the take (harass, hunt, capture, collect or kill) of marine mammals in U.S. waters and by U.S. citizens on the high seas. Marine mammals that populate the coastal and lagoon waters of KSC and CCAFS, include the bottlenose dolphin, the spotted dolphin, and the West Indian manatee (USAF, 1998).

The Migratory Bird Treaty Act (MBTA) establishes federal responsibilities to protect migratory birds. Under the MBTA, nearly all species of birds occurring in the United States are protected. The MBTA makes it illegal to intentionally take (hunt, pursue, wound, kill, possess, or transport by any means) listed bird species or their eggs, feathers, or nests unless otherwise authorized. Resident and migrating bird species at KSC and CCAFS include numerous common land and shore birds. In addition to protection under the ESA, the wood stork, piping plover, roseate tern, and Florida scrub jay receive protection under the MBTA.

Table 3-3. Federally Threatened and Endangered Species Documented to Occur at CCAFS or KSC

Common Name	Scientific Name	Federal Status
Reptiles and Amphibians		
American Alligator	*Alligator mississippiensis*	T
Atlantic (Kemp's) Ridley Sea Turtle	*Lepidochelys kempi*	E
Atlantic Green Sea Turtle	*Chelonia mydas*	E
Atlantic Salt Marsh Snake	*Nerodia clarkia taeniata*	T
Eastern Indigo Snake	*Drymarchon corais couperi*	T
Gopher Tortoise	*Gopherus polyphemus*	C
Hawksbill Sea Turtle	*Eretmochelys imbricata*	E
Leatherback Sea Turtle	*Dermochelys coriacea*	E
Atlantic Loggerhead Sea Turtle	*Caretta caretta*	T
Mammals		
Northern Right Whale	*Eubalaena glacialis*	E
Southeastern Beach Mouse	*Peromyscus polionotus niveiventris*	T
West Indian Manatee	*Trichechus manatus latirostris*	E
Fish		
Smalltooth Sawfish	*Pristis pectinata*	E
Birds		
Auburn's Crested Caracara	*Polyborus plancus audubonii*	T
Eastern Black Rail	*Laterallus jamaicensis ssp. Jamaicensis*	Proposed T
Everglade Snail Kite	*Rostrhamus sociabilis pumbeus*	E
Florida Scrub Jay	*Aphelocoma coerulescens*	T
Piping Plover	*Charadrius melodus*	T
Red Knot	*Calidris canutus rufa*	T
Red-cockaded Woodpecker	*Picoides borealis*	E
Roseate Tern	*Sterna dougallii*	T
Wood Stork	*Mycteria americana*	E
Bald Eagle	*Haliaeetus leucocephalus*	P
Flowering Plants		
Carter's Mustard	*Warea carteri*	E
Lewton's Polygala	*Polygala lewtonii*	E

Source: USFWS, 2019b.

Key:

C = candidate for Federal listing
E = endangered
T = threatened
P = protected under the Bald and Golden Eagle Protection Act.

3.4.2 Environmental Consequences

3.4.2.1 Proposed Action Alternative

Under normal operating conditions of the Proposed Action, there would be no impacts to biological resources from the use of RHUs.

Terrestrial and aquatic animal species receive external and internal doses of ionizing radiation from inhalation, ingestion, and immersion similar to exposure pathways experienced by humans. Ecological protection programs are based on the premise that radiological protection for humans also provides conditions that adequately protect wildlife. This has been qualitatively demonstrated by the IAEA (IAEA, 2014). Since the potential effects of radiation exposure after a release of Pu-238 are considered temporary and minor to human populations (Section 3.1, *Health and Safety)*, impacts to wildlife from the use of the RHUs in spacecraft are expected to be temporary and minor as well. This includes impacts to protected wildlife species. NASA and/or the USAF would coordinate the potential response activities with the USFWS and NMFS as required under the ESA and Marine Mammal Protection Act to determine appropriate mitigation for the protection of sensitive species.

The deposition of radiological material would be addressed through appropriate screening and other remediation as required, and any disturbed vegetation would be expected to reestablish after the completion of response activities. No permanent impacts to freshwater, salt water, or surface water ecosystems are expected, because Pu-238 would be released as an oxide that has low solubility in aquatic ecosystems. Pu-238 deposited in the Banana River or the Atlantic Ocean would be flushed and diluted by tides and currents. The impacts to the surrounding ecosystems from land and water contamination are considered negligible.

3.4.2.2 No Action Alternative

Under the No Action Alternative, impacts to biological resources would be evaluated on a mission-specific basis through project-specific NEPA documentation. The No Action Alternative would also have a very unlikely minor and temporary impact to individual organisms and negligible impacts to surrounding ecosystems.

3.5 Cultural Resources

The following subsections describe cultural resources at CCAFS and KSC, including archeological and historical sites. Federal agencies are required to ensure that cultural resources are considered in all of their undertakings and that significant resources are protected to the extent possible.

3.5.1 Affected Environment

The most relevant federal laws pertaining to cultural resources for the Proposed Action are the National Historic Preservation Act (NHPA), and the Archaeological Resources Protection Act (ARPA). The NHPA is generally considered the foundation for the preservation of cultural resources in the United States. The NHPA defines historic properties as any prehistoric or historic district, site, building, structure, or object included in, or eligible for, the National Register of Historic Places (NRHP). The NRHP is a federally maintained list of historic properties significant in American history, prehistory, architecture, archeology, engineering, and culture. To be listed in the NRHP, a property must have historic significance and integrity and generally be at least 50 years old. Certain properties less than 50 years old can be eligible if they possess exceptional importance. The region of influence for cultural resources is KSC and CCAFS; numerous NRHP listed and eligible sites are located on these facilities.

The ARPA forbids anyone from excavating or removing archaeological resources from federal or Indian land without a permit from a land managing agency. ARPA also forbids any sale, purchase, exchange, transport, or receipt of archaeological resources. An archeological resource is generally an item that is at least 100 years old and represents the remain of past human life or activities. Typical archaeological resources include: pottery, basketry, weapons, tools and graves.

3.5.1.1 KSC

NASA has a stewardship responsibility for managing the cultural resources on NASA-owned or NASA-administered lands and facilities and has developed an Integrated Cultural Resource Management Plan (ICRMP) that reflects its commitments to the protection of significant cultural resources at KSC. KSC has a designated Historic Preservation Officer (HPO) under NASA's Environmental Management Branch to manage the ICRMP. It is a goal at KSC to balance historic preservation considerations with NASA's missions and avoid conflict with ongoing operational requirements (NASA, 2016)

3.5.1.2 CCAFS

The USAF also has a stewardship responsibility for managing the cultural resources on USAF-owned lands and facilities and has developed an ICRMP that reflects its commitments to the protection of significant cultural resources at CCAFS. There is a designated HPO at CCAFS who manages the ICRMP. It is also a goal at CCAFS to balance historic preservation considerations with the USAF's missions and avoid conflict with ongoing operational requirements.

3.5.2 Environmental Consequences

3.5.2.1 Proposed Action

Under normal operating conditions, there would be no impacts to cultural resources from the use of RHUs. There is a potential for Pu-238 to be released into the environment under an extremely unlikely release scenario, as described in Section 3.1, *Health and Safety*. Such a release could theoretically result in a deposition of radiological material on a cultural resource. Consequently, potential cultural resource impacts were evaluated against the potential response requirements following a release of Pu-238 as defined in Section 3.2, *Land Use*.

Archeological Sites

Pu-238 is insoluble and will typically remain on the top 2 inches of surface soil after a release (NASA, 2014b). Consequently, the potential of impacting a known or unknown archeological site present in a contaminated area is limited. In the extremely unlikely event cleanup activities require the excavation of soil on a NRHP-listed or eligible archeological resource, the Florida SHPO will be notified prior to any response activities at the site, and appropriate mitigation measures will be developed per the NHPA. If a new archeological site is identified during cleanup activities, the respective KSC or CCAFS HPO will be notified immediately. The HPO will determine if the site is eligible for listing on the NRHP; if it is deemed eligible, the SHPO will be notified before any other response activities are conducted at that site to determine appropriate mitigation measures. Impacts to archeological sites are considered negligible, given the remote probability of a site being affected and NASA's and the USAF's commitment to work with the SHPO in the event an archeological site requires cleanup.

Historic Sites

Numerous NRHP-listed and eligible historic sites, as well as National Historic Landmarks, are located on KSC and CCAFS. These significant historic resources include the LCs, where missions containing RHUs could be launched. Potential effects to cultural resources after a launch mishap have been studied in detail in the documents listed in Appendix A. RHU-specific impacts would involve potential cleanup activities, primarily on the exterior of structures. If a historic structure were identified as part of a response activity, the Florida SHPO would be notified beforehand, and appropriate mitigation measures would be developed per the NHPA. Impacts to historic sites are considered negligible, given the remote probability of a site being affected and NASA's and the USAF's commitment to work with the SHPO in the event a historic site requires cleanup.

3.5.2.2 No Action Alternative

Under the No Action Alternative, impacts to cultural resources would be evaluated on a mission-specific basis through project-specific NEPA documentation. The No Action Alternative would also have negligible impacts to cultural resources, as the potential for noticeable effects to cultural resources would be expected to remain slight.

3.6 Hazardous Materials

Hazardous materials are substances defined by the Comprehensive Environmental Response, Compensation, and Liability Act as substances that, because of their quantity, concentration, or physical, chemical, or infectious characteristics, may present substantial danger to public health or the environment. Numerous types of hazardous materials are used to support missions and conduct general maintenance operations at KSC and CCAFS; however, the NEPA documents detailed in Appendix A analyzed the impacts associated with the use of these hazardous materials and resulting wastes; therefore, they are not considered in detail here. The only hazardous material unique to the Proposed Action is Pu-238; consequently, this analysis focuses only on Pu-238. The region of influence for hazardous material is the LCs at KSC and CCAFS. As described in Appendix A*,* environmental impacts associated with production and transport of Pu-238 have been analyzed in previous DOE NEPA documents (DOE, 1993, 2000, 2008, 2013).

3.6.1 Affected Environment

3.6.1.1 KSC

The Radiation Protection Program at KSC (KSC, 2009, 2016) manages the use of radioactive materials and ionizing radiation devices to ensure safe practices and operations. This includes the approval, procurement, use, transfer/shipment, and disposal of ionizing radiation sources. The goal of the KSC Radiation Protection Program is to ensure safe practices and operations, to preclude unnecessary exposure to personnel, and to limit exposure to levels as low as reasonably achievable (KSC, 2009, 2016).

NASA is responsible for providing adequate infrastructure (i.e., facilities and personnel) in conjunction with prelaunch and launch operations that meet criteria mutually acceptable to DOE and NASA for the storage, assembly, checkout, servicing, and repair of RHUs. The criteria also include safeguards and security protection (NASA/DOE, 2016) such as ensuring all personnel using sources of ionizing radiation are properly trained in safe practices for the possession and use of the materials and are familiar with the applicable regulatory and program requirements.

3.6.1.2 CCAFS

The Radiation Protection Program for the 45 SW manages radioactive materials at CCAFS. Controlled ionizing radiation devices transferred to, or stored or used on, CCAFS by NASA must be approved by the 45 SW Radiation Protection Officer. Radioactive sources are handled under the supervision of the Range User or Radiation Protection Officer named on the NRC license, state license, or USAF permit (USAF, 2018, 2019).

The 45 SW Range Safety requirements establish radioactive source design standards and requirements for radioactive sources carried on launch vehicles and payloads, including general design requirements, test requirements, launch approval requirements, and data requirements; RHUs are compatible with these regulatory specifications (USAF, 2017a, 2017b, 2019).

3.6.2 Environmental Consequences

3.6.2.1 Proposed Action Alternative

KSC and CCAFS have extensive infrastructure, safety controls, and policies in place for the handling and safeguard of nuclear material; these infrastructure and measures help to prevent the release of nuclear material, including Pu-238. No new infrastructure or safety controls would be needed for the continued use of RHUs for space missions. All established radiological safety controls and precautions relating to the receipt, storage, handling, and installation of radioactive materials would be followed. Therefore, under normal operating conditions, there would be no hazardous materials impacts from the use of RHUs in spacecraft.

In the extremely unlikely event a mission mishap resulted in a release of Pu-238, the impacts would reflect those described in Section 3.1, *Health and Safety*, and 3.2, *Land Use*.

3.6.2.2 No Action Alternative

Under the No Action Alternative, impacts from hazardous materials would be evaluated on a mission-specific basis through project-specific NEPA documentation. The No Action Alternative would have very unlikely minor and temporary impacts from hazardous materials.

3.7 Cumulative Impacts

Cumulative impacts are defined by the CEQ in 40 CFR Section 1508.7 as “impacts on the environment which result 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 such other actions.” Cumulative impacts must occur to the same resources, in the same geographic area, and within the same period for the Proposed Action and other projects.

At a local scale, other sources of radioactivity are present from the St. Lucie Nuclear Power Plant in South Hutchinson Island near Port St. Lucie, Florida, approximately 160 km (100 miles) directly south of CCAFS. The NRC has defined two emergency planning zones around nuclear power plants. The first zone is a plume exposure pathway with a radius of 16 km (10 miles), which is concerned primarily with exposure resulting from releases of airborne radioactive material. The second zone is an ingestion exposure pathway with a radius of 80 km (50 miles) and is concerned primarily with exposure via ingestion of food and liquid that may be contaminated by radioactivity. CCAFS and KSC are outside these two zones; therefore, there would be no cumulative impacts at the local scale (NRC, 2018b).

The environmental impacts associated with the Proposed Action are all negligible to minor; thus, the potential for the Proposed Action to cause collectively significant cumulative environmental impacts is unlikely. NASA and the USAF may conduct missions containing more than 130 RHUs or an RTG, which are circumstances beyond the scope of this PEA. However, given the remote chance that one of these missions results in a mishap with a release of Pu-238 (NASA, 1994, 1997, 2002, 2005, 2014b), there is limited potential for a cumulative impact from a launch containing RHUs.

SECTION 4

Summary of Impacts

The potential impacts associated with the Proposed Action and the measures that would be implemented to avoid or minimize those impacts are summarized in Table 4-1. The normal operating conditions as shown in the second column of Table 4-1 represent the most likely outcome of implementing the Proposed Action and includes the successful launch of future science missions. In the unlikely event of an accident, the most probable outcome is still an accident without the release of airborne Pu-238, as the RHU has been designed to withstand the majority of launch mishaps and Earth reentry. Multiple failures would have to occur and the RHU would have to be exposed to an extreme condition for the Pu-238 to be released; this scenario is referred to as the "Extremely Unlikely Release Scenario" in Table 4-1.

Table 4-1. Summary of Potential Impacts and Proposed Mitigation Measures

Resource Category	Normal Operating Conditions	Proposed Action: Extremely Unlikely Release Scenario	No Action: Extremely Unlikely Release Scenario	Measures to Minimize Impact
Health and Safety	No impact	Minor and temporary impacts to health and safety.	Minor and temporary impacts to health and safety.	Implement standard mitigation measures such as sheltering, evacuation, and cleanup. Follow established safety procedures, as described in Section 3.1.1.4, *Established Nuclear Safety Procedure*s.
Land Use	No impact	Minor and temporary impacts to land use.	Minor and temporary impacts to land use.	Coordinate any cleanup efforts per the National Response Framework. Undertake the appropriate radiological screening and other necessary response actions, in accordance with previously developed contingency plans.
Water Resources	No impact	Negligible impacts to water resources.	Negligible impacts to water resources.	Coordinate with USACE and state agencies if wetlands or waters of the US/State could be affected after a potential release of Pu-238.
Biological Resources	No impact	Minor and temporary impacts to wildlife species. Minor and temporary impacts to protected species Negligible ecosystem impacts.	Minor and temporary impacts to wildlife species. Minor and temporary impacts to protected species Negligible ecosystem impacts.	Coordinate with USFWS and NMFS if protected species could be affected after an accidental release of Pu-238.
Cultural Resources	No impact	Negligible impacts to cultural sites.	Negligible impacts to cultural sites.	Coordinate with Florida SHPO if a NRHP-eligible or listed cultural sites would be affected during response activities. Follow an established inadvertent discovery plan in the event a new archeological site is discovered during cleanup activities.

Resource Category	Normal Operating Conditions	Proposed Action: Extremely Unlikely Release Scenario	No Action: Extremely Unlikely Release Scenario	Measures to Minimize Impact
Hazardous Materials	No impact	Minor and temporary impacts from hazardous materials.	Minor and temporary impacts from hazardous materials.	Follow all hazardous material regulations and procedures, including training.
Cumulative Impacts	No impact	Minimal chance for a cumulative effect.	Minimal chance for a cumulative effect.	None

SECTION 5

Consultation and Coordination

The agencies, organizations, and persons responsible for contributing to this report are provided below.

5.1 Cooperating Agencies

NASA – lead federal agency
DOE – cooperating agency
USAF – cooperating agency
FAA – cooperating agency

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5.2 PEA Distribution List

NASA Headquarters
NASA Science Mission Directorate
NASA Office of International and Interagency Relations
NASA Kennedy Space Center
NASA Glenn Research Center
NASA Office of General Counsel
Jet Propulsion Laboratory
DOE Headquarters
DOE Idaho National Laboratory
DOE Los Alamos National Laboratory
DOE Oak Ridge National Laboratory
FAA Headquarters
FAA Alaskan Region Airports Division
USAF Cape Canaveral Air Force Station
USAF Air Force Space Command
Florida Department of Environmental Protection Clearinghouse
Central Brevard Library
Cocoa Beach Public Library
Melbourne Library
Merritt Island Public Library
Port St John Public Library
Titusville Public Library
Satellite Beach Public Library

SECTION 6

List of Preparers

The primary persons responsible for preparing and reviewing this report are listed in Table 6-1.

Table 6-1. List of Preparers and Reviewers

Name	Role	Experience
Michelle Rau, PMP	Project Manager and NEPA Lead	M.S., Business Administration; B.S., Ecology and Evolutionary Biology; 23 years of experience
Arthur Desrosiers, CHP	Senior Health Physicist	Sc.D., Radiation Protection; M.S., Nuclear Engineering; B.S. Physics; 42 years of experience
Stephen Petron	Senior NEPA Support	Ph.D. Zoology; M.S. Natural & Environmental Resources; B.S. Wildlife Management; 39 years of experience
Val Ross	Lead Technical Review	M.S., Regional Planning; B.S., Biology; 30 years of experience
Christina McDonough, PE	Water Resource Author	M.S. Civil Engineering; B.S. Civil Engineering; 25 years of experience
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Michael Witmer, EIT	Radiation Engineer	M.S., Environmental Engineering; B.S., Civil Engineering; 4 years of experience
Karen Sanders	Lead Editor	J.D., Law; B.A., Anthropology; 25 years of experience

SECTION 7
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Appendix A
Relevant NEPA Documents

APPENDIX A

Relevant NEPA Documents

NEPA Documents – Non-nuclear Spacecraft and Launch Site

The National Aeronautics and Space Administration (NASA), the U.S. Air Force (USAF), and the U.S. Federal Aviation Administration (FAA) have completed multiple National Environmental Policy Act (NEPA) analyses covering the routine activities of space launches at Kennedy Space Center (KSC) and Cape Canaveral Air Force Station (CCAFS) and the associated nonnuclear payloads. The following documents are incorporated by reference in this programmatic environmental assessment (PEA). Because these NEPA documents address the environmental effects associated with launches and nonnuclear payloads, the impacts associated with spacecraft launches are not analyzed in this PEA. Instead, this PEA focuses solely on the potential additional environmental effects associated with the use of radioisotope heater units (RHUs) in spacecraft.

- **Environmental Assessment for Operation and Launch of the Falcon 1 and Falcon 9 Space Vehicles at Cape Canaveral Air Force Station Florida** – The proposed action was to launch the Falcon 1 and 9 vehicles using Space Launch Complex (LC) 40, construction of a new facility, and recovery of launch vehicles. The environmental assessment (EA) analyzed potential environmental impacts of the proposed action and action alternatives to land use/visual resources, noise, biological resources, cultural resources, air quality, orbital debris, hazardous waste/hazardous materials, water resources, geology and soil, transportation, utilities, health and safety, socioeconomics, and environmental justice. The EA resulted in a finding of no significant impact (FONSI). Website: http://www.dtic.mil/dtic/tr/fulltext/u2/a611861.pdf
- **Supplemental Environmental Assessment for Space Florida Launch Site Operator License at Launch Complex 46** – The proposed action was for the FAA to issue a Launch Site Operator License to Space Florida to operate a launch facility at LC-46 at CCAFS. The potential impacts of the proposed action and action alternatives were analyzed in the EA, including the potential environmental impacts of successful launches on air quality, biological resources, water resources, noise, land use, socioeconomic, hazardous materials, solid waste, and pollution. The EA resulted in a FONSI. Website: https://www.faa.gov/about/office_org/headquarters_offices/ast/media/Sept%202008%20Space%20Florida%20EA%20and%20FONSI.pdf
- **Environmental Assessment for Launch of NASA Routine Payloads** – The proposed action comprised preparing, launching, and decommissioning missions designated as routine payloads. CCAFS and KSC were included as potential sites. The EA analyzed the potential environmental impacts to resources, including air quality, public health and safety, hazardous materials, geology/soils/land resources, water resources, noise/sonic boom, biological resources, cultural resources, socioeconomic factors, and environmental justice, orbital and reentry debris, perchlorate deposition, stratospheric ozone depletion, and global warming. The EA resulted in a FONSI. Website: https://www.nasa.gov/agency/nepa/routinepayloadea.html
- **Environmental Assessment for Multi-use of Launch Pads 39A and 39B, John F. Kennedy Space Center, Florida** – The proposed action is to allow multiple users, including commercial users, to prepare and launch vehicles from KSC LC-39A and LC-39B. The EA analyzed the following resource areas in detail: land use, facilities and infrastructure, health and safety, water quality, atmospheric environment, noise and vibration, biological resources, geology and soils, historic and cultural resources, hazardous materials and waste management, global environment, socioeconomics and

children's environmental health and safety, orbital and reentry debris, and aesthetics. The EA resulted in a FONSI. Website: https://www.patrick.af.mil/Portals/14/documents/NASA%20FInal%20Use%20Multi%20Use%20EA.pdf?ver=2017-05-22-143217-433

- **Environmental Assessment for Crew Dragon Pad Abort Test at LC-40, CCAFS, Florida** – The proposed action is for the FAA to issue a launch license to Space Exploration Technologies (SpaceX) for the Crew Dragon abort test at LC-40 at CCAFS. The EA resulted in a FONSI.

- **Environmental Assessment, Blue Origin Orbital Launch Site at CCAFS, Florida** – The proposed action was to construct and operate an Orbital Launch Site at the combined areas of LC-11 and LC-26 at CCAFS. The commercial facility would contain infrastructure to test rocket engines, integrate launch vehicles, and conduct launches of liquid-fueled, heavy-life-class orbital vehicles. Blue Origin would sign a lease directly with the USAF for both LC-11 and LC-36. The EA analyzed land use/visual resources, noise, biological resources, cultural resources, air quality, climate, hazardous materials/waste, orbital debris, water resources, geology and soils, transportation, utilities, health and safety, socioeconomics, environmental justice, and U.S. Department of Transportation Act Section 4(f) properties. The EA resulted in a FONSI. Website: https://www.patrick.af.mil/Portals/14/documents/Blue_Origin_EA_Draft_Final_10_19_16.pdf

- **Supplemental Environmental Assessment to the Space Exploration Technologies (SpaceX) Vertical Landing of the Falcon Vehicle and Construction EA at Launch Complex 13, CCAFS, Florida** – The proposed action included the construction of two additional landing pads and a small temporary processing building and operations that support landing of additional vehicles at LC-13 (LZ-1) at KSC. The Supplemental EA analyzed effects to land use, noise, biological resources, cultural resources, air quality, climate, hazardous materials/waste, water resources, geology/soils, transportation, utilities, health and safety, socioeconomics, and 4(f) properties. The supplemental EA resulted in a FONSI. Website: https://www.patrick.af.mil/Portals/14/documents/3-27-2017%20Final%20SpaceX%20LZ-1%20SEA-2.pdf?ver=2017-03-27-150629-603

- **Kennedy Space Center Center-Wide Operations Final Programmatic Environmental Impact Statement** – The programmatic environmental impact statement (EIS) was prepared to evaluate the potential environmental impacts from proposed center-wide KSC operations, activities, and facilities for planning horizons across a 20-year planning horizon. These operations, activities, and facilities are described in the 2013 Center Master Plan. Implementation of the Center Master Plan will facilitate a transformation from a single, government-user LC to a multi-user spaceport. The programmatic EIS analyzed potential impacts to soils and geology, water resources, hazardous materials and waste, air quality, climate change, acoustic environment (noise), biological resources, cultural resources, land use, transportation, utilities, socioeconomics, recreation, environmental justice and protection of children. Although there were adverse impacts associated with the implementation of the proposed action, none were significantly adverse. Because many of the impacts associated with the proposed action are related to the construction or operations of new projects, these environmental impacts would not accumulate by the increased use of RHUs. NASA issued a record of decision (ROD) in March 2017. Website: https://environmental.ksc.nasa.gov/EnvironmentalPlanning/EnvironmentalImpactStatement .

- **Final and Supplemental Final Environmental Impact Statement, Evolved Expendable Launch Vehicle Program, CCAFS and Vandenburg Air Force Base (VAFB)** – As part of the Evolved Expendable Launch Vehicle (EELV) Program, the proposed action was the development, deployment, and operation of EELV systems. EELV would use both medium and heavy lift systems at a lower launch cost than the present expendable launch systems. The proposed launch locations for the program were CCAFS and VAFB. The proposed action of the supplemental EIS was to allow the addition of up to five strap-on solid rocket motors on Atlas V life vehicle and to allow the use of larger solid rocket motors on the Delta IV lift vehicle. Both EISs analyzed potential impacts to the local community, land use and aesthetics, transportation, utilities, hazardous materials and hazardous waste management, health and safety, geology and soils, water resources, air quality, noise, orbital debris, biological resources, cultural resources, and environmental justice. Hazardous material and hazardous waste impacts would result from increased launch rates, due to the addition of commercial launches. Because the increased amount of materials and wastes would be consistent with those currently managed in accordance with applicable regulations, no significant impacts are expected. Health and safety impacts from launch-related failures are minimized to insignificant levels through implementation of applicable safety requirements and procedures at CCAFS. The USAF issued a ROD in 2000. Website: https://www.faa.gov/about/office_org/headquarters_offices/ast/licenses_permits/media/eelvSEis.pdf

NEPA Documents – Nuclear

NASA has studied the potential effects of using nuclear technology, including RHUs, through decades of NEPA documentation for major missions, which include EISs and EA in the following list.

- **Final Environmental Assessment for Mars Pathfinder Mission** – The purpose of the Mars Pathfinder Mission was to research the surface of Mars' northern hemisphere. Under the proposed action, the mission would deliver a small rover vehicle inside a landing craft to the surface of Mars and use three RHUs as a heat source. NASA issued a FONSI on October 24, 1994. The Mars Pathfinder launch occurred at CCAFS on December 4, 1996.

- **Final and Supplemental Environmental Impact Statement for the Cassini Mission** – The purpose of the Cassini mission was to conduct research on Saturn, its atmosphere, moons, rings, and magnetosphere. Under the proposed action and action alternatives, the Cassini spacecraft incorporated three RTGs to provide onboard electric power and 117 RHUs to regulate spacecraft temperature. NASA issued a ROD selecting the proposed action on October 20, 1995. While the 1995 Cassini EIS analysis used the best information available at that time, NASA and DOE continued to evaluate additional accident scenarios specific to the Cassini spacecraft and its launch vehicle and trajectory. Substantial changes to the safety analysis resulted in NASA determining a need for a Supplemental EIS for the Cassini Mission. The proposed action and action alternative differentiated between primary and secondary launch opportunities and both planned to use three RTGs and up to 129 RHUs. NASA issued a Supplemental ROD selecting the proposed action on August 12, 1997. The Cassini launch occurred at CCAFS on October 15, 1997. Website: https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19990054126.pdf

- **Final Environmental Impact Statement for the Mars Exploration Rover** – The purpose of the Mars Exploration Rover (MER) was to conduct surface water observations on Mars. Under the proposed action, the MER-2003 project involved two launches, MER-A and MER-B, of identical spacecraft from CCAFS. Each rover required eight RHUs as a heat source. NASA issued a ROD selecting the proposed action in January 2003. The two MER launches occurred at CCAFS on June 10, 2003, and July 7, 2003. Website: https://spacescience.nasa.gov/admin/pubs/mereis/index.htm

- **Final Environmental Impact Statement for the Mars Exploration Program** – The purpose of the Mars Exploration Program was to further the program's science goals by continuing the exploration and characterization of the planet Mars. The proposed action (Alternative 1) consisted of a long-term program that would send at least one spacecraft to Mars during each launch opportunity at CCAFS or VAFB extending through the first two decades of the twenty-first century. Alternative 2 consisted of NASA continuing to explore Mars through 2020, but on a less frequent, less comprehensive, mission-by-mission basis from CCAFS or VAFB. Under Alternative 1 and Alternative

2, some spacecraft could use radioisotope power systems (RPSs) for continuous electrical power and RHUs for thermal control. NASA issued a ROD selecting Alternative 1 in June 2005.

- **Final Environmental Impact Statement for the Mars 2020 Mission** – The purpose of the Mars 2020 mission is to continue conducting comprehensive science on the surface of Mars and demonstrate technological advancements in the exploration of Mars. The Action Alternatives would implement different power sources for the Mars Rover, including RPS (Alternative 1, which is NASA's preferred alternative), solar arrays (Alternative 2), and solar arrays and RHUs (Alternative 3) to continually provide heat and electrical power to the rover. NASA issued a ROD selecting Alternative 1 on January 27, 2015. The launch is scheduled for the July–August 2020 launch opportunity. Website: https://mars.nasa.gov/mars2020/files/mep/Mars2020_Final_EIS.pdf

The RHUs used in NASA are manufactured and assembled at three DOE facilities, including Los Alamos National Laboratory in New Mexico, Oak Ridge National Laboratory in Tennessee, and Idaho National Laboratory in Idaho. DOE is also responsible for the transportation of RHUs to the CCAFS or KSC launch site. The potential environmental impacts of these activities have previously been addressed in the following DOE NEPA documentation:

- **Environmental Assessment of the Import of Russian Pu-238** – DOE prepared an EA for the import of Plutonium-238 (Pu-238) from Russia. The EA addressed the impacts of importing the Pu-238 from Russia and the processing of the fuel within the United States. The FONSI was signed on June 25, 1993. Website: http://energy.gov/sites/prod/files/nepapub/nepa_documents/RedDont/EA-0841-FONSI-1993.pdf.

- **Final Programmatic EIS for Accomplishing Expanded Civilian Nuclear Energy Research and Development and Isotope Missions in the United States, Including the Role of the Fast Flux Test Facility** – Presented an evaluation of the environmental impacts associated with the proposed expansion of nuclear capabilities for nuclear energy research and development activities and the production of Pu-238 to support future NASA space exploration missions. The ROD was signed on January 26, 2001. Website: https://www.energy.gov/nepa/downloads/eis-0310-final-programmatic-environmental-impact-statement

- **Environmental Assessment for the Future Location of Heat Source/Radioisotope Power System Assembly and Test Operations Currently Located at the Mound Site** – The FONSI was signed on August 30, 2002. Website: https://www.energy.gov/sites/prod/files/migrated/nnsa/2017/11/f43/064_DOE%202003%20ISCORS.pdf

- **Supplemental Analysis Programmatic EIS for Accomplishing Expanded Civilian Nuclear Research and Development and Isotope Production Missions in the United States, Including the Role of the Fast Flux Test Facility** – Analyzed proposed changes in transportation and storage of neptunium-237, the starting feed material for production of Pu-238. The proposed change is to move the neptunium-237 storage location from Oak Ridge National Laboratory in Tennessee to Argonne National Laboratory in Idaho. The ROD was signed on August 5, 2004. Website: https://www.energy.gov/sites/prod/files/nepapub/nepa_documents/RedDont/EIS-0310-SA-01-2004.pdf

- **Final Site-wide EIS for Continued Operation of Los Alamos National Laboratory** Analyzed the potential impacts associated with the continued operation of Los Alamos National Laboratory. The primary effects were associated with public risk due to radiation exposure, collective worker risk due to radiation exposure, socioeconomic effects due to employment changes, electrical power and water demand, waste management, and transportation. A classified appendix assesses the potential impacts of terrorist acts. The ROD, as amended, was signed in July 2011. Website:

https://www.energy.gov/nepa/downloads/eis-0380-final-site-wide-environmental-impact-statement

- **Supplemental Analysis for the Nuclear Infrastructure Programmatic EIS for Pu-238 Production for Radioisotope Power Systems**– Analyzes the potential environmental impacts associated with DOE's maintaining the necessary nuclear material and infrastructure to supply Pu-238-fueled RPSs to support NASA's missions. The DOE determined that there are no significant changes from this Supplemental Analysis and the 2001 ROD from the 2004 Supplemental Analysis can be implemented. Website: http://energy.gov/sites/prod/files/2013/09/f2/EIS-0310-SA-02-2013_0.pdf.