National Aeronautics and Space Administration

Final
Environmental Assessment for the Dragonfly Mission

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Science Mission Directorate
National Aeronautics and Space Administration
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Acronyms and Abbreviations

Acronym	Definition
°F	degree(s) Fahrenheit
µCi/m^2	microcuries per square meter
APL	Johns Hopkins University Applied Physics Laboratory
ARPA	Archaeological Resources Protection Act
CCAFS	Cape Canaveral Air Force Station
CCSFS	Cape Canaveral Space Force Station
CEQ	Council on Environmental Quality
CFR	*Code of Federal Regulations*
CNS	Canaveral National Seashore
CRM	cultural resource manager
CZMA	Coastal Zone Management Act
DHS	U.S. Department of Homeland Security
DOE	U.S. Department of Energy
DSM	Deep Space Maneuver
EA	environmental assessment
EDL	entry, descent, and landing
EGA	Earth gravity assist
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
GPHS	general purpose heat source
HPO	Historic Preservation Officer
IAEA	International Atomic Energy Agency
ICRMP	Integrated Cultural Resources Management Plan
ICRP	International Commission on Radiological Protection
INL	Idaho National Laboratory
kg	kilogram(s)
km	kilometer(s)
km^2	square kilometer(s)
KSC	Kennedy Space Center

lb	pound(s)
LC	launch complex
LWRHU	light weight radioisotope heater unit
MBTA	Migratory Bird Treaty Act
MEI	maximally exposed individual
MINWR	Merritt Island National Wildlife Refuge
MMPA	Marine Mammal Protection Act
MMRTG	multi-mission radioisotope thermoelectric generator
MSL	Mars Science Laboratory
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act of 1969
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOA	Notice of Availability
NPS	National Park Service
NRHP	National Register of Historic Places
NSPM-20	*Presidential Memorandum on a Launch of a Spacecraft Containing Space Nuclear Systems*
OSIRIS-REx	Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer
Pu-238	Plutonium-238
Pu-238	Plutonium-238
RADCC	Radiological Control Center
rem	Roentgen Equivalent Man
RHU	radioisotope heater unit
RPS	radioisotope power systems
RTG	radioisotope thermoelectric generator
SHPO	State Historic Preservation Office
SJRWMD	St. Johns River Water Management District
SLC	space launch complex
SLD 45	Space Launch Delta 45
SMD	Science Mission Directorate
SpaceX	Space Exploration Technologies Corporation
U.S.	United States
U.S.C.	*United States Code*
USACE	U.S. Army Corps of Engineers
USAF	U.S. Air Force
USFWS	U.S. Fish and Wildlife Service
USSF	U.S. Space Force

SECTION 1

Purpose and Need for the Proposed Action

1.1 Introduction

The National Aeronautics and Space Administration (NASA) has prepared this Environmental Assessment (EA) to analyze the environmental impacts of launching the proposed New Frontiers Program's Dragonfly mission, which would use radioisotope power systems (RPS). The Dragonfly mission would include a multi-rotor vehicle, hereafter referred to as a rotorcraft lander, which would land on the surface of Saturn's largest moon, Titan. The mission would explore multiple locations on the surface of Titan and investigate the surface chemistry, atmospheric and surface properties, subsurface properties, liquid reservoirs, and areas where liquid water and complex organic materials that are key to life may have once existed. The launch would take place at the U.S. Space Force's (USSF's) Cape Canaveral Space Force Station[1] (CCSFS) or NASA's Kennedy Space Center (KSC) in Brevard County, Florida, no earlier than June 2027; however, the launch schedule is subject to change.

NASA is the lead federal agency for this Proposed Action. The U.S. Department of Energy (DOE) and the USSF are cooperating agencies. DOE's cooperating agency role stems from its responsibility in producing special nuclear material and its ownership of RPS, including the multi-mission radioisotope thermoelectric generators (MMRTGs) and the radioisotope heater units (RHUs) used by NASA. USSF is a cooperating agency because it manages the launch facilities at CCSFS and the Eastern Range and additionally has expertise in launches that include the use of nuclear materials at these locations. This EA has been prepared in accordance with the National Environmental Policy Act of 1969 (NEPA), as amended (*United States Code* [U.S.C.] Title 42, Section 4321, *et seq*.); the Council on Environmental Quality (CEQ) regulations for Implementing the Procedural Provisions of NEPA (*Code of Federal Regulations* [CFR] Title 40, Parts 1500 through 1508); and NASA's NEPA implementing regulations (14 CFR Subpart 1216.3) and policy. The NEPA process for the Dragonfly mission began prior to the promulgation of the 2020 CEQ revisions to 40 CFR Part 1500; consequently, this document has been written in accordance with the preceding 1978 regulations. This EA covers the potential use of radioisotope power and heating sources associated with the Dragonfly mission; all aspects associated with routine launches at either KSC or CCSFS are covered under existing NEPA documentation (NASA, 2011).

1.2 Background

1.2.1 New Frontiers Program

The Dragonfly mission is a part of NASA's New Frontiers Program (referred to as the Program) managed by the Planetary Missions Program Office under NASA's Science Mission Directorate (SMD). In 2002, the U.S. Congress approved NASA's establishing a program named in honor of John F. Kennedy's 1961 speech in which he stated, "We stand today on the edge of a new frontier." The Program encourages scientific teams to propose missions in response to an Announcement of Opportunity developed based on the National Research Council's 2013–2022 Decadal Survey, *Vision and Voyages for Planetary Science in the Decade* (National Research Council, 2012). The objective of the Program is to use innovative and effective approaches to accomplish specific solar system exploration goals that add to humankind's understanding of the solar system. The goals are prioritized by the planetary science community and the missions are awarded on a competitive peer-reviewed basis. The Program seeks to improve performance through the use of validated new technology and through commitment to, and control of, design, development, and

[1] On December 9, 2020, the Cape Canaveral Air Force Station (CCAFS) and Patrick Air Force Base were both redesignated as Space Force installations. Subsequently, on May 11, 2021, the 45th Space Wing was redesignated as Space Launch Delta 45.

operations costs. The Decadal Survey advises NASA to conduct two New Frontiers Program missions per decade (National Research Council, 2012).

In 2019, NASA selected the Dragonfly mission as part of the Program from a 2016 competitive announcement of opportunity. Dragonfly is the fourth mission approved under the New Frontiers Program. Previous missions under the Program include the following:

- **New Horizons** launched from Cape Canaveral Air Force Station (CCAFS) in January 2006 and flew through Pluto's system in 2015. The mission conducted scientific investigations of Pluto and its moons. The spacecraft arrived at and observed Kuiper Belt object Arrokoth (original designation 2014 MU69) in January 2019 and continues to explore the Kuiper Belt at this time.
- **Juno** launched from CCAFS in August 2011, began orbiting Jupiter in July 2016, and will continue mission operations through September 2025 or until the spacecraft's end of life. Juno is studying the gas giant's gravitational and magnetic fields and vast atmosphere, as well as several of its moons.
- **Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer (OSIRIS-REx)** launched from CCAFS in September 2016, approached the asteroid Bennu in 2018, and collected a sample of surface material in 2020. OSIRIS-REx will return to Earth in September 2023 carrying the sample from the asteroid. This will be a historic first mission achievement for the United States (U.S.).

1.2.2 Understanding Titan

Previous NASA missions to Saturn include Pioneer 11 (1973), Voyager 1 (1977), Voyager 2 (1977), and Cassini-Huygens (1997). The Cassini-Huygens mission included flybys to map Titan's surface and the deployment of the Huygens probe to perform in situ measurements of the atmosphere and surface of Titan. Data from the Cassini-Huygens mission indicate that Titan may contain the prebiotic chemistry necessary for life. Since the end of the Cassini-Huygens mission, NASA has identified a knowledge gap regarding the chemistry and the potential for life on Titan (Lorenz et al., 2018).

Saturn's largest moon, Titan, is the second largest moon in the entire solar system. Because the surface consists of rock-hard water ice, Titan is classified as an icy moon, and because of its deep interior water ocean, it is classified as an ocean world. Titan's dense atmosphere supports a methane cycle of clouds, rain, lakes, and seas, similar to Earth's water or hydrological cycle. The abundant complex organic material accessible on Titan's surface makes it an ideal destination for studying the conditions necessary for extraterrestrial life and the kinds of chemical interactions that occurred before life developed on Earth (APL, 2020a; National Research Council, 2003).

A few notable facts about Titan include the following (APL, 2020a):

- **Atmosphere:** Dense and extended (four times denser than Earth's) and composed of nitrogen (95%) and methane (5%), with small amounts of carbon-rich compounds.
- **Average Surface Temperature:** 94 Kelvin (-290 degrees Fahrenheit [°F]).
- **Bedrock:** Primarily water ice.
- **Three Liquid Systems:** Water, methane, and ethane.
- **Length of Day:** One Titan day is equal to approximately 16 Earth days.

1.3 Purpose and Need for the Proposed Action

NASA needs to fulfill the congressional mandate to carry out the Program objective. The proposed Dragonfly mission would satisfy this mandate by exploring Titan in partnership with the Johns Hopkins University Applied Physics Laboratory (APL). Additionally, the Planetary Science Decadal Survey identified Titan as a high priority for the planetary science community because it is an ocean world and the only moon in our solar system with a dense atmosphere. Titan is potentially the most Earth-like world in our solar system,

which makes it an ideal location for studying prebiotic chemistry and habitability as well as search for potential biosignatures for extraterrestrial life.

1.4 Organization of the Environmental Assessment

NASA has prepared this EA to provide an efficient and comprehensive analysis of the potential environmental effects associated with the implementation of the proposed Dragonfly mission.

This EA is organized as follows:

- **Section 1**, ***Purpose and Need for the Proposed Action***, provides background information relevant to 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 Proposed Action and presents an analysis of potential direct, indirect, and cumulative impacts to environmental resources.
- **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**, ***Distribution***, provides a list of agencies and individuals who were contacted for information in the preparation of this document and to whom the EA 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 EA.

1.5 Public Outreach and Involvement

The Notice of Availability (NOA) of the Draft EA was advertised in the *Florida Today* and *Orlando Sentinel* newspapers on April 24, 2022, as included in Appendix 1.5A. The Draft EA and associated NOA are also posted on the NASA NEPA Public Reviews webpage maintained by the NASA Environmental Management Division at NASA Headquarters (https://www.nasa.gov/content/public-reviews). Public comments were accepted through May 24, 2022. NASA also printed a limited number of hard copies of the Draft EA, which were available upon request by contacting hq-draftdragonflyeacmts@mail.nasa.gov. Copies of the Draft EA were 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

One set of comments was received on the Draft EA. The set of comments and responses to the comments are provided in Appendix 1.5B. When necessary, the Final EA was updated in response to these comments.

A Notice of Availability of the Final EA will also be posted on the NASA NEPA Public Reviews webpage (https://www.nasa.gov/content/public-reviews) and advertised in the *Florida Today* and *Orlando Sentinel*.

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SECTION 2

Description of the Proposed Action and No Action Alternative

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

2.1 Proposed Action

During its 10-year (120-month) mission[2], the Dragonfly mission would explore diverse Earth-like environments on Titan, bringing scientists closer to understanding the habitability of other planets and the origin of life itself. The rotorcraft lander instruments would study how far the development of life or pre-biological chemistry has progressed and investigate Titan's atmospheric, surface, and subsurface properties, including its methane ocean and liquid reservoirs. A detailed explanation of the Earth-like environment of Titan, as well as a description of Dragonfly mission, can be seen at this website: https://www.nasa.gov/dragonfly/dragonfly-overview/index.html.

The Dragonfly mission's science objectives include the following (Turtle et al., 2020):

- Analyze chemical components and processes that produce biologically relevant compounds.
- Measure atmospheric conditions, identify methane reservoirs, and determine transport rates.
- Investigate processes that mix organics with surface liquid water reservoirs or subsurface oceans.
- Search for chemical evidence of water-based or hydrocarbon-based life.

The mission would also take scientific measurements of Titan's surface and atmosphere during flights over the surface of Titan throughout the mission. The Dragonfly mission's surface and atmospheric science activities include the following (APL, 2020b):

- Analyze samples of surface materials with a mass spectrometer to search for chemical compounds that produce biologically relevant processes.
- Measure bulk elemental surface composition with a neutron-activated gamma-ray spectrometer.
- Monitor atmospheric and surface conditions, including diurnal and spatial variations, with meteorology instruments.
- Use imaging to characterize geologic features.
- Perform seismic studies to investigate subsurface activity and structure.

In-flight scientific activities include the following (APL, 2020b):

- Atmospheric measurements.
- Aerial images of surface geology.
- Surface measurements and scouting of sites of interest.

2.1.1 Mission Description

The Dragonfly mission's vehicle consists of an eight-bladed rotorcraft lander (Figure 2-1), the size of a subcompact car measuring approximately 3.4 meters (approximately 11 feet) by 1.6 meters (approximately 5 feet), which is designed to visit multiple sites across Titan's varied terrain. The mission would include four

[2] The mission duration starts at launch and includes cruise (approximately 7 years) and surface operations (approximately 3 years).

distinct phases: (1) launch phase; (2) cruise phase; (3) entry, descent, and landing (EDL) phase; and (4) the surface operations and science mission phase (APL, 2020a).

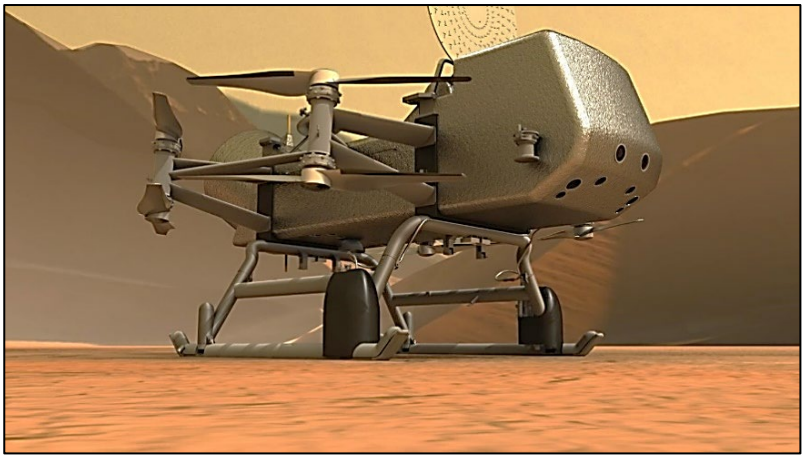
The first phase of the mission is the launch phase. The Dragonfly spacecraft would be launched from CCSFS or KSC in Brevard County, Florida, no earlier than 2027. However, this launch date is subject to change. Launching at a later date will not affect Dragonfly's science return or capabilities once at Titan (NASA, 2020d), and it would not change or cause an increase to the consequence analysis discussed in this EA.

The second and longest phase of the mission is the cruise phase. The mission cruise phase would begin when the spacecraft separates from the launch vehicle and would end prior to atmospheric entry at Titan. The cruise phase would last up to 10 years, depending on the spacecraft's cruise trajectory. The spacecraft's cruise trajectory from Earth to Titan is discussed further in Section 2.1.5, *Cruise Trajectory*.

The third phase of the mission, the EDL phase, would begin when the entry vehicle reaches an altitude of approximately 1,270 kilometers (km) (789 miles) above the surface of Titan and would end with a soft touchdown of the rotorcraft lander on Titan's surface.

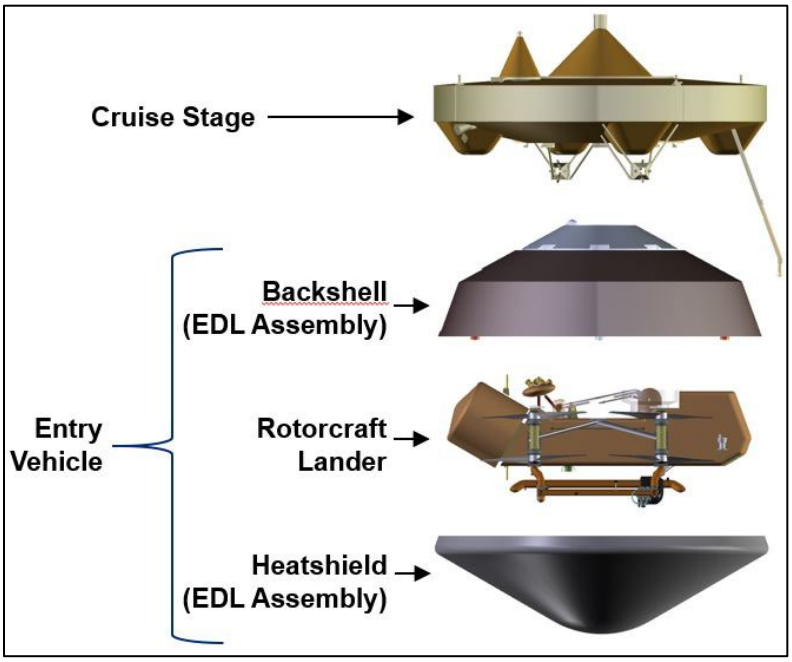
The final mission phase begins when the spacecraft lands on Titan. The initial landing site would be in a dune field, known as the Shangri-La Sand Sea, near Titan's equator. This location provides a relatively safe initial landing location and provides for diverse sampling opportunities. Once landed, the rotorcraft lander would explore nearby locations in short flights, building up to a series of longer "leapfrog" flights. Eventually, the rotorcraft lander would reach the Selk impact crater on Titan's surface, where past liquid water may have mixed with complex organics. During the 3.3-year duration of the mission, the rotorcraft lander would fly up to 180 km (108 miles) (APL, 2020b).

Figure 2-1. Conceptual Rendering of Dragonfly Rotorcraft Lander



2.1.2 Spacecraft Description

Figure 2-2. Conceptual Rendering of Dragonfly Spacecraft Components



The design of the spacecraft and its science payload considers the science objectives and the unique environment of Titan. The spacecraft design is based on previous successful designs and would include three main components: the cruise stage, the EDL assembly, and the rotorcraft lander, as shown on Figure 2-2 (APL, 2020a).

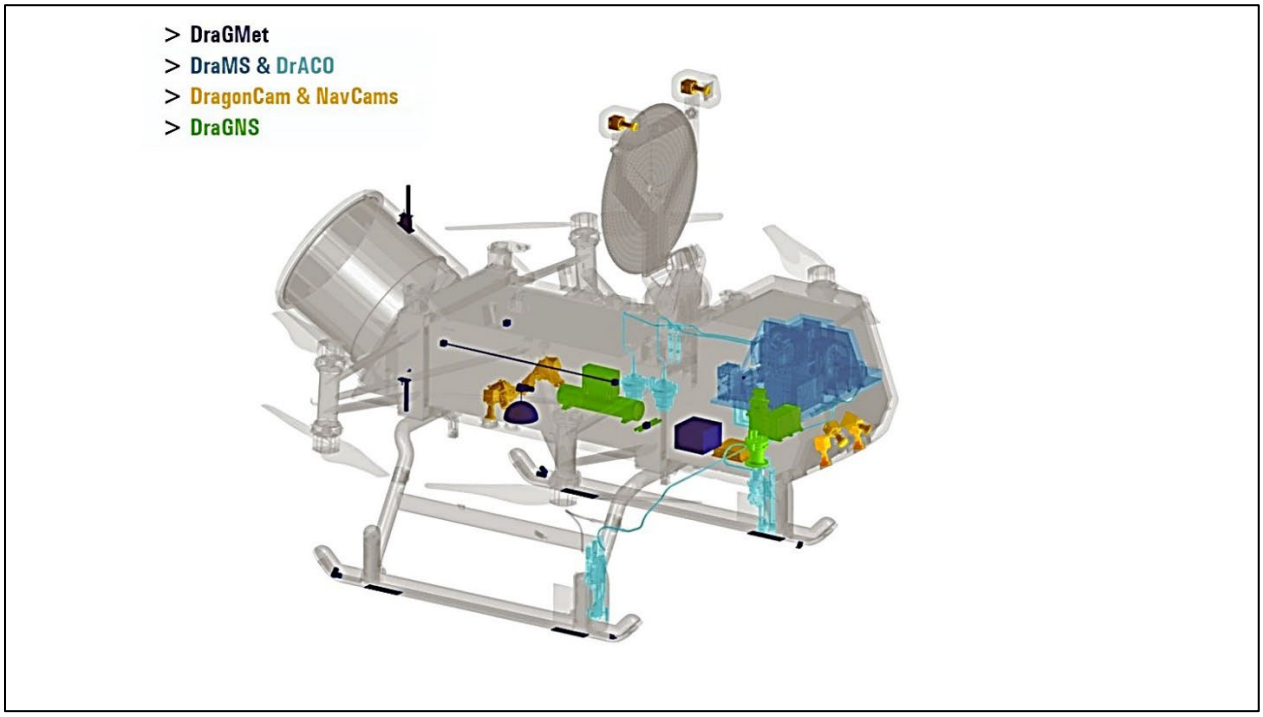
The cruise stage supports the necessary services to support the cruise trajectory from Earth to Titan. Supported services include communications with Earth, propulsion, and thermal control of the vehicle. The cruise stage is a relatively simple structure similar to the system used by NASA on missions such as the Phoenix Mars mission (2007) and the Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) Mars mission (2016). The cruise stage separates from the entry vehicle as it reaches Titan's atmosphere. The cruise stage is not protected and will burn up as it enters Titan's atmosphere.

The entry vehicle would contain the systems that enter Titan's atmosphere and deliver the rotorcraft lander to its designated landing site on the surface of Titan. The entry vehicle is made up of the EDL assembly with the rotorcraft lander inside. The EDL assembly is the aeroshell that includes a heatshield as its thermal protection system, a backshell that houses the parachute deceleration system, a low gain antenna, and the separation systems. The EDL assembly protects the lander during atmospheric entry and descent and delivers it to a specific release point approximately 1.2 km (0.75 mile) above Titan's surface, at which point the lander drops off from the backshell and uses its rotorcraft lander flight system to safely land on the surface.

The rotorcraft lander carries several scientific instruments, as shown in the conceptual rendering included as Figure 2-3. Each instrument serves a specific and important purpose, described as follows (APL, 2020a, 2020b; NASA, 2020a):

- **Mass Spectrometer (DraMS)**: An instrument used to analyze material from the surface directly under the lander, identify chemical components relevant to astrobiology and to detect patterns and functionalities in the molecules present, even if they are not carbon-based.
- **Drill for Acquisition of Complex Organics (DrACO)**: A sample acquisition and delivery system used to capture Titan's surface and near-surface material to deliver to DraMS.
- **Gamma-Ray Neutron Spectrometer (DraGNS)**: An instrument used to help analyze surface composition around the lander.
- **Geophysics and Meteorological Package (DraGMet)**: A suite of geophysical and meteorological sensors, including a seismometer, to detect Titanquakes and understand the moon's interior and its liquid subsurface ocean.
- **Camera Suite (DragonCam and NavCams)**: A variety of cameras used to image Titan's terrain and help the rotorcraft lander navigate and determine landing areas of scientific interest.

Figure 2-3. Conceptual Rendering of Dragonfly Rotorcraft Lander Instruments



2.1.3 Launch Location

The Dragonfly mission spacecraft would be launched from either CCSFS or KSC, both of which are located on the east coast of Florida in Brevard County. Previous NASA SMD missions using RPS have launched from these locations, and KSC and CCSFS have the trained personnel and the contingency requirements in place to appropriately approve, conduct, and respond to missions using radioisotope-based systems.

2.1.3.1 Description of CCSFS

CCSFS is operated by Space Launch Delta 45 (SLD 45) at Patrick Space Force Base, which is located 24 km (15 miles) south of CCSFS (Figure 2-4). SLD 45 provides launch facilities and services to support NASA, the U.S. Department of Defense, and commercial launch service providers, and is responsible for overseeing the preparation and launching of U.S. Government and commercial spacecraft from CCSFS. SLD 45 also operates the Eastern Range for the USSF. 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 CCSFS, mainland annexes, and down-range tracking stations on islands in the Caribbean Sea and the South Atlantic Ocean. All launch countdown activities and many NASA operations use Eastern Range Operations.

CCSFS encompasses 66 square kilometers (km^2) (16,198 acres); its northern boundary abuts KSC, and its southern boundary abuts the City of Port Canaveral, a tourist and cruise ship port. CCSFS is bordered to the east by the Atlantic Ocean and to the west by the Banana River. These water bodies serve as natural buffers to the launch facility operations. Natural areas near CCSFS include the Merritt Island National Wildlife Refuge (MINWR) and the Canaveral National Seashore (CNS), both of which contain biological and cultural resources (USAF, 2020a, 2020b).

CCSFS has four active space launch complexes (SLCs): SLC-37, SLC-40, SLC-41, and SLC-46. An additional landing site, referred to as SLC-13 (Landing Zone-1 and Landing Zone-2), is leased to Space Exploration Technologies Corporation (SpaceX) specifically for landing reusable boosters. Three additional SLCs are in various stages of design or construction: SLC-16, SLC-20, and SLC-36.

The land uses within CCSFS include open fields, an airfield, SLCs, supporting infrastructure, and areas of native habitat, including scrub habitat and coastal dunes. Several SLCs lie just inland of the beach dune community on CCSFS, but most of these SLCs are not active and are abandoned in place (USAF, 2020a).

2.1.3.2 Description of KSC

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

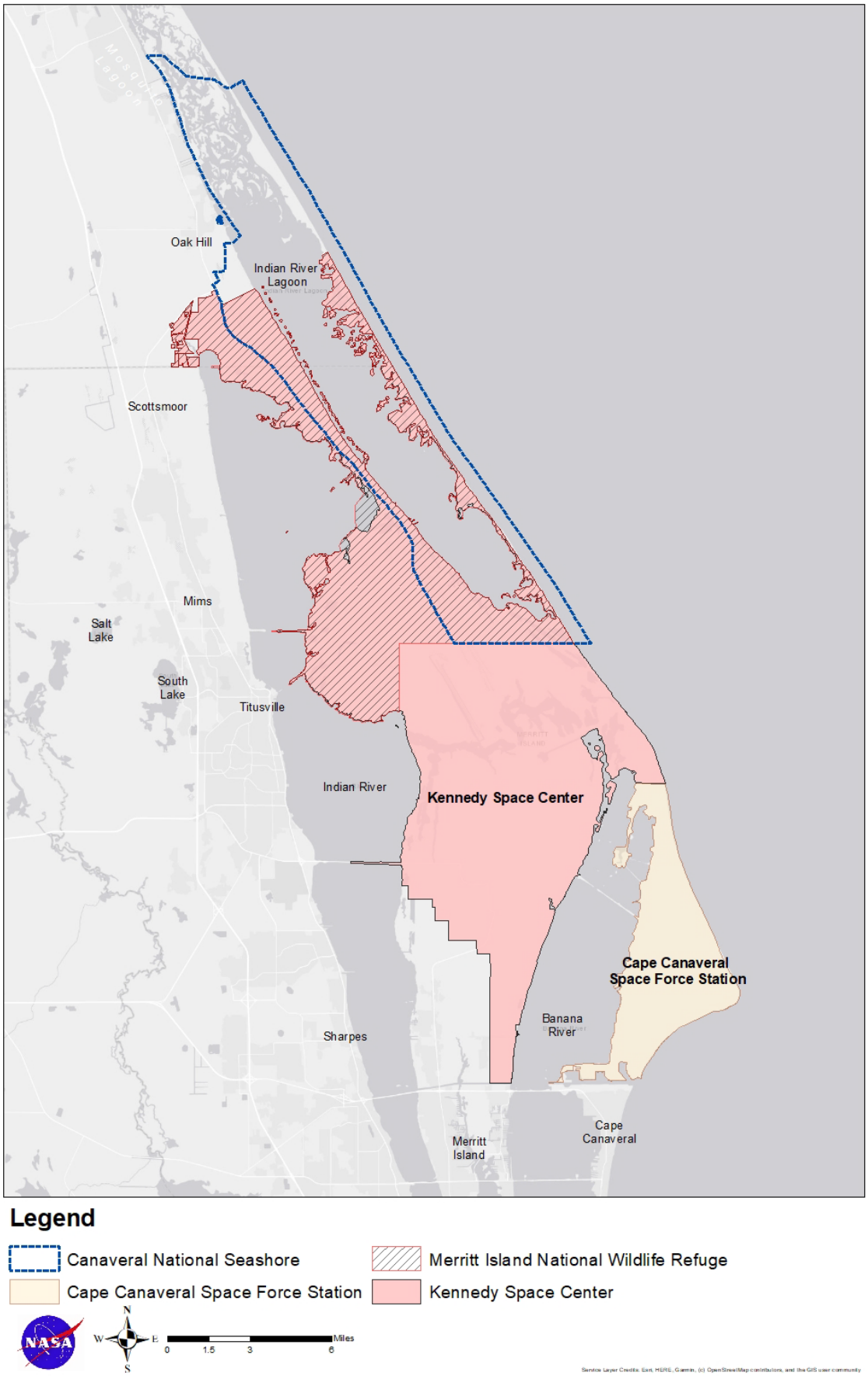
- Acquisition and management of launch services and commercial crew development.
- Launch vehicle and spacecraft processing, launching, landing and recovery, operations, and sustainment.
- Payload and flight science experiment processing, integration, and testing.
- Designing, testing, operating, and 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 its Nuclear Risk Assessments, which supported previous NEPA documents.

KSC has three active launch complex (LC) sites: LC-39A, LC-39B, and most recently, LC-48. The remaining LCs are either deactivated or inactive (USAF, 2018). 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 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 CCSFS. The northernmost end of the Banana River (another brackish water lagoon) lies between Merritt Island and CCSFS 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 system. A portion of the seashore on the easten 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 KSC and CCSFS. Because much of the installation is a restricted area and only 9% of the land is developed, the site also serves as an important wildlife sanctuary. The Indian River Lagoon, MINWR, and CNS 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).

Figure 2-4. KSC and CCSFS Launch Infrastructure



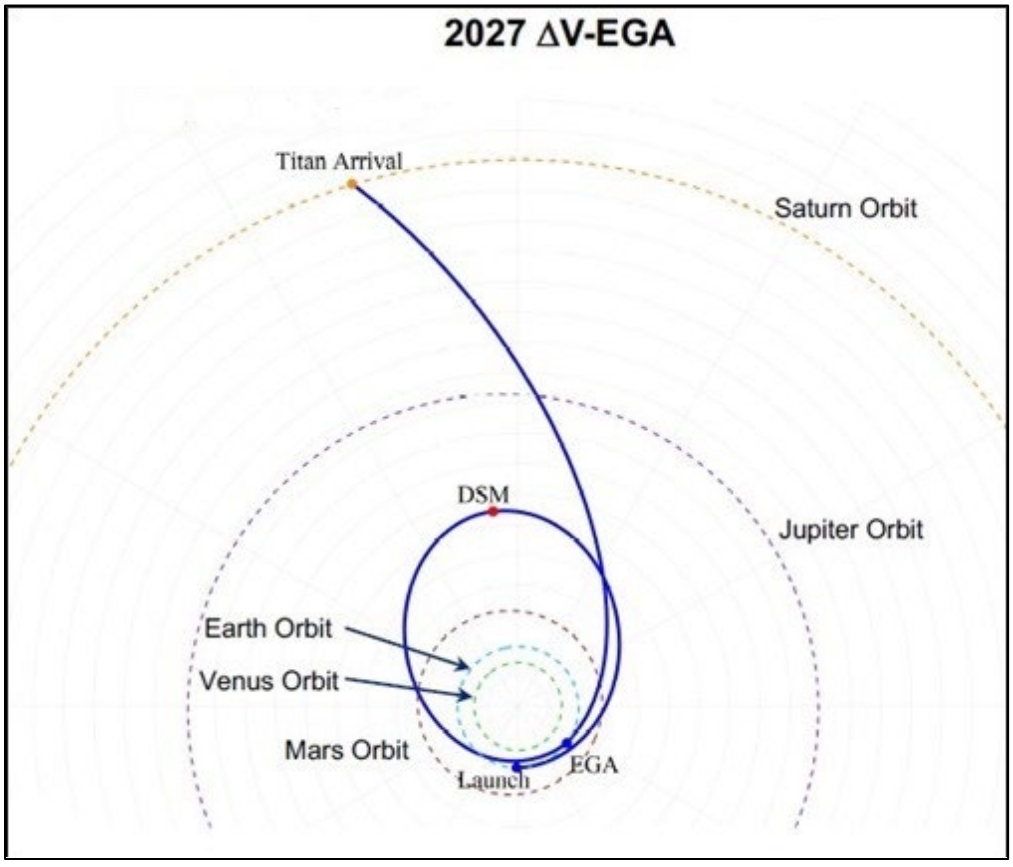
2.1.4 Launch Vehicle

A launch vehicle, also known as a rocket, provides the lift and velocity needed for a spacecraft to achieve the desired trajectory. The launch vehicle for the Dragonfly mission has not been formally chosen. It is reasonably foreseeable that environmental impacts associated with launch vehicles would be in keeping with the impacts disclosed in the environmental document of the selected vehicle and additionally in compliance with NASA's launch vehicle certification process. Because the environmental impacts of NASA's launch vehicles have been previously assessed and publicized, the impacts associated with the use of these launch vehicles are not discussed further in this EA. If NASA becomes aware of significant new circumstances or information relevant to environmental concerns and bearing on the Proposed Action or its impacts, NASA may prepare a supplemental EA or consider whether the new information triggers the need to prepare an environmental impact statement (EIS).

2.1.5 Cruise Trajectory

The prime launch window for the Dragonfly mission is in June 2027, with an arrival in the mid-2030s, though these dates are subject to change. The mission trajectory has not been finalized and is dependent on the launch vehicle selected for the Dragonfly mission. The current notional trajectory option includes using one Earth flyby and a Deep Space Maneuver (DSM) to obtain a suitable cruise trajectory to Titan, as shown on Figure 2-5. A gravity assist is the use of the orbit and gravity of a planet to alter the path and speed of a spacecraft and is typically implemented to save propellent or enable distant missions within the limits of available propellent loads. Importantly, the mission would be designed to ensure that during an Earth gravity assist (EGA) maneuver, the spacecraft would maintain an altitude of at least 450 km (280 miles) from the Earth, and the probability of an inadvertent Earth re-entry would be less than 1 in 1,000,000 (APL, 2020c, 2020d).

Figure 2-5. Conceptual Dragonfly Mission Trajectory



2.1.6 Nuclear Components

The rotorcraft lander would use a single MMRTG as the source of heat and electrical power for its systems and instruments. In addition, the rotorcraft lander's thermoelectric environment could be augmented by the heat output of up to 43 RHUs. The use of RHUs is not a component of the current Dragonfly design; however, the RHUs could supplement the MMRTG to keep the rotorcraft lander onboard systems at proper operating temperatures during the trip to Titan and in the extremely cold environment of Titan. In addition, the rotorcraft lander would include two small hardware sources, including the Dragonfly Gamma-ray and Neutron Spectrometer and a Pulse Neutron Generator, which would add an additional 27 Ci when combined. The amount of added material would not result in any noticeable increase in environmental impact; therefore, these sources are not discussed further. An analysis that includes the use of a single MMRTG and up to 43 RHUs is included in this EA because of the potential need for RHUs. In case NASA does not include the RHUs in the Dragonfly design, this EA is still considered satisfactory for compliance with NEPA regulations. The following is a detailed description of each of these systems.

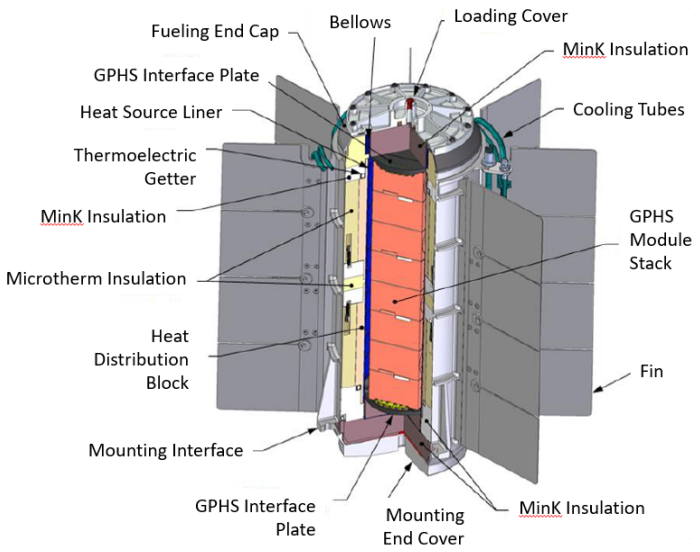
2.1.6.1 Multi-Mission Radioisotope Thermoelectric Generator

An MMRTG is a space nuclear power system that converts heat into electricity without using moving parts; instead, an MMRTG directly converts heat from the natural decay of Plutonium-238 (Pu-238) into electricity. The MMRTG is approximately 64 centimeters (25 inches) in diameter by 66 centimeters (26 inches) long and weighs 45 kilograms (kg) (94 pounds [lb]). The MMRTG contains approximately 4.8 kg (10.6 lb) of plutonium dioxide fuel, which provides approximately 2,000 watts of thermal power and 120 watts of electrical power at the time of fueling the MMRTG.

The MMRTG includes eight General Purpose Heat Source (GPHS) modules, which contain and protect the Pu-238 fuel. The GPHS modules are engineered and constructed with multiple protective design features that substantially mitigate the risk of a release and dispersal of nuclear material in an accident situation. These safety features include the ceramic form of the Pu-238 heat source material, iridium metal alloy cladding, graphite sleeves that protect the fuel, and the rugged carbon-fiber material that forms the shell (Figure 2-6).

Several types of radioisotope thermoelectric generators (RTGs) have been used successfully on 32 previous U.S. missions. Of these, 24 of these were NASA missions, including six Apollo flights and the Pioneer (1972), Viking 1 and 2 (1975), Voyager 1 and 2 (1977), Galileo (1989), Ulysses (1990), Cassini (1977), New Horizons (2006), Mars Science Laboratory (MSL) Curiosity (2011), and Mars 2020 Perseverance (2020) missions. The Dragonfly mission would be the 25th NASA mission with RTGs. The Dragonfly mission would employ an MMRTG similar to that used on the MSL and Mars 2020 missions. The interfaces and spacecraft accommodations, such as the external cooling loops and radiative fins, may be slightly different from those used on previous Mars missions, but the base generator will remain unchanged.

Figure 2-6. MMRTG Configuration



The MMRTG would be a mission-enabling technology for the Dragonfly mission, as it provides a continuous and simultaneous source of electric power and heat to warm the interior of the lander while on Titan, which has an average temperature of -179 °C (94 Kelvin or -290°F). The radiant heat (that is, thermal power) is a crucial component of maintaining an adequate operating temperature in Titan's cold environment. For power storage, the MMRTG would also be used to charge an 11.7-kilowatt-hour lithium-ion battery used for operations.

2.1.6.2 Radioisotope Heater Units

RHUs are small devices that use the natural decay of Pu-238 to provide thermal energy to heat electronics. This heat is transferred to spacecraft structures, systems, and instruments by direct radiant energy or heat pipes, without moving parts or electronic components. Consequently, RHUs are among the simplest of all space nuclear devices.

By using RHUs in conjunction with an MMRTG, the Dragonfly mission planners can allocate scarce electrical power to operate 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.

The current-generation RHUs are referred to as light weight radioisotope heater units (LWRHUs) and have heated deep space missions since the 1980s, though previous versions of RHUs have been used since the 1960s. An LWRHU contains a fuel pellet, about the size of a pencil eraser, which contains 2.7 grams (0.1 ounce) of plutonium dioxide (the quantity of Pu-238 in the plutonium dioxide is less than 2.7 grams). The entire LWRHU is approximately the size of a C-cell battery (Figure 2-7) and releases about 1 watt of heat (NASA, 2014a). Combined, the MMRTG and 43 LWRHUs would contain 4.9 kg (10.8 lb) of plutonium dioxide in total.

Figure 2-7. Radioisotope Heater Unit

Similar to MMRTGs, LWRHUs were designed to withstand most potential accidents without the release of Pu-238 by including multiple layers of protection. The outermost layer of protection is composed of fine-weave, pierced fabric carbon-carbon composite material that provides the primary protection to the metal capsule against impacts resulting from explosions or accidental reentry. Additionally, the outermost layer contains three layers of pyrolytic graphitic insulators that provide thermal protection that limits the heating of the metal capsule containing the fuel pellet in events such as fires and accidental reentry. The innermost level of protection is the platinum-rhodium metal alloy capsule that minimizes the dispersal of the fuel pellet under fires and accidental reentry. Finally, the hot-pressed ceramic fuel pellet itself ensures the Pu-238 is in its most stable form to minimize risk of release 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 tends to break into pieces to minimize the generation of fine dust during extreme impacts, thereby limiting the potential airborne release of Pu-238 (Tate, 1982).

2.2 No Action Alternative

Under the No Action Alternative, NASA would discontinue preparations for the Dragonfly mission, and the spacecraft would not be launched. The No Action Alternative would then necessitate that NASA satisfy the objective of the congressionally mandated New Frontiers Program in another way.

2.3 Alternatives Eliminated from Further Analysis

The following sections provide descriptions of the power and launch location alternatives that were analyzed for the Dragonfly mission but were determined to be infeasible and, therefore, eliminated from further analysis.

2.3.1 Power Alternatives

2.3.1.1 Exclusive Use of Solar Arrays

Titan's distance from the Sun and its dense atmosphere prevent sufficient solar radiation energy from reaching the surface to adequately power the spacecraft's scientific instruments and flight systems. A solar array on Titan would operate at extremely low intensity, in very low temperature conditions, and would consequently produce very low power output. The limited power output from the exclusive use of solar arrays would not meet the needs of the Dragonfly mission. Furthermore, the mass of the solar arrays would be incompatible with atmospheric flight in the Titan environment (NASA, 2020b).

2.3.1.2 Exclusive Use of Batteries

The requirements to conduct scientific measurements at different regions of Titan's surface and the time required to move to these locations result in a core mission duration of 3.3 years. The exclusive use of batteries would not provide sufficient energy needed for operating on Titan for the entire mission duration. A single day of operation on Titan would require approximately 2 tons of batteries. Furthermore, current launch vehicles cannot propel a spacecraft with such batteries for a suitable duration and trajectory. Therefore, the mission trajectory and duration prevent the exclusive use of batteries for surface operations (NASA, 2020b).

2.3.2 Launch Location Alternatives

Historically, KSC and CCSFS have successfully handled and integrated radioisotope materials and technology into spacecraft. Furthermore, KSC and CCSFS have the trained personnel and the contingency requirements in place to appropriately approve, conduct, and respond to missions using nuclear power systems. Currently, other NASA and USSF facilities do not have the capability to conduct a nuclear-enabled mission. Therefore, no other launch facilities were considered in the analysis.

2.4 Resources Analyzed

For the purpose of this analysis, resources have been divided into two groups: (1) resources studied in detail and (2) resources eliminated from further analysis.

2.4.1 Resources Studied in Detail

The only relevant resource concern related to the Proposed Action is the potential for radiation exposure during a mission mishap scenario. All other non-nuclear-related resource concerns, such as exposure to noise during a launch, have been previously addressed in the *NASA Routine Payload EA* (NASA, 2011) and other launch vehicle-specific NEPA documents (SpaceX, 2013; FAA, 2008, 2015, 2017, 2019, 2020; NASA, 2013, 2016; USAF, 2000). Although the specific launch vehicle is currently unknown, only launch vehicles that have undergone the NEPA process will be considered for the Dragonfly mission. This EA evaluates the potential impacts associated with radiation to the following environmental resources in Section 3, *Affected Environment and Environmental Consequences*:

- Nuclear Radiation
- Land Use
- Water Resources
- Biological Resources
- Hazardous Materials
- Cultural Resources

2.4.2 Resource Areas Eliminated from Further Analysis

In accordance with the CEQ directives to focus NEPA 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 Subpart 1502.2), some common resource areas have been eliminated from detailed study in this EA. The rationale for their elimination is summarized as follows:

- **Visual Resources**: The Dragonfly mission would be within the typical visual characteristics of CCSFS and KSC.
- **Noise and Noise-Compatible Land Use**: The noise associated with launches has been analyzed in NEPA documentation for the individual launch vehicles (NASA, 2011; SpaceX, 2013; FAA, 2008, 2015, 2017, 2019, 2020; NASA, 2013, 2016; USAF, 2000).
- **Utilities and Infrastructure**: There would be no substantial changes to existing utilities, building infrastructure, or energy supply under the Proposed Action. The Dragonfly mission would not result in additional resource or utility demands.
- **Environmental Justice**: 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 CCSFS boundary did not contain a disproportionate percentage of minority and low-income populations (EPA, 2020). Although minority and low-income individuals reside within the buffer area, the Proposed Action would not disproportionately impact these individuals; consequently, there is no likelihood for a 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 MMRTGs and RHUs have been addressed in existing DOE NEPA documentation (DOE, 2008, 2013).
- **Children's Environmental Health and Safety Risks**: 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. Although children reside within the buffer area, the Proposed Action would not disproportionately expose children (EPA, 2020). The potential for health effects to children from exposure to nuclear material is considered in Section 3.1, *Nuclear Radiation*.
- **Ambient Air Quality and Climate**: CCSFS is in full attainment of National Ambient Air Quality Standards for criteria pollutants under the Clean Air Act. Previous NEPA documents have analyzed the impacts of launches on air quality and climate. The Dragonfly mission would not result in noticeable changes to the current Clean Air Act criteria pollutants at KSC or CCSFS and would not result in a noticeable increase in greenhouse gas emissions. Furthermore, the Proposed Action would also be in full compliance with KSC and CCSFS's Title V Operating Permits (KSC, 2021; 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, *Nuclear Radiation*.
- **Socioeconomics**: Missions that attract significant public interest often result in socioeconomic benefits both locally (in Brevard County) and regionally because of increased economic activity (hotel room

occupancy, restaurants, merchandising, and similar activities). No additional onsite personnel would be hired to implement the Proposed Action, and no population growth resulting from the Proposed Action is expected. Similar to other launches, there would not be any socioeconomics effects under the Proposed Action. Potential impacts to land use, including nearby seaports, farmland, and recreational areas, are discussed in Section 3.2, *Land Use*.

- **Transportation**: The potential environmental effects associated with the transportation of RHUs and MMRTGs have been addressed in existing DOE NEPA documentation (DOE 2000, 2008, 2013), and no changes to transportation infrastructure are expected from the Proposed Action.
- **Geology and Soils**: In the unlikely event of a release of Pu-238 during a launch accident, the depth of potential soil cleanup outside immediate impact sites would be approximately 2 inches (NASA, 2020c), which would be too shallow to affect geology. Regional soils should be only negligibly affected; potential effects to cropland are discussed in Section 3.2*, Land Use*.
- **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 zones. Federal agencies are responsible for making consistency determinations within coastal zone areas. The Proposed Action area is located within Florida's 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 (Appendix 2.6A).

SECTION 3

Affected Environment and Environmental Consequences

This section provides an explanation of the affected environment for each of the potentially impacted resources, along with an explanation of the potential environmental consequences associated with the Dragonfly mission.

Affected Environment

The following Affected Environment sections provide 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.

The Affected Environment sections are organized by resource type and include 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 CCSFS installation boundaries, as shown on Figure 2-4. 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. Consistent with these requirements, the Environmental Consequences 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 Subpart 1508.27), a determination of significance requires consideration of context and intensity. Accordingly, impacts described in this EA are evaluated in terms of type (beneficial or adverse), context (local or regional), intensity (none, negligible, minor, moderate, or significant), and duration (temporary or permanent). These terms are further defined in the introductory tables in each of the following resource sections.

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

3.1 Nuclear Radiation

3.1.1 Affected Environment

The following sections provide an overview of nuclear radiation, an explanation of the health concerns associated with radiation exposure, and a description of the current radiological conditions at CCSFS 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 are emitted when the nucleus of a radioisotope decays. The particles or waves are considered 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. Radioactive decay generates heat through the interaction of emitted particles or waves with nearby atoms. MMRTGs and RHUs function through the

release of heat from the radioactive decay of Pu-238 (an isotope of the element plutonium). In an MMRTG, a portion of the released heat is converted to electrical power.

3.1.1.2 Health Effects from Radiation Exposure

Humans are constantly exposed to ionizing radiation from both natural and artificial sources, including cosmic radiation (for example, the Sun) and terrestrial radiation (for example, certain rocks and soils). These types of radiation are commonly referred to as background radiation. Common artificial sources of radiation also exist; for example, smoke detectors, cigarette smoke, and certain coatings on camera lenses emit small amounts 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 breathing, they can deposit in internal organs and deliver a radiation dose to tissues (Nuclear Regulatory Commission, 1991).

The International Commission on Radiological Protection 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 (or inhalation) is approximately 1,000 times more effective than eating (or ingesting) for transporting plutonium to the sensitive tissues in the human body. Ingested Pu-238 particles would quickly pass through the digestive system and be excreted, with only a minute fraction being absorbed into the bloodstream. Inhaled Pu-238 particles could be transported to the deep portions of the lungs, depending on the particle size. Generally, particles larger than 5 microns in diameter would be intercepted in the nose or throat, swallowed, and passed through the digestive tract and excreted. Particles smaller than 5 microns in diameter 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 bloodstream. Once Pu-238 has entered the bloodstream, it would be deposited primarily in the liver and bone marrow tissues, creating a potential for cancer if the radiation dose were sufficiently large (ICRP, 1986; National Research Council, 2006). Therefore, most of the radiological impacts associated with mission mishaps are attributed to the potential release of Pu-238 particles in a respirable form. Mishap scenarios that do not result in a release of Pu-238 or that result in a release of Pu-238 in coarse fragments (large particle sizes) are a relatively minor component of potential effects.

The unit of radiation dose measurement to humans 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 a combination of natural background and artificial sources of radiation. The single largest source of radiation exposure to the average resident of the U.S. is medical radiation, which amounts to approximately 0.30 rem per year. Cosmic radiation and radon exposure amount to approximately 0.26 rem per year to an average person in the U.S. This yearly dose of 0.62 rem has not been shown to cause harm to humans, including children and other sensitive populations (Nuclear Regulatory Commission, 2021).

3.1.1.3 Existing Conditions

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

3.1.1.4 Established Nuclear Safety Procedures

Regional Safety Procedures

CCSFS, KSC, the City of Cape Canaveral, and Brevard County have a mutual-aid agreement in the event of emergencies. During launch activities, CCSFS remains in communication with KSC, Brevard County Emergency Management, the Florida Marine Patrol, the U.S. Coast Guard, and the Florida Division of Emergency Management. The CCSFS Range Safety Program 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 the Dragonfly launch approval, a comprehensive set of plans will be developed by NASA to ensure that any launch accident would be met with a well-developed and tested response. NASA's plans are developed in accordance with the National Response Framework (DHS, 2019) and the National Response Framework Nuclear/Radiological Incident Annex (DHS, 2016) in coordination with DOE, USSF, other federal agencies, the State of Florida, Brevard County, and other local governmental organizations. These organizations and agencies could be involved in response to a radiological emergency, as needed (Scott et al., 2012).

Onsite Safety Procedures

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 the 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 a network of 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. Prior to each NASA launch, a joint NASA/USSF 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 Procedures

For incidents that occur post-launch and outside the jurisdiction of the U.S., NASA and DOE would assist the U.S. Department of State in coordinating the U.S. response via diplomatic channels and deploying federal resources as requested. If an impact occurs in the ocean following an accident, NASA and DOE coordinate with the U.S. Department of Homeland Security (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 MMRTGs and RHUs are based on an assessment of technical feasibility, potential risks to recovery personnel, and potential environmental impacts.

3.1.2 Environmental Consequences

The following analysis considers potential radiation exposure after a mission mishap involving a release of Pu-238 during the Dragonfly mission. The concept of a maximally exposed individual[3] (MEI) is used to evaluate potential effects. MEI analysis is a standard method for calculating doses to members of the general public and can be compared to U.S. standards and regulations for exposure limits. The threshold for evaluating the intensity of potential impacts from radiation exposure is based on known exposure limits and established radiation exposure standards, including:

[3] The MEI is a hypothetical individual who–because of realistically assumed proximity, activities, and living habitats–would receive the highest radiation dose, considering all pathways, from a given event, process, or facility (DOE Order 458.1).

- National Security Presidential Memorandum-20 (NSPM-20), *Presidential Memorandum on Launch of Spacecraft Containing Space Nuclear Systems* (White House, 2019)
- Nuclear Regulatory Commission: 10 CFR Subpart 20.1301, *Dose Limits for Individual Members of the Public* (Nuclear Regulatory Commission, 1991)
- EPA: 40 CFR Part 190, *Environmental Radiation Protection Standards for Nuclear Power Operations* (EPA, 1997)

Table 3.1-1 identifies and defines the thresholds for nuclear radiation impacts. Table 3.1-2 depicts the gradient scale of impacts for radiation exposure, as described in Table 3.1-1. The grades are established based on the probability of release and the MEI exposure to a member of the general public.

TABLE 3.1-1
Impact Thresholds for Nuclear Radiation
Environmental Assessment for the Dragonfly Mission, NASA SMD, Washington, DC

Impact	Description
No Impact	No potential for radiation exposure.
Negligible	Impacts from radiation exposure would be very small (less than 0.025 rem MEI exposure) or beyond extremely unlikely (less than a 1-in-1,000,000 probability).
Minor	Impacts from radiation exposure would be small (0.025 to 5 rem MEI exposure) and unlikely (1-in-100 to 1-in-10,000 probability) or large (5 to 25 rem MEI exposure) and extremely unlikely (1-in-10,000 to 1-in-1,000,000 probability).
Moderate	Impacts from radiation exposure would be small (0.025 to 5 rem MEI exposure) and likely (greater than 1-in-100 probability); large (5 to 25 rem MEI exposure) and unlikely (1-in-100 to 1-in-10,000 probability); or very large (greater than 25 rem MEI exposure) and extremely unlikely (1-in-10,000 to 1-in-1,000,000 probability).
Significant	Impacts from radiation exposure would be very large (greater than 25 rem MEI exposure) and unlikely (1-in-100 to 1-in-10,000 probability) to likely (greater than a 1-in-100 probability).
Quality:	Beneficial–would have a beneficial effect Adverse–would have an adverse effect
Duration:	Temporary–would occur only during the launch Permanent–would continue beyond the launch

MEI = maximally exposed individual
rem = Roentgen Equivalent Man

TABLE 3.1-2
NEPA Impact Thresholds for Radiation Exposure
Environmental Assessment for the Dragonfly Mission, NASA SMD, Washington, DC

	Probability of Airborne Release[a]			
MEI Exposure (Member of the Public)[b]	**Beyond Extremely Unlikely (less than 1 in 1,000,000[c])**	**Extremely Unlikely (1 in 10,000 to 1 in 1,000,000)**	**Unlikely (1 in 100 to 1 in 10,000)**	**Likely (greater than 1 in 100)**
Greater than 25 rem	Negligible	Moderate	Significant	Significant
5 rem to 25 rem	Negligible	Minor	Moderate	Moderate
0.025 rem to 5 rem	Negligible	Minor	Minor	Moderate
Less than 0.025 rem	Negligible	Negligible	Negligible	Negligible

[a] Probability thresholds (likely, unlikely, extremely unlikely, and beyond extremely unlikely) are based on definitions provided in DOE-STD-3009-2014.

[b] A member of the public is defined as an individual who is outside the restricted area around a launch site. The rem exposures thresholds are derived from guidance provided in NSPM-20 (White House, 2019)

[c] 1:1,000,000 or 1E-6 is defined as an acceptable probability level for a severe consequence by EPA (EPA, 1991), the Federal Aviation Administration (FAA, 2000), and the U.S. Air Force (USAF, 2019).

MEI = maximally exposed individual
rem = Roentgen Equivalent Man

3.1.2.1 Proposed Action

The most likely outcome of implementing the Proposed Action is the successful launch of the Dragonfly mission; this scenario represents the normal operating conditions and would result in no release of Pu-238. In the unlikely event of an accident, it is still probable the accident would not result in a release of Pu-238, as MMRTGs and RHUs are designed to withstand most energetic accident conditions associated with launch mishaps without compromising the Pu-238. Nonetheless, certain low-probability accident scenarios could involve a sequence of thermal and mechanical insults to the MMRTG GPHS modules or RHUs that may result in the release of Pu-238. The following sections discuss the potential for this scenario along with the associated environmental consequences.

Low Probability Release Scenarios

For an accident to result in a release of Pu-238, a sequence of thermal conditions and multiple mechanical system failures within the MMRTG GPHS modules or RHUs would need to occur for the Pu-238 pellets to vaporize into a respirable form; refer to Section 3.1.1.2, *Health Effects from Radiation Exposure*, for further information on the importance of respirable form. In the history of using GPHS modules and RHUs in spacecraft, there have been no such releases of Pu-238. However, such failure scenarios have been postulated and the following credible scenarios could result in a respirable release of Pu-238:

- The GPHS modules and RHUs both have safety features designed to withstand most accident scenarios throughout the launch phases, 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. Prolonged proximity to burning fuel represents the upward bounds of potential release scenarios; therefore, accidents of this type include the highest bounding case for a potential release. However, the likelihood of this occurrence is extremely unlikely, as it would require burning fuel to land on, or very close to, the GPHS modules or RHUs after a mishap.
- A suborbital (below Earth's orbit), orbital, or supraorbital (above Earth's orbit) re-entry accident, in which the space vehicle unintentionally returns to Earth outside of the launch area, could occur and result in a release of Pu-238. However, GPHS modules and RHUs are designed to withstand most re-entry accident scenarios, and missions are planned such that the potential for unintentional re-entry with a release of plutonium is extremely unlikely. Furthermore, rocket boosters, which contain the rocket fuel, are jettisoned relatively early in the flight sequence, which greatly reduces the potential and respirable quantity of released Pu-238. Other less likely scenarios, such as striking a hard surface, could result in a release of Pu-238 after a re-entry; however, these scenarios require a series of unlikely events to occur that culminate in an extremely unlikely occurrence. The aiming of the Dragonfly spacecraft and minimum altitude during EGA maneuvers set the potential for a mishap to beyond extremely unlikely. Despite its extremely low probability of occurrence, all re-entry scenarios would be closely monitored, with support given to the USSF and DOE to attempt to recover the Pu-238, as applicable.

The probability of a potential release of Pu-238 during the Dragonfly mission was assessed by reviewing analyses performed for previous NASA missions involving MMRTGs and RHUs (NASA, 1997, 2020c). Table 3.1-3 provides the estimated probability of a release of Pu-238 through the various mission phases of the Dragonfly mission. These probabilities are based on numerous variables specific to the previous missions, including launch vehicle type and payload configurations. Currently, the specific vehicle type and payload configuration for the Dragonfly mission is unknown; however, it is expected that the release probabilities would be in keeping with previously calculated release probabilities. If NASA becomes aware of significant new circumstances or information relevant to environmental concerns and bearing on the Proposed Action or its impacts, NASA may prepare a supplemental EA or consider whether the new information triggers the need to prepare an EIS.

TABLE 3.1-3
Probability of a Radiological Release
Environmental Assessment for the Dragonfly Mission, NASA SMD, Washington, DC

Mission Phase	Scenario	Probability of a Release of Pu-238 after a mishap[a]	Definition[b]
Phase 0 Pre-launch	Accident before launch sequence initiation.	1 in 10,000 to 1 in 1,000,000	Extremely Unlikely
Phase 1 Early Launch			
On-pad Explosion	Accident involving an outward explosion on the launch pad.	1 in 10,000 to 1 in 1,000,000	Extremely Unlikely
Full-stack Impact	Accident in which the entire launch vehicle impacts the ground. This scenario represents the upper bounds of a respirable Pu-238 potential release.	Less than 1 in 1,000,000	Beyond Extremely Unlikely
Intact Stage 2 and Space Vehicle Impact	Accident in which the intact Stage 2 component and launch vehicle impact the ground.	1 in 10,000 to 1 in 1,000,000	Extremely Unlikely
Space Vehicle Intact Impact	Accident in which only the space vehicle impacts the ground.	Less than 1 in 1,000,000	Beyond Extremely Unlikely
Low-Altitude Flight Termination System	Accident in which the launch vehicle is destroyed at low altitude and debris impacts the ground. While this scenario represents the highest probability, the MMRTG or RHU would be separated from the fuel source, and the release of respirable Pu-238 would be much lower than other scenarios.	1 in 100 to 1 in 10,000	Unlikely
Phase 2 Late Launch	Accident occurs shortly after launch. Would affect the Atlantic Ocean.	1 in 10,000 to 1 in 1,000,000	Extremely Unlikely
Phase 3 Suborbital	Accident occurs prior to orbit. Would affect the Atlantic Ocean or African Continent.	1 in 10,000 to 1 in 1,000,000	Extremely Unlikely
Phase 4 Orbital	Accident occurs during orbit. Latitudes between 35° North and 35° South would be most likely affected.	1 in 10,000 to 1 in 1,000,000	Extremely Unlikely
Phase 5 Long Term	Accident post orbit. Would affect any latitude.	1 in 10,000 to 1 in 1,000,000	Extremely Unlikely
Earth Gravity Assist Maneuver	Accident during an Earth gravity assist of the spacecraft. Would affect any latitude.	Less than 1 in 1,000,000	Beyond Extremely Unlikely

Sources: NASA, 1997, 2020c.
[a] The total probability of a release includes the probability of the accident occurring and the conditional probability of Pu-238 release.
[b] Probability thresholds (likely, unlikely, extremely unlikely, and beyond extremely unlikely) are based on definitions provided in DOE-STD-3009-2014
Pu-238 = Plutonium-238

Dose Consequences Associated with a Release of Pu-238

DOE's Idaho National Laboratory (INL) performed a comprehensive review of nuclear risk assessments and NEPA documents from previous NASA missions using MMRTGs and RHUs to assess the potential effects associated with a launch mishap during the Dragonfly mission (INL, 2021). Specifically, the consequence calculations for the Mars 2020 mission were used to assess the potential effects for the Dragonfly mission, because the Dragonfly mission would employ a nearly identical MMRTG as the Mars 2020 mission. Furthermore, the Mars 2020 analysis involved more advanced modeling and provided more accurate dose consequence analysis than prior mission assessments (INL, 2021). Although the interfaces and spacecraft accommodations, such as the external cooling loops and radiative fins, may be slightly different from the Mars 2020 mission, the base MMRTG design, which is the most important component for the release

probability, would remain unchanged for the Dragonfly mission. The deterministic analysis[4] performed by INL was also independent of a launch vehicle, launch location, and time of year Various release types were calculated to determine the worst-case accident scenario, including a 1-, 5-, 10-, 20-, 100-, 1,000-, and 10,000-megawatt fire; and a 100-, 500-, 1,000-, 5,000-, 10,000-, and 82,500-lb TNT-Equivalent explosion under low and high wind speed meteorological conditions[5] (Figure 3-1).

Based on INL's analysis and applying the probabilities in Table 3.1-3, a deterministic estimate of the highest radiation dose to the MEI would be between 2.98 and 21.4 rem resulting from an extremely unlikely event in Phase 0, 1, or 2 (probability less than 1 in 10,000)[6]. This range is based on the upper level of exposure under the low and high wind speed meteorological conditions. For the highest level of exposure (21.4 rem) to occur, a launch mishap would have to occur during low wind speeds; however, higher wind speeds are more typical along the Florida coastline, making this event even more unlikely and placing the potential consequence closer to the 2.98 rem estimate associated with higher winds. Applying the 2.98 to 21.4 rem consequence to the probability of occurrence (less than 1 in 10,000) to the Table 3.1-2 results in a **negligible to minor, adverse, and permanent** impact to the MEI from potential radiation exposure after a launch mishap. The impacts associated with other launch mishap scenarios or to other potentially exposed members of the general public would be of less consequence.

3.1.2.2 No Action Alternative

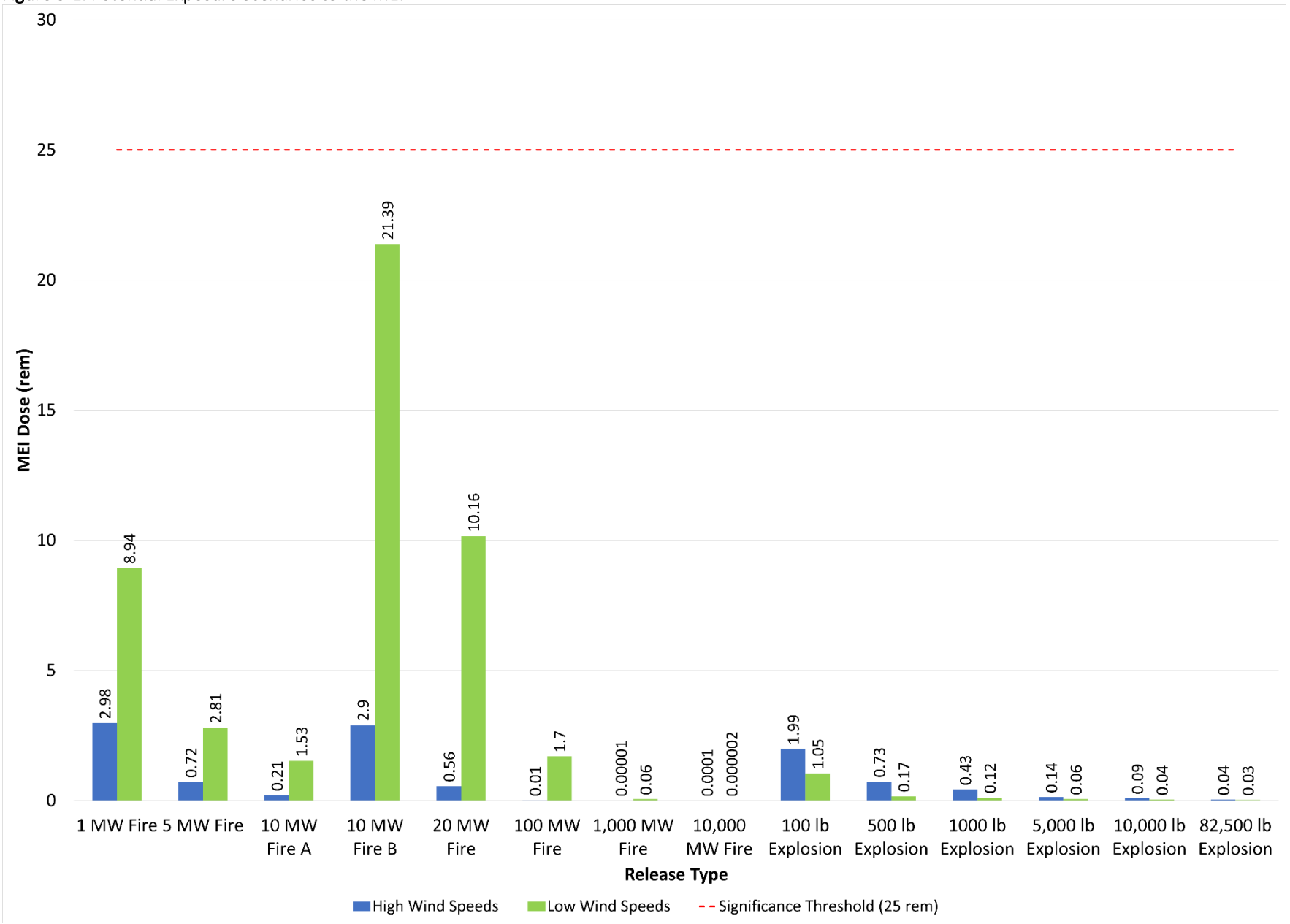
Under the No Action Alternative, the Dragonfly mission would not be launched; therefore, there would be **no potential effect** to health and safety from the mission. However, MMRTGs and RHUs could continue to be used in future missions at KSC and CCSFS and environmental impacts evaluated through separate NEPA documentation, as applicable.

[4] A deterministic analysis relies solely on parameter values for outputs, whereas probabilistic analysis incorporates the probability of an event into the output along with the parameter values. Consequently, the same set of parameter values and initial conditions will lead to a group of different outputs between these types of analysis.

[5] The Pasquill stability classes categorize the stability of the atmosphere. For the purposes of the DOE INL analysis, the Pasquill stability class F (1 m/s) represents low wind speeds and class D (4.5 m/s) represents high wind speeds.

[6] Low-Altitude Flight Termination System mishap would result in a higher probability release (1:100 to 10,000); however, while this scenario represents the highest probability, the MMRTG or RHU would be separated from the fuel source, and the release of respirable Pu-238 would be much lower than other scenarios.

Figure 3-1. Potential Exposure Scenarios to the MEI



3.2 Land Use

3.2.1 Affected Environment

The following sections describe land resources at CCSFS and KSC, including administrative and natural areas. The region of influence for land use includes KSC, CCSFS, and the surrounding areas, as shown on Figure 3-2.

3.2.1.1 Kennedy Space Center

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 are incorporated into land use planning (NASA, 2014c).

KSC is located on the northern part of Merritt Island adjacent to CCSFS and consists of 565 km^2 (139,490 acres) of land and lagoon waters (Figure 3-2). The majority (95%) of KSC is identified as undeveloped area, which includes uplands, wetlands, mosquito control impoundments, and open water areas. Nearly 40% of this undeveloped area is 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). Undeveloped lands within the operational areas are dedicated safety zones or are reserved for planned and future expansion. The remaining 5% (18 km^2 [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 LC-39A, LC-39B, and LC-48.

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 MINWR and the National Park Service (NPS) at the CNS. The NPS administers 27 km^2 (6,644 acres) of the CNS, and the USFWS administers 206 km^2 (50,945 acres) of the CNS and the 305 km^2 (75,383 acres) of the MINWR (NASA, 2013).

MINWR and CNS provide an operational buffer between KSC 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).

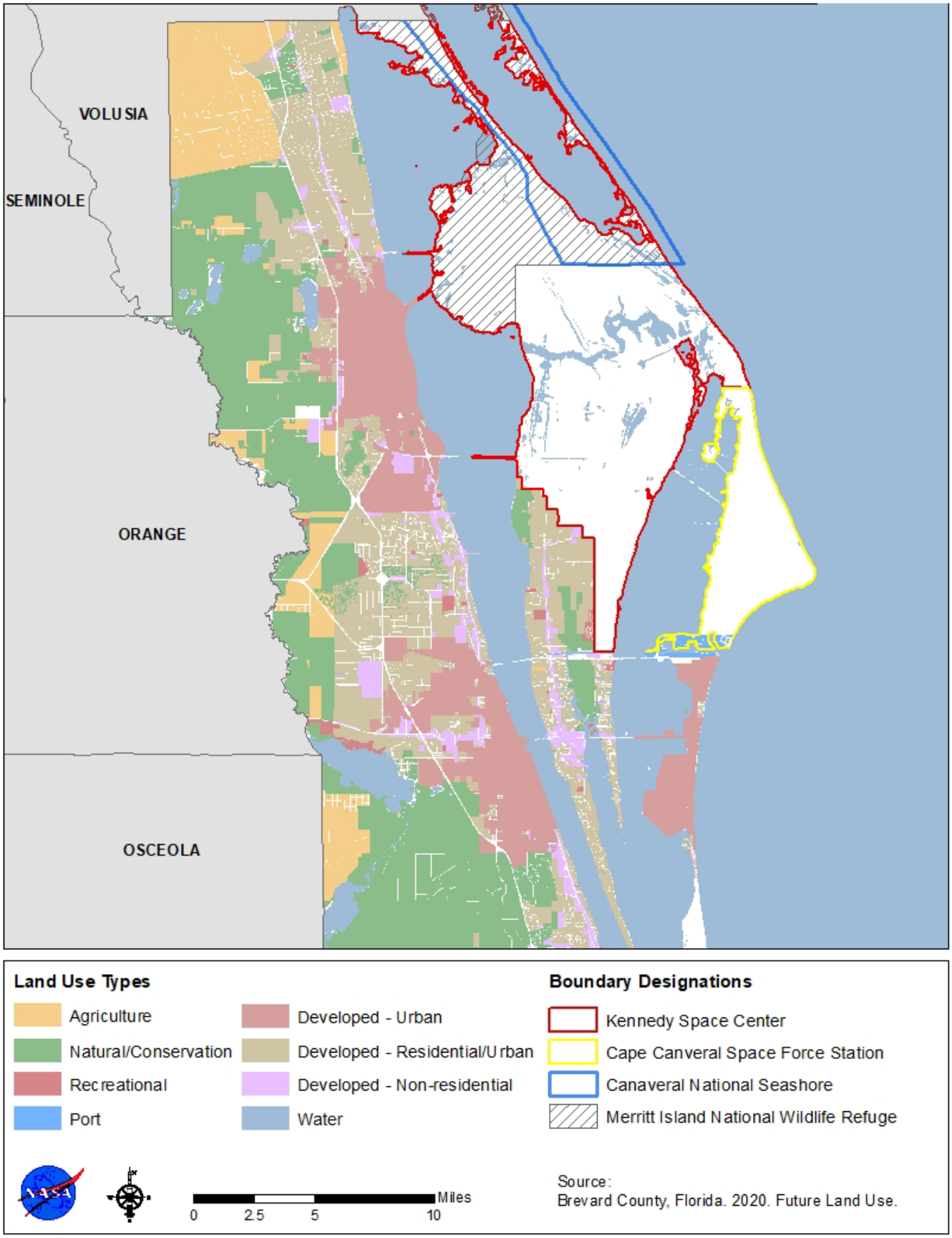
3.2.1.2 Cape Canaveral Space Force Station

CCSFS includes approximately 66 km^2 (16,198 acres) that support multiple land use types (Figure 3-2), including administrative, airfield operations, industrial, munitions and weapons storage, open space, and outdoor recreation. 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 CCSFS 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 CCSFS. All land uses at CCSFS are under operational control of the USSF SLD 45 at Patrick Space Force Base (NASA, 2013). The beaches along CCSFS are used for launch operations and are restricted from public use (USAF, 2020a).

3.2.1.3 Surrounding Land Use

Land use surrounding KSC and CCSFS includes an active seaport; residential, recreation, and wildlife management areas; and agricultural uses that include citrus, mixed tropical fruits and other crops and pasture (Figure 3-2). Port Canaveral to the south of CCSFS has several cruise ship and commercial port terminals. Security personnel regularly patrol the Port waters to ensure unauthorized personnel do not access CCSFS via the Port. 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; these areas are open to the public but are closed during some launch operations at the discretion of USSF (USAF, 2020a).

Figure 3-2. Land Cover Types of Surrounding Area



3.2.2 Environmental Consequences

This section identifies potential impacts to land use that may result from implementing the Proposed Action or the No Action Alternative. The following analysis considers impacts associated with the deposition of radionuclides after a mission mishap involving a release of Pu-238. Table 3.2-1 identifies and defines the thresholds for land use impacts.

TABLE 3.2-1
Impact Thresholds for Land Use
Environmental Assessment for the Dragonfly Mission, NASA SMD, Washington, DC

Impact	Description
No Impact	No potential for impacts to land use.
Negligible	Impacts to land use would be at the lowest levels of detection.
Minor	Impacts to land use would be detectable but would not permanently alter the use of the land as it is currently intended.
Moderate	Impacts to land use would be readily detectable and would permanently alter the use of the land as it is currently intended; however, valued resources such as farmland and residential and recreational areas would likely not be affected.
Significant	Impacts to land use would be readily detectable and would permanently alter the use of the land as it is currently intended. Valued resources such as farmland and residential and recreational areas would likely be affected.
Quality:	Beneficial–would have a beneficial effect Adverse–would have an adverse effect
Duration:	Temporary–would occur only during the launch Permanent–would continue beyond the launch

3.2.2.1 Proposed Action

Under normal operating conditions, there would be no impacts to land use from the Proposed Action. 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 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 unlikely release scenario, as described in Section 3.1, *Nuclear Radiation*. Such a release could result in the deposition of radiological materials on the ground. The U.S. Food and Drug Administration has defined Pu-238 contamination of 7.3 microcuries per square meter ($\mu Ci/m^2$) (NASA, 2020c) as the threshold for intervention of farmland. However, in the highest consequence release event (a launch pad accident), the potential soil contamination would remain at or below 6.41 $\mu Ci/m^2$ and the potentially impacted land would be within the boundaries of KSC and CCSFS (INL, 2021). Consequently, there is little potential for an impact to valued land uses such as the seaport, recreational areas, residential areas, or agricultural/farmland areas outside KSC or CCSFS (Figure 3-2). Impacts within KSC or CCSFS would be mitigated by the federal government.

There is an extremely unlikely potential for radiological materials to be deposited outside KSC or CCSFS during a late-phase accident (Table 3.1-3); however, any depositions would be expected to remain below the 6.41 $\mu Ci/m^2$ contamination threshold. If a launch mishap resulting in a release of Pu-238 were to happen, NASA and DOE would coordinate response activities in accordance with the National Response Framework (DHS, 2019). 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 were addressed.

Land use impacts within or outside of KSC and CCSFS associated with an accidental release of Pu-238 from the Proposed Action would be **minor, adverse, and temporary**. This determination was made based on the highest projected disposition, which is below U.S. Food and Drug Administration contamination thresholds; the high probability of the affected area remaining within KSC and CCSFS boundaries; and the mitigation measures currently in place.

3.2.2.2 No Action Alternative

Under the No Action Alternative, the Dragonfly mission would not be launched; therefore, there would be **no potential effect** to land use from the mission. However, MMRTGs and RHUs could continue to be used in future missions at KSC and CCSFS and environmental impacts evaluated through separate NEPA documentation, as applicable.

3.3 Water Resources

The following sections describe water resources at CCSFS and KSC, including surface water, groundwater, drinking water supply, and wetlands. The region of influence for water resources includes the Upper St. Johns River and Cape Canaveral watersheds (FDEP, 2018) as well as the aquifers beneath the watersheds.

3.3.1 Affected Environment

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 3-3). CCSFS 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 CCSFS is the Port Canaveral channel, which connects the Banana River to the Atlantic Ocean.

The Florida Department of Environmental Protection (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 MINWR and CNS have been designated as 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 23 to 53 meters (75 to 175 feet) 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 152 meters (0 to 500 feet) in thickness and disappears in a small area near the St. Johns River and west of KSC. The intermediate aquifer begins 23 to 53 meters (75 to 175 feet) 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 23 to 152 meters (75 to 500 feet) below land surface. These aquifers are recharged primarily through rainfall infiltration (SJRWMD, 1990).

3.3.1.3 Drinking Water Supply

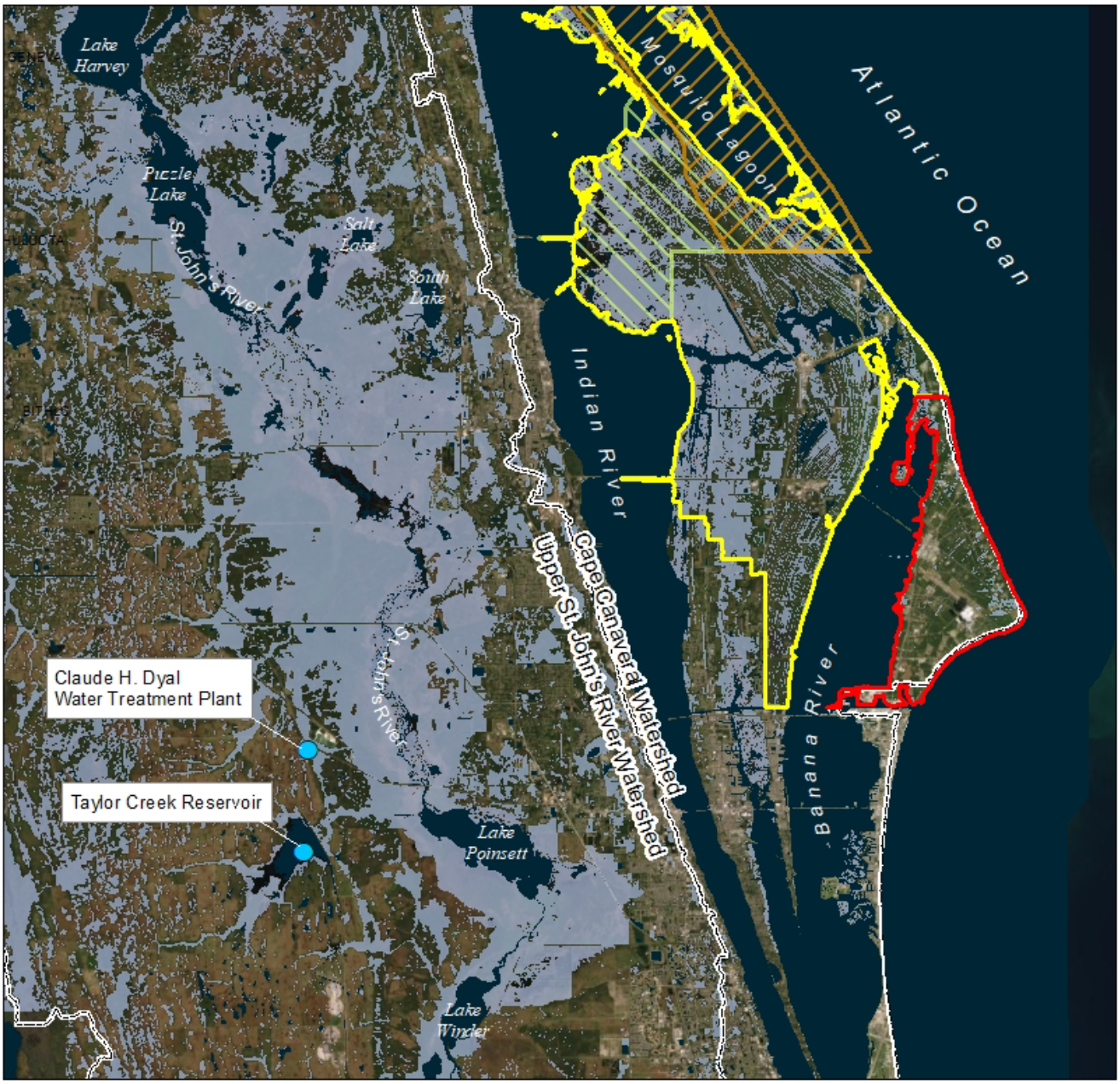
CCSFS, KSC, and much of Brevard County obtain drinking water from the City of Cocoa's Claude H. Dyal Water Treatment Plant, which treats and distributes water obtained from the Taylor Creek Reservoir and 34 Floridian aquifer wells approximately 122 to 183 meters (400 to 600 feet) deep and 14 wells in the

intermediate aquifer (City of Cocoa, 2009). The reservoir and wells are located more than 24 km (15 miles) west of KSC and CCSFS. 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. Wetland locations for the region of influence were obtained from the National Wetlands Inventory database (USFWS, 2020a) and are shown on Figure 3-3.

Figure 3-3. Surface Water Features



3.3.2 Environmental Consequences

This section identifies potential impacts to water resources that may result from implementing the Proposed Action or the No Action Alternative. Table 3.3-1 identifies the NEPA impact thresholds for water resources.

TABLE 3.3-1
Impact Thresholds for Water Resources
Environmental Assessment for the Dragonfly Mission, NASA SMD, Washington, DC

Impact	Description
No Impact	No impacts to water resources would be expected.
Negligible	Impacts to water resources would be barely detectable and would not alter water resources conditions.
Minor	Impacts to water resources would be detectable but would be within historical hydrologic or desired water quality conditions.
Moderate	Impacts to water resources would appreciably alter resource conditions. Historical baseline or desired water quality conditions would be altered temporarily.
Significant	Impacts would permanently alter water resources from the historical hydrologic baseline or desired water quality conditions or water supply.
Quality:	Beneficial–would have a beneficial effect Adverse–would have an adverse effect
Duration:	Temporary–would occur only during the launch Permanent–would continue beyond the launch

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 MMRTGs and RHUs. The following impacts are evaluated only for the unlikely event that Pu-238 is released during a launch accident as described in Section 3.1, *Nuclear Radiation*.

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 that portions of a Pu-238 pellet came into contact with water, the pellet fragments would sink into 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 relatively 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 low solubility 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 relatively insoluble, there is no direct mechanism for transport into groundwater. Soil studies have shown that more than 95% of Pu-238 oxide remains in the top 2 inches of undisturbed surface soil after deposition. The remaining 5% 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, 2019); 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 KSC and CCSFS and is far removed from the potential affected area (Figure 3-3). In the highly improbable event that debris containing an MMRTG from a suborbital mishap is carried far enough to reach the reservoir or tributary streams, 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, 2020), which are effective in removing Pu-238 (NASA, 1990). The impact from Pu-238 exposure from drinking water is **negligible** due to the low solubility of Pu-238 oxide, the distance of the Taylor Creek Reservoir from the launch pads, the low probability that ingested Pu-238 would remain in the human body, and existing infrastructure that meets EPA drinking water standards.

Wetlands

In the unlikely event that Pu-238 is released in a launch accident, site response would be conducted in accordance with the National Response Framework (DHS, 2019) (Figure 3-3). Any effects to wetlands would likely require Clean Water Act permitting through the U.S. Army Corps of Engineers (USACE) and state agencies if wetlands or waters of the U.S. or the State of Florida were affected after an accidental release of Pu-238. Impacts to wetlands are expected to be **negligible** because the potential for an impact is unlikely and because NASA would coordinate potential wetland impacts with USACE and obtain necessary permits prior to affecting wetlands.

3.3.2.2 No Action Alternative

Under the No Action Alternative, the Dragonfly mission would not be launched; therefore, there would be **no potential effect** for water resources from the mission. However, MMRTGs and RHUs could continue to be used in future missions at KSC and CCSFS and environmental impacts evaluated through separate NEPA documentation, as applicable.

3.4 Biological Resources

3.4.1 Affected Environment

The following sections describe biological resources at CCSFS and KSC, including the ecological setting, vegetation, fish and wildlife, and protected species. The region of influence for biological resources consists of CCSFS, 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

CCSFS and KSC occupy a coastal habitat on a barrier island complex that parallels Florida's mid-Atlantic coast. The MINWR and CNS are located north of KSC and CCSFS. Most of the land adjacent to the KSC/CCSFS barrier island complex is developed.

3.4.1.2 Vegetation

Natural vegetation communities on KSC and CCSFS are dominated by forests and wetlands. This includes upland scrub and pine flatwoods (beach dune, coastal strand, coastal grassland, 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, estuaries, basin marsh, coastal interdunal swale) (NASA, 2016; USAF, 2020a).

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 CCSFS. Common animals occurring at KSC and CCSFS include frogs, turtles, lizards, snakes, birds, mammals, fish, alligators, and invertebrates. 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, 2020a).

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. CCSFS and KSC contain 25 federally listed wildlife species and 8 federally listed plant species on CCSFS or KSC (Table 3.4-1).

The Marine Mammal Protection Act (MMPA) 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 CCSFS 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 U.S. are protected. The MBTA makes it illegal to 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 CCSFS 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 3.4-1
Federally Threatened and Endangered Species Documented to Occur at CCSFS or KSC
Environmental Assessment for the Dragonfly Mission, NASA SMD, Washington, DC

Species Type	Common Name	Scientific Name	Federal Status
Reptiles and Amphibians	American Alligator	*Alligator mississippiensis*	Threatened
Reptiles and Amphibians	Atlantic (Kemp's) Ridley Sea Turtle	*Lepidochelys kempi*	Endangered
Reptiles and Amphibians	Atlantic Green Sea Turtle	*Chelonia mydas*	Endangered
Reptiles and Amphibians	Atlantic Salt Marsh Snake	*Nerodia clarkia taeniata*	Threatened
Reptiles and Amphibians	Eastern Indigo Snake	*Drymarchon corais couperi*	Threatened
Reptiles and Amphibians	Gopher Tortoise	*Gopherus polyphemus*	Candidate for Federal Listing
Reptiles and Amphibians	Hawksbill Sea Turtle	*Eretmochelys imbricata*	Endangered
Reptiles and Amphibians	Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered
Reptiles and Amphibians	Atlantic Loggerhead Sea Turtle	*Caretta caretta*	Threatened
Mammals	Northern Atlantic Right Whale	*Eubalaena glacialis*	Endangered
Mammals	Southeastern Beach Mouse	*Peromyscus polionotus niveiventris*	Threatened
Mammals	West Indian Manatee	*Trichechus manatus latirostris*	Endangered
Fishes	Smalltooth Sawfish	*Pristis pectinata*	Endangered

Species Type	Common Name	Scientific Name	Federal Status
Fishes	Nassau grouper	*Epinephalus striatus*	Threatened
Birds	Auburn's Crested Caracara	*Polyborus plancus audubonii*	Threatened
Birds	Crested Caracara	*Caracara cheriway*	Threatened
Birds	Eastern Black Rail	*Laterallus jamaicensis* ssp. *Jamaicensis*	Proposed Threatened
Birds	Everglade Snail Kite	*Rostrhamus sociabilis pumbeus*	Endangered
Birds	Florida Scrub Jay	*Aphelocoma coerulescens*	Threatened
Birds	Piping Plover	*Charadrius melodus*	Threatened
Birds	Red Knot	*Calidris canutus rufa*	Threatened
Birds	Red-cockaded Woodpecker	*Picoides borealis*	Endangered
Birds	Roseate Tern	*Sterna dougallii*	Threatened
Birds	Wood Stork	*Mycteria americana*	Endangered
Birds	Bald Eagle	*Haliaeetus leucocephalus*	Protected under the Bald and Golden Eagle Protection Act
Plants	Carter's Mustard	*Warea carteri*	Endangered
Plants	Four-petal Pawpaw	*Asimina tetramera*	Endangered
Plants	Florida Perforate Lichen	*Cladonia perforafa*	Endangered
Plants	Lakela's mint	*Dicerandra immaculata*	Endangered
Plants	Lewton's Polygala	*Polygala lewtonii*	Endangered
Plants	Johnson's Seagrass	*Halophila johnsonii*	Threatened
Plants	Beach jacquemontia	*Jacquemontia reclinate*	Endangered
Plants	Tiny Polygala	*Polygala smallii*	Endangered

Source: USFWS, 2020b; USAF, 2020a.

3.4.2 Environmental Consequences

This section identifies potential impacts to biological resources that may result from implementing the Proposed Action or the No Action Alternative. Table 3.4-2 identifies the NEPA impact thresholds for biological resources.

TABLE 3.4-2
Impact Thresholds for Biological Resources
Environmental Assessment for the Dragonfly Mission, NASA SMD, Washington, DC

Impact	Description
No Impact	No impacts to biological resources would be expected.
Negligible	Impacts to biological resources would not be detectable and would not alter resource conditions.
Minor	Impacts to biological resources would be detectable but they would result in minimal loss of resource integrity. Impacts would not appreciably alter resource conditions or permanent changes of population use of habitats.

Impact	Description
Moderate	Impacts to biological resources would result in disturbance to a site, loss of integrity, and/or alteration of resource conditions. Impacts would appreciably alter biological resource conditions; however, the scale of the impacts would not be expected to affect resource or species population stability in the region.
Significant	Impacts to biological resources would result in severe disturbance to a site, loss of integrity, and/or alteration of resource conditions. Impact would appreciably alter resource conditions and could affect regional population stability.
Quality:	Beneficial–would have a beneficial effect Adverse–would have an adverse effect
Duration:	Temporary–would occur only during the launch Permanent–would continue beyond the launch

3.4.2.1 Proposed Action

Under normal operating conditions of the Proposed Action, there would be no impacts to biological resources from the use of an MMRTG and RHUs, as there would be no release of plutonium dioxide.

Terrestrial and aquatic wildlife 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, including sensitive species. This has been qualitatively demonstrated by the International Atomic Energy Agency (IAEA, 2014). Because the potential effects of radiation exposure after an accidental release of Pu-238 are considered negligible to minor, adverse, and permanent to human populations (Section 3.1, *Nuclear Radiation*), impacts to wildlife from the use of the MMRTGs and RHUs in spacecraft are expected to be **negligible to minor, adverse, and permanent** as well. NASA and/or USSF will coordinate any necessary response activities with the USFWS and the National Marine Fisheries Service (NMFS) as required under the ESA and the MMPA to determine appropriate mitigation for the protection of sensitive species. NASA will informally consult with the USFWS regarding the Proposed Action. In the unlikely event of a launch mishap that results in a release of radiological material into the environment where threatened or endangered species may be affected, NASA would enter into formal ESA Section 7 emergency consultation under 50 CFR Subpart 402.05. The ESA Section 7 consultation documents can be found in Appendix 3.4A.

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. As discussed in Section 3.3, *Water Resources*, no permanent impacts to freshwater, saltwater, or surface water ecosystems are expected, because Pu-238 would be released as an oxide that has low solubility in aquatic ecosystems. Therefore, 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, the Dragonfly mission would not be launched; therefore, there would be **no potential effect** from the use to biological resources from the mission. However, MMRTGs and RHUs could continue to be used in future missions at KSC and CCSFS and environmental impacts evaluated through separate NEPA documentation, as applicable.

3.5 Cultural Resources

The following sections describe cultural resources at CCSFS and KSC, including archeological and historical sites. The region of influence for cultural resources is KSC and CCSFS. 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 U.S. 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. Numerous NRHP-listed and eligible sites are located within the region of influence, due to their roles in current and previous space programs.

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 remains of past human life or activities. Typical archaeological resources include pottery, basketry, weapons, tools, and graves.

3.5.1.1 Kennedy Space Center

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 Cultural Resource Manager (CRM) under NASA's Environmental Management Division 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 Cape Canaveral Space Force Station

USSF has a stewardship responsibility for managing the cultural resources on USSF-owned lands and facilities and has developed an ICRMP (USAF, 2020b) that reflects its commitments to the protection of significant cultural resources at CCSFS. A designated CRM at CCSFS manages the ICRMP. It is also a goal at CCSFS to balance historic preservation considerations with USSF's missions and avoid conflict with ongoing operational requirements.

3.5.2 Environmental Consequences

This section identifies potential impacts to cultural resources that may result from implementing the Proposed Action and the No Action Alternative. Table 3.5-1 identifies and defines the NEPA impact thresholds for cultural resources.

TABLE 3.5-1
Impact Thresholds for Cultural Resources
Environmental Assessment for the Dragonfly Mission, NASA SMD, Washington, DC

Impact	Description
No Impact	No impacts to cultural resources would be expected.
Negligible	Impacts to cultural resources would be barely detectable and would not alter cultural resources conditions, such as site preservation, or the relationship between the resource and the affiliated group's body of practice or beliefs.

Minor	Impacts on cultural resources would result in little, if any, loss of integrity and would be slight but noticeable. Impacts would not appreciably alter resource conditions or the relationship between the resource and the affiliated group's body of practices or beliefs.
Moderate	Impacts on cultural resources would result in readily noticeable disturbance to a site, loss of integrity, and/or alteration of resource conditions. Impacts would appreciably alter resource conditions and/or the relationship between the resource and the affiliated group's body of practices or beliefs.
Significant	Impacts on cultural resources would result in severe and permanent disturbance to a site, loss of integrity, and/or alteration of resource conditions. Impacts would appreciably alter resource conditions and/or the relationship between the resource and the affiliated group's body of practices or beliefs.
Quality:	Beneficial–would have a beneficial effect Adverse–would have an adverse effect
Duration:	Temporary–would occur only during the launch Permanent–would continue beyond the launch

3.5.2.1 Proposed Action

Under normal operating conditions, there would be no impacts to cultural resources from the use of an MMRTG and RHUs. However, there is a potential for Pu-238 to be released into the environment under an unlikely release scenario, as described in Section 3.1, *Nuclear Radiation*. 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*. NASA will informally consult with the Florida State Historic Preservation Office (SHPO) regarding the Proposed Action. The NHPA Section 106 consultation documents can be found in Appendix 3.5A.

Archeological Sites

Pu-238 is relatively insoluble and typically remains on the top 2 inches of surface soil after a release (NASA, 2014b). Consequently, the potential for impacting a known or unknown archeological site present in a contaminated area is limited. In the extremely unlikely event that cleanup activities require the excavation of soil on a NRHP-listed or eligible archeological resource, the Florida SHPO will be notified prior to any non-emergency response activities at the site, and appropriate mitigation measures will be developed in accordance with the NHPA. If a new (inadvertent) archeological site is identified during cleanup activities, the respective KSC or CCSFS Historic Preservation Officer (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 USSF'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 CCSFS. These significant historic resources include the LCs where the Dragonfly spacecraft could be launched. Potential effects to cultural resources after a launch mishap have been studied in detail in previous EAs and EISs for KSC and CCSFS (NASA 1994, 1997, 2002, 2005, 2014b, 2020c). Radioisotope-specific impacts could 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 in accordance with the NHPA. Impacts to historic sites are considered **negligible**, given the remote probability of a site being affected and NASA's and USSF's commitment to work with the Florida SHPO in the event a historic site requires cleanup.

3.5.2.2 No Action Alternative

Under the No Action Alternative, the Dragonfly mission would not be launched; therefore, there would be **no potential effect** to cultural resources from the mission. However, MMRTGs and RHUs could continue to be used in future missions at KSC and CCSFS and environmental impacts evaluated through separate NEPA documentation, as applicable.

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 CCSFS; however, previous EAs and EISs analyzed the impacts associated with the use of these hazardous materials and resulting wastes for launches (NASA 1994, 1997, 2002, 2005, 2014b, 2020c); therefore, they are not considered in further detail in this EA. 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 SLCs at CCSFS. Environmental impacts associated with production and transport of Pu-238 have been analyzed in previous DOE NEPA documents (DOE, 2000, 2002, 2008, 2013).

3.6.1 Affected Environment

3.6.1.1 Kennedy Space Center

The Radiation Protection Program at KSC 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 prevent unnecessary exposure to personnel and to limit exposure to levels as low as are reasonably achievable (KSC, 2009, 2016).

NASA is responsible for providing adequate infrastructure (that is, 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 RPS. The criteria include safeguards and security protection (NASA and 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 Cape Canaveral Space Force Station

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

The SLD 45 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; RPS are compatible with these regulatory specifications (USAF, 2017a, 2017b, 2019).

3.6.2 Environmental Consequences

This section identifies potential impacts from hazardous materials that may result from implementing the Proposed Action or the No Action Alternative. Table 3.6-1 identifies and defines the NEPA impact thresholds for hazardous materials.

TABLE 3.6-1
Impact Thresholds for Hazardous Materials
Environmental Assessment for the Dragonfly Mission, NASA SMD, Washington, DC

Impact	Description
No Impact	No potential for impact from hazardous materials.
Negligible	Impacts from the use of hazardous materials would be barely detectable. No new infrastructure, safety controls, or policies would be necessary.
Minor	Impacts from the use of hazardous materials would be measurable. Any release of hazardous materials or solid waste could be remediated by onsite personnel.
Moderate	Impacts from the use of hazardous materials would be measurable.
Significant	Impacts from the use of hazardous materials would be measurable. The resulting impacts could be severe and permanent.
Quality:	Beneficial–would have a beneficial effect Adverse–would have an adverse effect
Duration:	Temporary–would occur only during the launch. Permanent–would continue beyond the launch.

3.6.2.1 Proposed Action

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

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

3.6.2.2 No Action Alternative

Under the No Action Alternative, the Dragonfly mission would not be launched; therefore, there would be **no potential effect** from the use of hazardous materials from the mission. However, MMRTGs and RHUs could continue to be used in future missions at KSC and CCSFS and environmental impacts evaluated through separate NEPA documentation, as applicable.

3.7 Cumulative Impacts

Cumulative impacts are defined by the CEQ in 40 CFR Subpart 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 CCSFS. The Nuclear Regulatory Commission has defined two emergency planning zones around the St. Lucie Nuclear Power Plant. 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. CCSFS and KSC are outside these two zones; therefore, there would be no cumulative impacts at the local scale (Nuclear Regulatory Commission, 2020).

Because there is a minimal chance of environmental impacts associated with the Proposed Action, the potential for the Proposed Action to cause collectively significant cumulative environmental impacts is unlikely. NASA and USSF may conduct other missions containing nuclear devices such as RHUs or MMRTGs; however, the chance of one of these missions resulting in a mishap with a release of nuclear material in the same timeframe as a mishap from the Dragonfly mission, resulting in a release of Pu-238, is remote.

SECTION 4

Summary of Impacts

The potential impacts associated with the Proposed Action and No Action Alternative 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 the Dragonfly mission. Multiple failures would have to occur and the MMRTG or RHUs would have to be exposed to an extreme condition for the Pu-238 to be released; this scenario is referred to as the "Unlikely Release Scenario" in Table 4-1.

TABLE 4-1
Summary of Potential Impacts and Proposed Mitigation Measures
Environmental Assessment for the Dragonfly Mission, NASA SMD, Washington, DC

Resource Category	Proposed Action: Normal Operating Conditions	Proposed Action: Unlikely Release Scenario	No Action Alternative	Measures to Minimize Impact
Nuclear Radiation	No impact	Negligible to minor, adverse, and permanent impacts to the public.	No impact	Implement standard mitigation measures such as sheltering, evacuation, and cleanup. Follow established radiation procedures, as described in Section 3.1.1.4, *Established Nuclear Safety Procedures*.
Land Use	No impact	Minor, adverse, and temporary impacts to land use.	No impact	Coordinate any cleanup efforts in accordance with the National Response Framework. Undertake the appropriate radiological screening and other necessary response actions in accordance with a mission-specific contingency plan.
Water Resources	No impact	Negligible impacts to water resources.	No impact	Coordinate with USACE and state agencies if wetlands or waters of the U.S. or the State of Florida could be affected after a potential release of Pu-238.
Biological Resources	No impact	Negligible to minor, adverse, and permanent impacts to wildlife species, including protected species. Negligible impacts to ecosystems.	No impact	Coordinate with the 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.	No impact	Coordinate with Florida SHPO if a NRHP-eligible or listed cultural site would be affected during response activities. Follow an established inadvertent discovery plan in the event a new archeological site is discovered during cleanup activities.
Hazardous Materials	No impact	Minor, adverse, and temporary impacts from hazardous materials.	No impact	Follow all hazardous material regulations and procedures, including training.

Resource Category	Proposed Action: Normal Operating Conditions	Proposed Action: Unlikely Release Scenario	No Action Alternative	Measures to Minimize Impact
Cumulative Impacts	No impact	Minimal chance for a cumulative effect.	No impact	None

SECTION 5

Distribution

Although NASA was the lead federal agency for this EA, DOE and USSF served as cooperating agencies. Numerous subject matter experts, including a wide range of NEPA planners, scientists, engineers, nuclear experts, and attorneys from these agencies reviewed and provided input on this EA.

The EA was distributed to the following NASA centers, DOE laboratories, government agencies, and public libraries:

- NASA Headquarters
- NASA SMD
- NASA Office of International and Interagency Relations
- NASA KSC
- NASA Glenn Research Center
- NASA Office of General Counsel
- Johns Hopkins University APL
- DOE Headquarters
- DOE INL
- USSF CCSFS
- USSF Space Force Space Command
- USFWS
- FDEP Clearinghouse
- Florida SHPO
- 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

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SECTION 6

List of Preparers

The NASA NEPA contractors responsible for preparing this report are listed in Table 6-1.

TABLE 6-1
List of Preparers
Environmental Assessment for the Dragonfly Mission, NASA SMD, Washington, DC

Name	Role	Experience
Michelle Rau, PMP	Project Manager and NEPA Lead	M.S., Business Administration; B.S., Ecology and Evolutionary Biology; 24 years of experience
Arthur Desrosiers, CHP	Senior Health Physicist	Sc.D., Radiation Protection; M.S., Nuclear Engineering; B.S. Physics; 43 years of experience
Christina McDonough, PE	Senior Reviewer	M.S., Environmental Engineering; B.S., Civil Engineering; 26 years of experience
Emily Gulick, CEP-IT	NEPA Support	B.A., Environmental Studies; B.A., Geography; 4 years of experience
Michael Witmer, EIT	Radiation Engineer	M.S., Environmental Engineering; B.S., Civil Engineering; 5 years of experience
Molly Turner	Technical Editor	B.A., English; 13 years of experience
Karen Sanders	Technical Editor	J.D., Law; B.A. Anthropology; 25 years of experience

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SECTION 7

References

Cape Canaveral Air Force Station (CCAFS). 2014. Title V Air Operation Permit.

City of Cocoa. 2009. *Water Supply Facility Workplan*. https://www.cocoafl.org/DocumentCenter/View/1219/Water-Supply-Facilities-Work-Plan?bidId=.

City of Cocoa. 2020. Claude H Dyal Water Treatment Plant. Accessed September 23, 2020. https://www.cocoafl.org/267/Claude-H-Dyal-Water-Treatment-Plant.

Federal Aviation Administration (FAA). 2000. "Licensing and Safety Requirements for Launch." *Federal Register*. Vol. 65, No. 207. October 25.

Federal Aviation Administration (FAA). 2008. *Environmental Assessment for Space Florida Launch Site Operator License at Launch Complex-46*. September. https://www.faa.gov/about/office_org/headquarters_offices/ast/media/Sept%202008%20Space%20Florida%20EA%20and%20FONSI.pdf

Federal Aviation Administration (FAA). 2015. *Environmental Assessment for the Space Exploration Technologies Vertical Landing of the Falcon Vehicle and Construction at Launch Complex 13 at Cape Canaveral Air Force Station, Florida*. https://www.faa.gov/space/environmental/nepa_docs/media/20151201_FAA_FONSI_for_F9_RTLS_at_LC-1.pdf.

Federal Aviation Administration (FAA). 2017. *Adoption of the Environmental Assessment and Finding of No Significant Impact for Blue Origin's Orbital Launch Site at Cape Canaveral Air Force Station, Florida*. April. https://www.faa.gov/space/environmental/nepa_docs/media/20170413_FONSI_for_Blue_Origin_Orbital_Launch_Site_at_CCAFS_final.pdf.

Federal Aviation Administration (FAA). 2019. *Environmental Assessment and Finding of No Significant Impact for Issuing SpaceX a Launch License for an In-flight Dragon Abort Test, Kennedy Space Center, Brevard County, Florida*. Final. August. https://www.faa.gov/about/office_org/headquarters_offices/ast/environmental/nepa_docs/review/launch/media/Final_EA_and_FONSI_for_SpaceX_In-flight_Dragon_Abort_508_A.pdf.

Federal Aviation Administration (FAA). 2020. *Environmental Assessment and Finding of No Significant Impact for SpaceX Falcon Launches at Kennedy Space Center and Cape Canaveral Air Force Station*. Final. July. https://www.faa.gov/space/environmental/nepa_docs/media/SpaceX_Falcon_Program_Final_EA_and_FONSI.pdf.

Florida Department of Environmental Protection (FDEP). 2018. Florida Watersheds Map. Accessed August 31, 2020. https://floridadep.gov/sites/default/files/FL_Watersheds%20Map_0.pdf.

Idaho National Laboratory (INL). 2021. *Radiological Consequences Evaluation for Dragonfly Mission*. Final. INL/EXT-21-65050 Revision 0. December 9.

International Atomic Energy Agency (IAEA). 2014. Technical Reports Series No. 479, *Handbook of Parameter Values for the Prediction of Radionuclide Transfer to Wildlife*. June. https://www-pub.iaea.org/MTCD/Publications/PDF/Trs479_web.pdf.

International Commission on Radiological Protection (ICRP). 1986. *The Metabolism of Plutonium and Related Elements*. ICRP Publication 48. https://journals.sagepub.com/doi/pdf/10.1177/ANIB_16_2-3.

Johns Hopkins University Applied Physics Laboratory (APL). 2020a. Dragonfly Mission Overview. NEPA Kickoff Meeting. Presented by Zibi Turtle, Dragonfly Principal Investigator. May 19.

Johns Hopkins University Applied Physics Laboratory (APL). 2020b. Dragonfly website. https://dragonfly.jhuapl.edu/index.php.

Johns Hopkins University Applied Physics Laboratory (APL). 2020c. Inner Cruise and ΔV-EGA Interplanetary Trajectory Options for 2026-2027. Presented by Martin Ozimek. September 14.

Johns Hopkins University Applied Physics Laboratory (APL). 2020d. NEPA Related Requirements. Presented by Kenneth Hibbard. September 15.

Kennedy Space Center (KSC). 2009. KNPD 1860.1, *KSC Radiation Protection Program*.

Kennedy Space Center (KSC). 2016. Kennedy NASA Procedural Requirements 1860.1, *KSC Ionizing Radiation Protection Program*. https://tdglobal.ksc.nasa.gov/servlet/sm.web.Fetch/KNPD_1860.1__Rev._Basic-5_Revalidated_FINAL_10-26-16.pdf?rhid=1000&did=7199&type=released.

Kennedy Space Center (KSC). 2021. Title V Air Operation Permit.

Lorenz, R., E. Turtle, J. Barnes, M. Trainer, D. Adams, K. Hibbard, C. Sheldon, K. Zacny, P. Peplowski, D. Lawrence, M. Ravine, T. McGee, K. Sotzen, S. MacKenzie, J. Langelaan, S. Schmitz, L. Wolfarth, and P. Bedini. 2018. Dragonfly: A rotorcraft lander concept for scientific exploration at Titan. https://www.researchgate.net/publication/329129271_Dragonfly_A_rotorcraft_lander_concept_for_scientific_exploration_at_titan.

National Aeronautics and Space Administration (NASA). 1990. *Environmental Impact Statement for the Ulysses Mission (Tier 2)*. Final. Solar System Exploration Division, Office of Space Science and Applications, NASA Headquarters. Washington, DC. June.

National Aeronautics and Space Administration (NASA). 1994. *Environmental Assessment for Mars Pathfinder Mission.* Final.

National Aeronautics and Space Administration (NASA). 1997. *Supplemental Environmental Impact Statement for the Cassini Mission*. Final. Mission and Payload Development Division, Office of Space Science, NASA Headquarters, Washington, DC. June.

National Aeronautics and Space Administration (NASA). 2002. *Environmental Impact Statement for Implementation of the Mars Exploration Rover (MER) – 2003 Project*. Final. Science Mission Directorate, NASA Headquarters, Washington, DC. December.

National Aeronautics and Space Administration (NASA). 2005. *Environmental Impact Statement for the New Horizons Mission*. Final.

National Aeronautics and Space Administration (NASA). 2011. *Environmental Assessment for Launch of NASA Routine Payloads.* November. https://www.nasa.gov/agency/nepa/routinepayloadea.html.

National Aeronautics and Space Administration (NASA). 2013. *Environmental Assessment for Multi-Use of Launch Complexes 39A and 39B, John F. Kennedy Space Center, Florida*. November. https://netspublic.grc.nasa.gov/main/finalMultiuseEA.pdf.

National Aeronautics and Space Administration (NASA). 2014a. Thermal Systems, General Purpose Heat Source. Light-Weight Radioisotope Heating Unit. https://rps.nasa.gov/power-and-thermal-systems/thermal-systems/light-weight-radioisotope-heater-unit/.

National Aeronautics and Space Administration (NASA). 2014b. *Environmental Impact Statement for the Mars 2020 Mission*. Final. Science Mission Directorate, National Aeronautics and Space Administration. November.

National Aeronautics and Space Administration (NASA). 2014c. NASA Procedural Requirement 8715.2B, *NASA Emergency Management Program Procedural Requirements*.

National Aeronautics and Space Administration (NASA). 2016. *Kennedy Space Center Center-Wide Operations Final Programmatic Environmental Impact Statement*. https://netspublic.grc.nasa.gov/main/Kennedy%20Space%20Center%20Final%20PEIS%2011-28-2016.pdf.

National Aeronautics and Space Administration (NASA). 2020a. Dragonfly Frequently Asked Questions. https://www.nasa.gov/dragonfly/frequently-asked-questions/index.html.

National Aeronautics and Space Administration (NASA). 2020b. *Dragonfly Nuclear Power Justification Memorandum.*

National Aeronautics and Space Administration (NASA). 2020c. *Supplemental Environmental Impact Statement for Mars 2020.* Final.

National Aeronautics and Space Administration (NASA). 2020d. Dragonfly launch moved to 2027. Updated September 25, 2020. https://www.nasa.gov/feature/dragonfly-launch-moved-to-2027.

National Aeronautics and Space Administration (NASA) and U.S. Department of Energy (DOE). 2016. *Memorandum of Understanding between DOE and NASA Concerning Radioisotope Power Systems for Space Missions.*

National Research Council. 2003. *New Frontiers in the Solar System: An Integrated Exploration Strategy*. Washington, DC: The National Academies Press. https://doi.org/10.17226/1043.

National Research Council. 2006. *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2*. Washington, DC: The National Academies Press. https://doi.org/10.17226/11340.

National Research Council. 2012. Vision and Voyages for Planetary Science in the Decade 2013-2022. https://solarsystem.nasa.gov/resources/598/vision-and-voyages-for-planetary-science-in-the-decade-2013-2022/.

Nuclear Regulatory Commission. 1991. "Radiation Dose Limits for Individual Members of the Public." *Federal Register* (FR). Vol. 56, No. 88. May 21, 1991. As amended at 60 FR 48625, September 20, 1995; 62 FR 4133, January 29, 1997; 67 FR 20370, April 24, 2002; 67 FR 62872, October 9, 2002. https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1301.html.

Nuclear Regulatory Commission. 2020. Emergency Planning Zones. Accessed December 28, 2021. https://www.nrc.gov/about-nrc/emerg-preparedness/about-emerg-preparedness/planning-zones.html.

Nuclear Regulatory Commission. 2021. Dose in our daily lives. Accessed December 28, 2021. https://www.nrc.gov/about-nrc/radiation/around-us/doses-daily-lives.html.

Scott, R. E., J. M. Phillips, S. G. Homann, R. L. Baskett, and D. Carins-Gallimore. 2012. Technological advances in the Radiological Contingency Plan for the 2011 Mars Science Laboratory Mission. LLNL-CONF-597012. American Nuclear Society Nuclear and Emerging Technologies for Space Albuquerque, NM, United States. October 30. https://e-reports-ext.llnl.gov/pdf/688092.pdf.

Space Exploration Technologies Corporation (SpaceX). 2013. *Supplemental Environmental Assessment to the November 2007 Environmental Assessment for the Operation and Launch of the Falcon 1 and Falcon 9 Space Vehicles at Cape Canaveral Air Force Station Florida*. Final. August. https://netspublic.grc.nasa.gov/main/Final_Falcon_Launch_EA.pdf.

St. Johns River Water Management District (SJRWMD). 1990. *Upper St. Johns Ground Water Basin Resource Availability Inventory.* Technical Publication SJ 90-10. https://indianriverswcd.org/docs/References/SJ90-10_TechPub.pdf.

Tate, R. E. 1982. *The Light Weight Radioisotope Heater Unit (LWRHU): A Technical Description of the Reference Design*. LA 9078 MS. https://inis.iaea.org/collection/NCLCollectionStore/_Public/14/719/14719998.pdf.

Turtle, E. P., J. W. Barnes, M. G. Trainer, R. D. Lorenz, K. E. Hibbard, D. S. Adams, P. Bedini, J. W. Langelaan, K. Zacny, and the Dragonfly Team. 2020. Dragonfly: New Frontiers mission concept: Exploring Titan's prebiotic organic chemistry and habitability. Lunar and Planetary Science Conference, 48, March 2018. https://dragonfly.jhuapl.edu/News-and-Resources/docs/1958.pdf.

U.S. Air Force (USAF). 1998. *Environmental Impact Statement for the Evolved Expendable Launch Vehicle Program, CCAFS and VAFB*. Final. https://www.faa.gov/about/office_org/headquarters_offices/ast/licenses_permits/media/EIS1998-AF.pdf.

U.S. Air Force (USAF). 2000. *Supplemental Environmental Impact Statement for the Evolved Expendable Launch Vehicle Program, CCAFS and VAFB.* Final. https://www.faa.gov/about/office_org/headquarters_offices/ast/licenses_permits/media/eelvSEis.pdf.

U.S. Air Force (USAF). 2017a. Air Force Instruction (AFI) 40-201: *Radioactive Materials (RAM) Management*. https://static.e-publishing.af.mil/production/1/45sw/publication/afi40-201_45swsup/afi40-201_45swsup.pdf.

U.S. Air Force (USAF). 2017b. Air Force Space Command Manual 91-710: *Range User Launch Safety Requirements*. https://kscsma.ksc.nasa.gov/RangeSafety/reqDocs/DoDlinks.

U.S. Air Force (USAF). 2018. Space and Missile Museum. Cape Canaveral Air Force Station. http://afspacemuseum.org/ccafs/.

U.S. Air Force (USAF). 2019. Air Force Manual 91-110: *Nuclear Safety Review and Launch Approval for Space or Missile Use of Radioactive Material and Nuclear Systems.* May 22. https://fas.org/irp/doddir/usaf/afman91-110.pdf.

U.S. Air Force (USAF). 2020a. *Integrated Natural Resources Management Plan for the 45th Space Wing, Cape Canaveral Air Force Station, Patrick Space Force Base, Malabar Transmitter Annex, Jonathan Dickinson Missile Tracking Annex*. Final. September.

U.S. Air Force (USAF). 2020b. *Integrated Cultural Resources Management Plan for the 45th Space Wing*. Final. July.

U.S. Department of Energy (DOE). 1987. Environmental Research on Actinide Elements. Document Number DOE 86008713. Washington, DC. August.

U.S. Department of Energy (DOE). 2000. *Programmatic Environmental Impact Statement for Accomplishing Expanded Civilian Nuclear Energy Research and Development and Isotope Production Missions in the United States, Including the Role of the Fast Flux Test Facility.* Final. DOE/EIS-0310. December. https://www.energy.gov/nepa/downloads/eis-0310-final-programmatic-environmental-impact-statement.

U.S. Department of Energy (DOE). 2002. *Environmental Assessment for the Future Location of Heat Source/Radioisotope Power System Assembly and Test Operations Currently Located at the Mound Site.* http://energy.gov/sites/prod/files/nepapub/nepa_documents/RedDont/EA-1438-FONSI-2002.pdf.

U.S. Department of Energy (DOE). 2008. *Site-Wide Environmental Impact Statement for Continued Operation of Los Alamos National Laboratory, Los Alamos, New Mexico.* Final. DOE/EIS-0380. https://www.energy.gov/nepa/downloads/eis-0380-final-site-wide-environmental-impact-statement.

U.S. Department of Energy (DOE). 2013. *Supplement Analysis for the Nuclear Infrastructure Programmatic Environmental Impact Statement for Plutonium-238 Production for Radioisotope Power Systems*. DOE/EIS 031 0-SA-02. September. https://www.energy.gov/sites/prod/files/2013/09/f2/EIS-0310-SA-02-2013_0.pdf.

U.S. Department of Homeland Security (DHS). 2016. Nuclear/Radiological Incident Annex. Washington, DC. June. https://www.fema.gov/media-library-data/1478636264406-cd6307630737c2e3b8f4e0352476c1e0/NRIA_FINAL_110216.pdf.

U.S. Department of Homeland Security (DHS). 2019. *U.S. Department of Homeland Security. National Response Framework. Fourth Edition*. Washington, DC. October. https://www.fema.gov/sites/default/files/2020-04/NRF_FINALApproved_2011028.pdf.

U.S. Environmental Protection Agency (EPA). 1991. *Risk Assessment Guidance for Superfund: Volume I – Human Health Evaluation Manual* (Part B, Development of Risk-based Preliminary Remediation Goals). https://semspub.epa.gov/work/03/2218723.pdf.

U.S. Environmental Protection Agency (EPA). 1997. EPA: 40 CFR Part 190, *Environmental Radiation Protection Standards for Nuclear Power Operations*. EPA-HQ-OAR-2013-0689. January 13. https://www.epa.gov/radiation/environmental-radiation-protection-standards-nuclear-power-operations-40-cfr-part-190.

U.S. Environmental Protection Agency (EPA). 2020. EJScreen Report (Version 2018), 20-mile Ring Centered at 28.526140,-80.681360, Florida, EPA Region 4. https://ejscreen.epa.gov/mapper/.

U.S. Fish and Wildlife Service (USFWS). 2020a. National Wetlands Inventory: Wetlands Mapper. Accessed March 1, 2019. https://www.fws.gov/wetlands/data/mapper.htm.

U.S. Fish and Wildlife Service (USFWS). 2020b. "Information for Planning and Consultation" (IPaC), Version 1.4. Brevard County. https://ecos.fws.gov/ipac/.

White House. 2019. National Security Presidential Memorandum (NSPM) 20, *Presidential Memorandum on Launch of Spacecraft Containing Space Nuclear Systems.* August 20. https://trumpwhitehouse.archives.gov/presidential-actions/presidential-memorandum-launch-spacecraft-containing-space-nuclear-systems/.

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Appendix 1.5A
Notice of Availability for the Draft EA

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LEGAL NOTICE AS REQUIRED BY ...

legal notice

As required by the National Environmental Policy Act (NEPA), the National Aeronautics and Space Administration (NASA) has prepared a Draft Environmental Assessment (EA) that analyzes the potential environmental impacts of launching the proposed New Frontiers Program Dragonfly mission. The Dragonfly spacecraft would explore the surface of Saturn's largest moon, Titan and would launch from either the U.S. Space Force's Cape Canaveral Space Force Station or NASA's Kennedy Space Center, Brevard County, Florida in 2027. The Dragonfly spacecraft's electrical power and heat, both during interplanetary transit and while operating on Titan, would be provided by a radioisotope power system/multi-mission radioisotope thermoelectric generator, possibly supplemented by heat producing radioisotope heater units.

The EA evaluates the Dragonfly mission's potential environmental effects associated with nuclear radiation, land use, water resources, biological resources, hazardous materials, and cultural resources. The EA's analysis supports a conclusion that the Dragonfly mission would not result in or contribute to significant impacts on any natural or cultural resources.

Public comments on the Draft EA will be accepted for a period of 30 days until May 24, 2022. Comments may be submitted via email to hq-draftdragonflyeacmts@mail.nasa.gov or the mailing address below. Public comments will be considered as NASA prepares the Final EA. NASA will not amend comments it receives in any manner, and any personally identifiable information supplied may become part of the public record.

Copies of the Draft EA are available at the following library locations: Central Brevard Library and Reference Center (308 Forrest Ave., Cocoa FL), Cocoa Beach Public Library (550 N Brevard Ave., Cocoa Beach, FL), Melbourne Library (540 E Fee Ave., Melbourne, FL), Merritt Island Public Library (1195 N Courtenay Pkwy., Merritt Island, FL), Port St John Public Library (6500 Carole Ave., Cocoa, FL), Titusville Public Library (2121 S Hopkins Ave., Titusville, FL), and Satellite Beach Public Library (751 Jamaica Blvd., Satellite Beach, FL). The EA will also be posted on the NASA NEPA Public Reviews webpage https://www.nasa.gov/content/public-reviews. A limited number of hard copies of the Draft EA are available upon request by emailing hq-draftdragonflyeacmts@mail.nasa.gov.

For additional information or to submit written comments, please contact:
NASA Environmental Management Division
Suite 5B11
300 E Street SW
Washington, D.C. 20546

florida today

Public Notice

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AD#5228374 04/24/2022 NOTICE OF AVAILABILITY As required by the National Environmental Policy Act (NEPA), the National Aeronautics and Space Administration (NASA) has prepared a Draft Environmental Assessment (EA) that analyzes the potential environmental impacts of launching the proposed New Frontiers Program Dragonfly mission. The Dragonfly spacecraft would explore the surface of Saturn's largest moon, Titan and would launch from either the U.S. Space Force's Cape Canaveral Space Force Station or NASA's Kennedy Space Center, Brevard County, Florida in 2027. The Dragonfly spacecraft's electrical power and heat, both during interplanetary transit and while operating on Titan, would be provided by a radioisotope power system/multi-mission radioisotope thermoelectric generator, possibly supplemented by heat producing radioisotope heater units. The EA evaluates the Dragonfly mission's potential environmental effects associated with nuclear radiation, land use, water resources, biological resources, hazardous materials, and cultural resources. The EA's analysis supports a conclusion that the Dragonfly mission would not result in or contribute to significant impacts on any natural or cultural resources. Public comments on the Draft EA will be accepted for a period of 30 days until May 24, 2022. Comments may be submitted via email to hq-draftdragonflyeacmts@mail.nasa.gov or the mailing address below. Public comments will be considered as NASA prepares the Final EA. NASA will not amend comments it receives in any manner, and any personally identifiable information supplied may become part of the public record. Copies of the Draft EA are available at the following library locations: Central Brevard Library and Reference Center (308 Forrest Ave., Cocoa FL), Cocoa Beach Public Library (550 N Brevard Ave., Cocoa Beach, FL), Melbourne Library (540 E Fee Ave., Melbourne, FL), Merritt Island Public Library (1195 N Courtenay Pkwy., Merritt Island, FL), Port St John Public Library (6500 Carole Ave., Cocoa, FL), Titusville Public Library (2121 S Hopkins Ave., Titusville, FL), and Satellite Beach Public Library (751 Jamaica Blvd., Satellite Beach, FL). The EA will also be posted on the NASA NEPA Public Reviews webpage https://www.nasa.gov/content/public-reviews. A limited number of hard copies of the Draft EA are available upon request by emailing hq-draftdragonflyeacmts@mail.nasa.gov. For additional information or to submit written comments, please contact: NASA Environmental Management Division Suite 5B11 300 E Street SW Washington, D.C. 20546

Appendix 1.5B
Comments Received on the Draft EA

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Comment Segment Number	Commenter	Comment	Response	Date Comment Received
1a	Reed Wilcox	Page/Section 1-1/1.1: The opening paragraph states that this EA is, "to analyze the environmental impacts of launching" the proposed Dragonfly mission. However, NASA, by preparing an EA and not an EIS, is failing to assess the potential environmental impacts that are "reasonably foreseeable" as defined by the CEQ: ``reasonably foreseeable'' includes impacts which have catastrophic consequences, even if their probability of occurrence is low, provided that the analysis of the impacts is supported by credible scientific evidence" (40 CFR 1502.22). From the outset of NEPA, NASA has always prepared EISs to support the environmental decision-making for mission applications of RTGs. In fact, even NASA's own NEPA regulations state that actions normally requiring an EIS include, "Development and operation of a space flight project/program which would launch and operate a nuclear reactor or radioisotope power systems …" (14 CFR 1216.306 (b)(2). **What is NASA's rationale for preparing an EA instead of an EIS for the Dragonfly mission?**	NASA thanks the commenter for the comment. Please note that the Dragonfly Environmental Assessment (EA) was prepared under the Council on Environmental Quality's (CEQ's) 1978 National Environmental Policy Act (NEPA) implementing regulations. All references to CEQ regulations (*Code of Federal Regulations* (CFR) Title 40 1500–1508) are to the CEQ's 1978 regulatory framework. NASA's NEPA process is intended to help decision makers make decisions that are based on an understanding of environmental consequences. The purpose of NEPA is to foster better decisions, not to generate unnecessary paperwork. The commenter correctly notes that NASA's NEPA implementing regulations (14 CFR 1216.306(b)(2)) list development and operation of a space flight project/program that would launch and operate a radioisotope power system (RPS) as an action which would *normally* require an Environmental Impact Statement (EIS). The use of the word "*normally*" in the caption to 1216.306 is instructive and makes clear that NASA has the discretion to determine the most appropriate level of NEPA analysis when commencing the environmental impact review of a Proposed Action. This discretion is supported by the CEQ's regulations, which allow agencies to "prepare an [EA] on any action at any time in order to assist agency planning and decision making" (40 CFR 1501.3(b)). With the goal of reducing unnecessary and repetitive analysis and promoting administrative efficiency, NASA considered the data contained in seven previously prepared NEPA documents for RPS-enabled missions spanning the past three decades. None of these documents identified a significant environmental impact related to the use of a RPS in a payload. NASA concluded that preparation of an EA for the proposed Dragonfly mission was appropriate. While the potential consequence resulting from a mishap could be considered reasonably foreseeable, the low probability of the event allows for the finding of less than significant (see footnote in EA Table 3.1-2). If NASA becomes aware of significant new circumstances or information relevant to environmental concerns and bearing on the Proposed Action or its impacts, NASA may prepare a supplemental EA or consider whether the new information triggers the need to prepare an EIS.	5/10/2022
1b	Reed Wilcox	Page 1-1 / Section 1.1: NASA's NEPA regulations state that "NASA will prepare an EIS for actions with the potential to significantly impact the quality of the human environment, including actions for which an EA analysis demonstrates that significant impacts will potentially occur which will not be reduced or eliminated by changes to the proposed action or mitigation of its potentially significant impacts." (emphasis added) (Ref. 14 CFR 1216.306(a)) **How does the current EA demonstrate that significant impacts that will potentially occur can be reduced, eliminated or mitigated?**	The commenter is referred to Section 3 of the EA, which describes the affected environment and environmental consequences of the Proposed Action. Section 3 provides an explanation of the affected environment for each of the potentially impacted environmental resources and the potential environmental impacts to those resources. The environmental resources NASA analyzed include nuclear radiation, land use, water resources, biological resources, cultural resources, and hazardous materials. The analysis conducted for each of those resources supports a conclusion that the Proposed Action would not result in significant impacts to the potentially affected environment. Because significant impacts from the Proposed Action were not identified for any resource area, preparation of an EA is appropriate. NASA refers the commenter to a helpful "Summary of Impacts" table, which is available for the public's reference in Section 4 of the EA.	5/10/2022

1c	Reed Wilcox	Page 1-7 /Section 2.1.4: The draft EA acknowledges that, "The launch vehicle for the Dragonfly mission has not been formally chosen." Past NASA EISs involving RTGs have demonstrated that the choice and mission-specific design of launch vehicles/systems is relevant to assessing reasonably foreseeable significant adverse impacts associated with a proposed mission involving RTGs and/or RHUs. The potential launch vehicles for the proposed Dragonfly mission include those whose overall reliability could: be less than that of the Atlas V (the baseline for the Mars 2020 assessment, and the analytical baseline for the Dragonfly Draft EA); involve significantly higher initiating event accident probabilities for risk-driving accidents (e.g. much longer land-clear times) and new accident environments (e.g. LOx/methane explosions) that heretofore have not been analyzed by NASA/DOE. **Per 40 CFR 1502.22, why does NASA ostensibly believe that this information is not essential to the assessment of reasonably foreseeable significant adverse impacts and why doesn't the draft EA address the cost of obtaining this information?**	NASA thanks the commenter for the comment. However, NASA believes the commenter is conflating the purpose of NEPA (evaluation of the environmental impact of the Proposed Action) and the separate responsibility to evaluate and certify the safety and reliability of launch vehicles for use in future NASA missions (e.g., for Dragonfly or any number of other missions appropriate for the launch vehicle). To keep NASA's NEPA analysis for future nuclear-enabled missions from being dependent on the characteristics of a particular launch vehicle, NASA has evolved its approach to evaluating the significance of the environmental impact of using an RPS. In support of the preparation of the Dragonfly EA, the Department of Energy (DOE), a Cooperating Agency in NASA's NEPA processes for all space nuclear system-enabled missions, prepared, through the Idaho National Laboratory (INL),a consequence analysis for the Dragonfly EA. DOE's consequence analysis uses a deterministic statistical approach that is not launch vehicle dependent to evaluate the potential likelihood of a release of nuclear material into the environment during launch phases and what effects such a release may have on the environment and maximally exposed individual (MEI). In contrast, the Mars 2020 Supplemental EIS, and the other EISs prepared prior to Mars 2020, used a probabilistic risk assessment that ***is*** dependent on the launch vehicle being known. Therefore, in summary, coansideration of the launch vehicle under the deterministic approach is not necessary, as the probability of a mishap relies on broad tolerance categories based on in DOE-STD-3009. NASA and DOE used the best available, reasonably attainable information to estimate the probabilities of a mishap. If it is determined during the SAR process that the chosen launch vehicle is outside the tolerances demonstrated in this EA, a supplemental NEPA analysis may be published. While this may be a change in analytical approach from NASA's previously prepared nuclear-enabled mission NEPA documents, the deterministic approach provides a repeatable, robust, and accurate analytical framework, and has a collateral benefit that it also supports a more administratively streamlined conclusion to the NEPA process.	5/10/2022
1d	Reed Wilcox	Page 2.7 / Section 2.14: No launch vehicle EIS or EA prepared by NASA, the USAF or FAA has ever assessed the potential environmental impacts associated with a launch of an RTG. Such impacts have always been assessed as part of a NASA mission-specific EIS. This draft EA states that, "If a launch vehicle is selected that has not been previously analyzed using the NEPA process, NASA may prepare an additional or supplemental environmental analysis …". **How does NASA satisfy NEPA requirements by first selecting a launch vehicle for the mission and then making a decision whether to prepare additional environmental analysis that would inform decision-makers on the potential environmental effects of their launch vehicle selection? How does this not bias the selection of reasonable alternatives for the mission, including the no-action alternative?**	NASA thanks the commenter for the comment and has amended the text of the EA to more aptly describe the considerations that may require preparation of a supplemental environmental analysis (refer to 40 CFR 1502.9(c)(ii) – a section of the CFR that applies to an EIS, but which, by policy, NASA also applies to EAs). The revised text reads: "If NASA becomes aware of significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts, NASA may prepare a supplemental EA or consider whether the new information triggers the need to prepare an EIS."	5/10/2022
1e	Reed Wilcox	Page 2-8 / Section 2.1.6.1: The draft EA states that "The GPHS modules are engineered and constructed with multiple protective design features that substantially mitigate the risk of a release and dispersal of nuclear material in an accident situation. These safety features include the ceramic form of the Pu-238 heat source material, iridium metal alloy cladding, …". *However, the draft EA doesn't address the significant new and seemingly contradictory information that was contained in the Supplemental Environmental Impact Statement for the Mars 2020 Mission pertinent to the safety design of the MMRTG.* • Original Design Safety Design The 2014 FEIS for the Mars 2020 mission states on p. 2-23, "Iridium Clads: The iridium that encases each plutonium dioxide pellet is a strong, ductile metal that resists corrosion and does not react chemically with the radioisotope fuel. In the event of an accident involving an impact, the iridium cladding is designed to deform yet contain the fuel." (emphasis added). In furtherance of this assertion, the Supplemental FEIS (SEIS) for the Mars 2020 mission, states on p. 2-2 that, "2.1.3 Rover Electrical Power The description of the	This EA analyzes and identifies the potential effects of the use of radioisotope power and heating sources associated with the Dragonfly mission, including the Proposed Action and No Action Alternative, as presented in the Announcement of Opportunity. NASA and DOE have continued to invest in the development, design, and testing of the MMRTG for over two decades. Investigations regarding clad ductility associated with the MMRTGs are outside the scope of the Dragonfly EA, but continue nonetheless. The Mars 2020 Supplemental EIS, which issued a supplemental ROD in March 2020, confirmed that the new information did not equate to any substantial increase in environmental impacts.	5/10/2022

		rover's electrical power system (the MMRTG) is the same as presented in Section 2.1.3 of the 2014 FEIS." (emphasis added) • Failure to Achieve Safety Design Performance However, in the SEIS three separate statements indicate that the iridium is much less ductile than originally intended; in fact, the available information in the SEIS suggests the possibility that the iridium could be brittle in Dragonfly's MMRTG at launch. ○ "Impact testing conducted in May 2017, which was performed at a fuel clad temperature representative of the MMRTG launch conditions, revealed that the iridium cladding was less ductile than previously modeled in the risk analysis for the 2014 FEIS." (Mars 2020 Supplemental EIS, NASA, p.3-7); ○ "The GPHS-RTG used thermoelectric materials made from silicon-germanium dioxide and operated in a high fuel clad temperature range above 900 degrees Celsius (°C). At these temperatures, iridium clads are very ductile and will tend to deform rather than break open during impacts from launch accidents. (Mars 2020 Supplemental EIS, NASA, p. A-4) ○ However, the SEIS indicates that the Mars 2020 MMRTG was operating at 750 °C, a temperature well below 900 °C at launch: "Though the MMRTG uses an enhanced version of the same GPHS blocks for the heat source, it uses different thermoelectric materials (made from lead telluride), which operate at a lower temperature range (with average iridium clad temperatures of about 750°C during launch conditions)." (Mars 2020 Supplemental EIS, NASA, p. A-5). • Limited Environmental Decision-making NASA acknowledged in the Supplemental FEIS for the Mars 2020 mission that environmental decision-making was limited: "Since publication of the 2014 FEIS and issuance of the ROD in 2015, NASA has made investments of time and money that are irrevocable as well as decisions that cannot be reversed. These include: Mars 2020 rover and payload design … Selection of launch vehicle … and launch period …" (emphasis added) (Mars 2020 Supplemental EIS, NASA, p. 1-3). **Why has NASA not considered this new and significant information in the NEPA decision-making for Dragonfly in defining reasonable alternatives for the mission before an irrevocable commitment of resources is made that would limit the payload design (including possible design safety enhancements to the MMRTG to meet its original design intent of having the cladding "deform yet contain the fuel"), and the selection of launch vehicles and/or launch period?**		
1f	Reed Wilcox	Page 2-10 / Section 2.3.1: **Why doesn't NASA and DOE consider the alternative to find another alloy of iridium that would be as ductile as the iridium in the GPHS-RTG but at the launch temperature of MSL, Mars 2020 and the level expected for Dragonfly?**	The potential effects of the use of radioisotope power and heating sources associated with the Dragonfly mission, including the Proposed Action and the No Action Alternative, were analyzed in this EA. Investigations on clad ductility are outside the scope of the Dragonfly EA. The Mars 2020 Supplemental EIS, which issued a supplemental Record of Decision (ROD) in March 2020, confirmed that this new information (clad response to impacts at lower temperature) did not equate to any substantial increase in environmental impacts.	5/10/2022

1g	Reed Wilcox	Page 2-10 / Section 2.3.1: **Since, according to the SEIS, NASA has been aware of the reduced clad ductility of MMRTGs since 2017, what efforts have NASA and DOE undertaken to define and/or investigate design options for achieving clad ductility comparable to that in the GPHS-RTG?**	As stated previously, investigations on clad ductility of MMRTGs are outside the scope of this Dragonfly EA. Information on cladding temperatures will be accounted for in DOE's Dragonfly mission safety analysis. Acceptable detail and information required by NEPA is covered in this EA and, moving forward, mission-specific analysis will be presented in the safety analysis.	5/10/2022
1h	Reed Wilcox	Page 2-11 / Section 2.4.2: The EA states that "Similar to other launches, there would be only beneficial socioeconomics effects under the Proposed Action." **A launch area accident resulting in the release of PuOx could contaminate on-site and off-site visitors and their vehicles, launch pads, launch systems and cruise terminals. Even if dose exposure levels were considered small, would officials preclude the transport and dispersal of PuOx beyond the launch area by personal vehicles and, if so, what would be the socioeconomic impacts of such actions? What would be the socioeconomic impacts of precluding use of cruise terminals and cruise ships contaminated with PuOx?**	NASA thanks the commenter for the comment. With regard to an accident in the launch area that results in the release of nuclear material into the environment, it would be speculative to analyze what possible specific actions officials may take in response to such an accident. Nonetheless, as described in the EA, NASA works closely in advance with federal, state, and local officials (e.g., public information services and emergency management organizations) to prepare contingency response plans to respond to launch-related accidents. With regard to accidents that involve an RPS-enabled mission, such emergency response planning and interagency coordination is required by the Nuclear/Radiological Incident Annex to the National Response Framework (e.g., Table 1, Nuclear/Radiological Incident Annex). This ensures that a timely and effective incident response is performed after any mishap involving nuclear materials. These plans are discussed in Section 3.1.1.4 *(Established Nuclear Safety Procedures*) of the EA. The EA was also revised to state that there is no socioeconomic effect under the Proposed Action.	5/10/2022
1i	Reed Wilcox	Page 2-11 / Section 2.4.2: **What would be the socioeconomic impacts resulting from precluding the use of contaminated launch systems and/or launch pads during post-accident clean-up operations?**	NASA thanks the commenter for the comment. Regarding an accident in the launch area that results in the release of nuclear material into the environment, it would be speculative to analyze what possible specific actions officials may take in response to such an accident. Nonetheless, as described in the EA, NASA works closely in advance of a launch with federal, state, and local officials (e.g., public information services and emergency management organizations) to prepare contingency response plans to respond to launch-related accidents. Regarding accidents that involve an RPS-enabled mission, such emergency response planning and interagency coordination is required by the Nuclear/Radiological Incident Annex to the National Response Framework (e.g., Table 1, Nuclear/Radiological Incident Annex). This ensures that a timely and effective incident response is performed after any mishap involving nuclear materials. These plans are discussed in Section 3.1.1.4 *(Established Nuclear Safety Procedures*) of the EA.	5/10/2022
1j	Reed Wilcox	Page 2-12 / Section 2.4.2: Under "Geology and Soils", the statement is made, "In the extremely unlikely event of a release of Pu-238 during a launch accident …". However, Table 3.1-2 indicates that an event on the order of 1 in 1000 (i.e. the Mars 2020 probability of releasing PuOx in the launch area) is "unlikely" not "extremely unlikely". **Why does NASA apparently not use consistent terminology in the Draft EA to characterize radiological releases?**	NASA appreciates the comment. The text of the EA has been revised to clarify the narrative.	5/10/2022

1k	Reed Wilcox	The characterization of the risk in this draft EA document does not coincide with that of one of the draft EA's listed references, "Technological Advances in Radiological Contingency Planning for the 2011 Mars Science Laboratory Mission", (Scott, Phillips, Homann, et. Al). The listed reference, "work performed under the auspices of NASA and U.S. DOE and LLNL under DOE Contract DE-ACX52-07NA27344 (LLNL-CONF-597012)", states that the launch of MSL was in a class of "[l]ow probability events with high potential consequences [that] demand preparation commensurate with the potential consequences." **Given that the government's own experts characterize missions such as MSL as low probability events with high potential consequences, how can NASA rationalize preparing an EA instead of an EIS for Dragonfly?**	Impact significance should take into consideration the probability of an event in relation to the consequence of the event. To date, NASA has prepared seven NEPA documents for RPS-enabled missions spanning the past three decades. None of these documents identified a significant environmental impact related to the use of a RPS in a payload. NASA began the NEPA process for the Dragonfly mission with an EA. This discretion is supported by the CEQ's regulations, which allow agencies to "prepare an [EA] on any action at any time in order to assist agency planning and decision making" (40 CFR 1501.3(b)). While the potential consequence resulting from a mishap could be considered reasonably foreseeable, the low probability of the event allows for the finding of less than significant. If NASA becomes aware of significant new circumstances or information relevant to environmental concerns and bearing on the Proposed Action or its impacts, NASA may prepare a supplemental EA or consider whether the new information triggers the need to prepare an EIS. As noted in response to Comment 1i, regarding accidents that involve an RPS-enabled mission, such emergency response planning and interagency coordination is required by the Nuclear/Radiological Incident Annex to the National Response Framework (e.g., Table 1, Nuclear/Radiological Incident Annex). This ensures NASA, other federal partners, and appropriate State and local officials are involved in executing a timely and effective incident response. These plans are discussed in Section 3.1.1.4 *(Established Nuclear Safety Procedures*) of the EA.	5/10/2022
1l	Reed Wilcox	Page 3-5 / Section 3.1.2.1: The draft EA states that, "In the unlikely event of an accident, the most probable outcome is still an accident with no release of Pu-238, as MMRTGs and RHUs are designed to withstand most energetic accident conditions associated with launch mishaps without compromising the Pu-238." This statement is true for the overall Dragonfly mission, but it is false for the accidents that occur in the immediate launch area, the focus of Section 3 of the draft EA. As documented in the Mars 2020 SEIS, given an accident during Pre-Launch and Early Launch, the conditional probability of releasing Pu-238 is 60% and 52%, respectively. (Mars 2020 Supplemental EIS, NASA, p. A-7). **How are members of the public and NASA decision-makers to rely on the substance of the EA when it doesn't accurately represent the most significant potential environmental impact scenarios associated with the proposed action? Also, as noted in comment #5 above, what is the basis for the draft EA's conclusion that MMRTGs "are designed to withstand most energetic accident conditions associated with launch mishaps without compromising the Pu-238" when the accidents of greatest concern have a probability of greater than 50% of releasing Pu-238 into the environment (especially considering that these accidents would occur at a time when the greatest number of unprotected visitors with limited options for sheltering in the event of a launch accident are present in the vicinity of the launch site)?**	The EA accurately presents the total probability of a release and the resulting dose consequences. The total probability of an accident resulting in a release for all phases of Mars 2020 was unlikely (~1 in 10,000) to beyond extremely unlikely (1 in 1,000,000) as shown in Table 3.1-3 in the EA. The comment regarding the conditional probability of a release in the Mars 2020 Supplemental EIS, NASA, p. A-7, is correctly summarized but must be combined with the probability of the postulated accident to reflect the overall total probability of a release of Pu in an accident scenario. The language in Section 3.1.2.1 and Table 3.1-3 has been revised to clarify the conditional probability of a release and to avoid understating the consequence after the mishap. While the potential consequence resulting from a mishap could be considered reasonably foreseeable, the low probability of the event allows for the finding of less than significant. The EA uses the information of previously performed Monte Carlo accident analysis to provide an overall deterministic dose consequence for postulated accidents.	5/10/2022
1m	Reed Wilcox	Page 3-5 / Section 3.1.2.1: The draft EA states, "The probability of a potential release of Pu-238 during the Dragonfly mission was assessed by reviewing analyses performed for previous NASA missions involving MMRTGs and RHUs (NASA, 1997, 2020c)." NASA's NEPA regulations state that "The Responsible Official will prepare an EA when a proposed action cannot be categorically excluded, and the proposed action is not expected to result in impacts that require analysis in an EIS." (emphasis added) (14 CFR 1216.305(a)) **How is the proposed action in this draft EA expected not to result in impacts that require analysis in an EIS when the EA explicitly characterizes the proposed action as based on the Mars 2020 analysis, a mission for which NASA prepared both an EIS and SEIS?**	NEPA regulations encourage agencies to perform an EA to determine the potential for a significant effect (40 CFR 1501.3(a)); past EIS documents do not necessitate a requirement to conduct future EISs, if the potential effect from the proposed action is less than significant. To date, NASA has prepared seven EISs for RPS-enabled missions spanning the past three decades. NASA has also prepared a Programmatic Environmental Assessment on the use of radioisotope heater units (RHUs) as a payload component. None of these analyses concluded that there is the potential for a significant environmental impact from the use of RPS or RHUs. Aligning with CEQ's NEPA guidance, NASA began the NEPA process for Dragonfly with an EA.	5/10/2022

1n	Reed Wilcox	Page 3-5 / Section 3.1.2.1: The draft EA states under the "Low Probability Release Scenarios" subsection that, "The GPHS modules and RHUs both have safety features designed to withstand most accident scenarios throughout the launch phases, 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." While this statement is true, it is a secondary concern relative to the much higher probability scenarios of the MMRTG impacting the ground in either a pre-launch or early launch accident scenario and releasing Pu-238 (with conditional release probabilities estimated at 60% and 52%, respectively), including respirable particles, and the creation of additional respirable particles as a result of exposure to both solid fuel or liquid propellant fire environments (Mars 2020 Supplemental EIS, NASA, Table A-4). **Why does the draft EA not explicitly address these highest probability accident scenarios in the immediate launch area during pre-launch and launch? Also, why doesn't the draft EA discuss potential MMRTG design changes that could reduce the probability and size of Pu-238 releases if the iridium was at a temperature closer to that of the GPHS-RTG where similar ground impacts of less robust GPHS modules had lower probabilities of and smaller releases of Pu-238?** (see NASA Final and/or Supplemental Environmental Impact Statements for the Cassini and New Horizons missions)	This EA leverages previous launch safety analysis such as that of the Mars 2020 Supplemental EIS and presents deterministic dose consequence analysis for early launch failures. Section 3.1.2.1 presents the highest radiation dose to the MEI resulting from an unlikely event in Phase 0 (Pre-launch), 1 (early launch), or 2 (late launch). As previously stated, MMRTG design changes are outside the scope of this EA.	5/10/2022
1o	Reed Wilcox	Page 3-5 / Section 3.1.2.1: The draft EA apparently assumes that a suborbital or orbital accident for the Dragonfly mission would have a similar result to that of the Mars 2020 mission because it makes the statement that "GPHS modules and RHUs are designed to withstand most reentry accident scenarios, and missions are planned such that the potential for unintentional re-entry with a release of plutonium is extremely unlikely." This statement is not supported by any analysis of the Dragonfly heatshield or backshell. The Mars 2020 heatshield and backshell were designed to withstand entry into the Mars atmosphere. The Mars 2020 FEIS noted, "Reentry from circular orbital decay or long-term reentry is predicted to cause breakup of the SV [space vehicle] and the MMRTG with subsequent release of the GPHS modules." (Mars 2020 Supplemental EIS, NASA, p. 4-32) However, no comparable information is presented in the draft EA indicating the reentry conditions the Dragonfly spacecraft would have to withstand at Titan. If the reentry conditions for Dragonfly at Titan are greater than those for Mars 2020 at Mars, then the Dragonfly spacecraft will have a higher probability of intact impact (i.e. not releasing the GPHS modules) in potential orbital reentry scenarios. **What analysis has NASA conducted to assess whether the Mars 2020 spacecraft reentry design is an adequate proxy for assessing the Dragonfly reentry design performance in reentry accident scenarios?**	Mars 2020 used an MMRTG on a very similar mission as the Dragonfly mission. Comparisons between Mars 2020 and Dragonfly are conducted and evaluated throughout the entire Dragonfly mission lifecycle as appropriate. Reentry accident scenarios in the context of the Dragonfly spacecraft design will be addressed as part of the Safety Analysis Report (SAR). If NASA becomes aware of significant new circumstances or information relevant to environmental concerns and bearing on the Proposed Action or its impacts, NASA may prepare a supplemental EA or consider whether the new information triggers the need to prepare an EIS.	5/10/2022
1p	Reed Wilcox	Page 3-7 / Section 3.1.2.1: The draft EA asserts "A conservative estimate of the highest radiation dose to the MEI would be between 2.98 and 21.4 rem resulting from an extremely unlikely event in Phase 0, 1 or 2 (probability less than 1 in 10,000)." **What is the rationale for asserting that any of the estimates in this draft EA are "conservative" given that the Dragonfly mission could launch on a launch vehicle that is potentially less reliable than the Atlas V, could involve different propellants (i.e. methane and LOx) that could present more severe accident environments than the Atlas V, and has a spacecraft design that could differ markedly in an Earth reentry accident scenario than either the MSL or Mars 2020 missions?**	The term conservative has been replaced with deterministic. NASA thanks the commenter for the comment. However, NASA believes the commenter is conflating the purpose of NEPA (evaluation of the environmental impact of the proposed action) and the separate responsibility to evaluate and certify the safety and reliability of launch vehicles for use in future NASA missions (e.g., Dragonfly or any number of other missions appropriate for the launch vehicle). To avoid NASA's NEPA analysis for nuclear-enabled missions from being dependent on the characteristics of a particular launch vehicle, NASA has evolved its approach to evaluating the significance of the environmental impact of using an RPS in a payload. In support of the preparation of the Dragonfly EA, the DOE, a Cooperating Agency in NASA's NEPA process for all space nuclear-system-enabled missions, prepared, through the INL, a consequence analysis for	5/10/2022

			the Dragonfly EA. DOE's consequence analysis uses a deterministic statistical approach that is not launch vehicle dependent to evaluate the potential likelihood of a release of nuclear material into the environment during launch phases and what effects such a release may have on the environment and MEI. In contrast, the Mars 2020 Supplemental EIS, and EISs prepared prior to Mars 2020, used a probabilistic risk assessment that ***is*** dependent on the launch vehicle being known. Therefore, in summary, consideration of the launch vehicle under the deterministic approach is not necessary, as the probability of a mishap is managed as a separate consideration. While this may be a change in analytical approach from NASA's previously prepared nuclear-enabled mission NEPA documents, the deterministic approach provides a repeatable, robust, and accurate analytical framework and has a collateral benefit that also supports a more administratively streamlined conclusion to the NEPA process. NASA would only launch the Dragonfly mission on a certified launch vehicle that supports NASA's commitment to safety.	

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Appendix 2.6A
Coastal Zone Management Act (CZMA) Consultation Documents

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From: State_Clearinghouse <State.Clearinghouse@dep.state.fl.us>
Sent: Monday, April 25, 2022 7:05 AM
To: Dankert, Donald J. (KSC-SIE30); State_Clearinghouse
Subject: [EXTERNAL] RE: NASA Dragonfly Environmental Assessment Clearinghouse Submittal

Follow Up Flag: Follow up
Flag Status: Flagged

While it is covered by EO 12372, the Florida State Clearinghouse does not select the project for review. You may proceed with your project.

Please continue to send future electronic requests directly to the State of Florida Clearinghouse email address, state.clearinghouse@floridadep.gov.

Good Luck.

Chris Stahl

Chris Stahl, Coordinator
Florida State Clearinghouse
Florida Department of Environmental Protection
3800 Commonwealth Blvd., M.S. 47
Tallahassee, FL 32399-2400
ph. (850) 717-9076
State.Clearinghouse@floridadep.gov

From: Dankert, Donald J. (KSC-SIE30) <donald.j.dankert@nasa.gov>
Sent: Monday, April 25, 2022 9:26 AM
To: State_Clearinghouse <State.Clearinghouse@dep.state.fl.us>
Cc: Dankert, Donald J. (KSC-SIE30) <donald.j.dankert@nasa.gov>
Subject: NASA Dragonfly Environmental Assessment Clearinghouse Submittal

Dear Mr. Stahl:

This email provides the State of Florida with the National Aeronautics and Space Administration's (NASA's) Negative Determination under Section 307 of the CZMA, 16 United States Code Section 1456, and Title 15 *Code of Federal Regulations* (CFR) Section 930.35. The information in this Negative Determination is also provided pursuant to 15 CFR Section 930.35. A copy of the Draft EA is attached for your use. The document and Notice od Availability can also be accessed at : Public Reviews | NASA

Overview

NASA has prepared an Environmental Assessment (EA) to analyze the environmental impacts of launching the Dragonfly mission, which would use a single multi-mission radioisotope thermoelectric generator (MMRTG) and up to 43 radioisotope heater units (RHUs). The Dragonfly mission would employ a multi-rotor vehicle to explore and investigate Saturn's largest moon, Titan. The launch would take place at Cape Canaveral Space Force Station (CCSFS) or Kennedy Space Center (KSC) in Brevard County, Florida, during 2027; however, the launch schedule is subject to change.

Purpose and Need

NASA needs to fulfill the congressional mandate to carry out the New Frontiers Program objective. The proposed Dragonfly mission would satisfy this mandate by exploring Titan in partnership with the Johns Hopkins University Applied Physics Laboratory. Additionally, the National Research Council's 2013-2022 Decadal Survey, *Vision and Voyages for Planetary Science in the Decade*, identified Titan as a high priority of the planetary science community because it is an ocean world and the only moon in our solar system with a dense atmosphere. It is potentially the most Earth-like world in our solar system, which makes it an ideal location for studying prebiotic chemistry and the potential for extraterrestrial life. Therefore, the Decadal Survey advises NASA to conduct two New Frontiers missions per decade.

Radioisotope Power Systems

Some of the most significant challenges in deep space exploration is efficiently keeping spacecraft warm and providing sustained power in deep space environments where the use of solar or batteries are ineffective. For these reasons, alternative sources are necessary for operating the spacecraft under these harsh conditions. NASA proposes to use a single MMRTG and up to 43 RHUs for providing electrical power and heat to the spacecraft for the duration of the Dragonfly Mission. Due to the extended length of the mission, the distance from the sun, and the density of the atmosphere, the Dragonfly mission is unable to implement solar or batteries into the spacecraft design.

The process of harnessing the heat from the natural decay of radioisotope is established technology that has been refined based on decades of experience and demonstrated success; recent nuclear-enabled space missions include the 2006 launch of the New Horizons spacecraft, the 2011 launch of the Mars Science Laboratory, and most recently the Mars 2020 Perseverance Rover. Radioisotope power systems (RPS) can produce heat for decades under the harsh conditions of deep space without refueling or needing sunlight. Consequently, NASA needs to be able to use RPS for a successful Dragonfly mission.

Federal Review

After review of the Florida Coastal Management Program and its enforceable policies, NASA decided that this activity would not affect the state of Florida coastal zone or its resources.

Thank you for your attention to this matter. Please feel free to contact me if you have any questions or concerns.

Sincerely,

Donald Dankert
Technical Lead, Environmental Planning
Environmental Management Branch
SI-E3, NASA Kennedy Space Center
(c)321.222.8825

Enclosures: Florida Coastal Management Program Consistency Review

Florida Coastal Management Program Consistency Review

Statute	Consistency	Scope
Chapter 161 Beach and Shore Preservation	The Proposed Action would not affect beach or shore management in Florida. All land activities would occur on existing federal facilities.	Authorizes the Bureau of Beaches and Coastal Systems within DEP to regulate construction on, or seaward of, the state's beaches.
Chapter 163, Part II Growth Policy; County and Municipal Planning; Land Development Regulation	The Proposed Action would not affect local government comprehensive plans.	Requires local governments to prepare, adopt, and implement comprehensive plans that encourage the most appropriate use of land and natural resources in a manner consistent with the public interest.
Chapter 186 State and Regional Planning	The Proposed Action would not affect Florida's plans for water use, land development, or transportation.	Details state-level planning efforts. Requires the development of special statewide plans governing water use, land development, and transportation.
Chapter 252 Emergency Management	The Proposed Action would not affect Florida's vulnerability to natural disasters. The Proposed	Provides for planning and implementation of the state's response to, efforts to recover from,

	Action would not affect emergency response or evacuation procedures.	and the mitigation of natural and man-made disasters.
Chapter 253 State Lands	All activities would occur on federal property; therefore, the Proposed Action would not affect state public lands.	Addresses the state's administration of public lands and property of this state, and provides direction regarding the acquisition, disposal, and management of all state lands.
Chapter 258 State Parks and Preserves	The Proposed Action would not affect state parks, recreational areas, and aquatic preserves.	Addresses administration and management of state parks and preserves.
Chapter 259 Land Acquisition for Conservation or Recreation	The Proposed Action is not likely to affect tourism and/or outdoor recreation. If on the remote chance a recreational resource is affected by the Proposed Action, NASA and/or the USSF would coordinate with the U.S. Fish and Wildlife Service and National Park Service.	Authorizes acquisition of environmentally endangered lands and outdoor recreation lands.
Chapter 260 Recreational Trails System	The Proposed Action would not include the acquisition of land and would not affect the Greenways and Trails Program.	Authorizes acquisition of land to create a recreational trails system and to facilitate management of the system.
Chapter 267 Historical Resources	The Proposed Action is not likely to affect cultural resources of Florida. If on the remote chance a historic resource is affected by the Proposed Action, NASA and/or the USSF would coordinate with the Florida State Historic Preservation Office, per the National Historic Preservation Act.	Addresses management and preservation of the state's archaeological and historical resources.
Chapter 288 Commercial Development and Capital Improvements	The Proposed Action would not affect future business opportunities on state lands, or the promotion of tourism in the region.	Provides the framework for promoting and developing the general business, trade, and tourism components of the state economy.
Chapter 334 Transportation Administration	The Proposed Action would not affect transportation.	Addresses the state's policy concerning transportation administration.
Chapter 339 Transportation Finance and Planning	The Proposed Action would not affect the finance and planning needs of the state's transportation system.	Addresses the finance and planning needs of the state's transportation system.
Chapter 373 Water Resources	The Proposed Action does not include construction and would not affect Florida's water resources.	Addresses the state's policy concerning water resources.
Chapter 375 Multipurpose Outdoor Recreation; Land Acquisition, Management and Conservation	The Proposed Action is not likely to affect tourism and/or outdoor recreation. If on the remote chance a recreational resource is affected by the Proposed Action, NASA and/or the USSF would coordinate with the U.S. Fish and Wildlife Service and National Park Service.	Develops comprehensive multipurpose outdoor recreation plan to document recreational supply and demand, describe current recreational opportunities, estimate the need for additional recreational opportunities, and propose means to meet the identified needs.
Chapter 376 Pollutant Discharge Prevention and Removal	The Proposed Action would be consistent with Florida's statutes and regulations regarding the transfer, storage, or transportation of pollutants.	Regulates transfer, storage, and transportation of pollutants and cleanup of pollutant discharges.
Chapter 377 Energy Resources	The Proposed Action would not affect energy resource production, including oil and gas, and/or the transportation of oil and gas.	Addresses regulation, planning, and development of oil and gas resources of the state.
Chapter 379 Fish and Wildlife Conservation	The Proposed Action is not likely to affect wildlife. The Proposed Action should not affect marine fisheries. NASA and the USSF will work with the U.S. Fish and Wildlife Service if there is any potential to affect threatened or endangered species. NASA and the USSF will work with the U.S. National Marine Fisheries Service if there is any potential to affect fisheries.	Establishes public policy concerning marine fisheries resources and the hunting, fishing, and taking of game.
Chapter 380 Land and Water Management	The Proposed Action would not result in growth-inducing effects.	Establishes land and water management policies to guide and coordinate local decisions relating to growth and development.
Chapter 381 Public Health, General Provisions	The Proposed Action would not affect Florida's policy concerning the public health system.	Establishes public policy concerning the state's public health system.
Chapter 388 Mosquito Control	The Proposed Action would not affect mosquito control efforts.	Addresses mosquito control effort in the state.
Chapter 403 Environmental Control	The Proposed Action would not affect water quality, air quality, pollution control, solid waste management, or other environmental control efforts in Florida.	Establishes public policy concerning environmental control in the state.
Chapter 553 Building Construction Standards	The Proposed Action would not involve constructing new buildings.	Establishes policy concerning building and construction in coastal zone areas.
Chapter 582 Soil and Water Conservation	The Proposed Action does not involve any construction in Florida. Therefore, the Proposed Action would not affect State of Florida soil and water conservation efforts.	Provides for the control and prevention of soil erosion.
Chapter 597 Aquaculture	The Proposed Action would not affect aquaculture production efforts.	Provides for the coordination, prioritization, and conservation of aquaculture production efforts.

Appendix 3.4A
Endangered Species Act (ESA) Consultation Documents

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From: Dankert, Donald J. (KSC-SIE30) <donald.j.dankert@nasa.gov>
Sent: Monday, April 25, 2022 6:53 AM
To: jaxregs@fws.gov
Cc: Dziergowski, Annie; Dankert, Donald J. (KSC-SIE30)
Subject: NASA Dragonfly Draft EA ESA Section 7 Consultation Request
Attachments: dragonfly_public_draft_ea_april_2022.pdf

Annie,
Please find the attached DRAFT EA and supplemental consultation information for the NASA Dragonfly mission for your use and review. The Draft EA and Notice of Availability can also be accessed at : Public Reviews | NASA
This consultation request is similar to our consultation for the Mars 2020 Supplemental Environmental impact Statement in 2019 in that there is no construction associated with the action and the consultation centers on the use of multi-mission radioisotope thermoelectric generators (MMRTG) and up to 43 radioisotope heater units (MRTG) . Don't hesitate to let me know if you have any questions or need any additional information.

V/r,
Don

Donald Dankert
Technical Lead, Environmental Planning
Environmental Management Branch
SI-E3, NASA Kennedy Space Center
(c)321.222.8825
Chat with me on Teams

1. The National Aeronautics and Space Administration (NASA) requests your concurrence on a "not likely to adversely affect" determination for federally listed species from the launching of the Dragonfly mission from CCSFS or KSC.

2. NASA is preparing an environmental assessment (EA) per the National Environmental Policy Act (NEPA) regulations at 40 Code of Federal Regulations (CFR) for NASA's upcoming Dragonfly Mission. As part of this EA, NASA is analyzing the environmental impacts of launching the Dragonfly mission, which would use a single multi-mission radioisotope thermoelectric generator (MMRTG) and up to 43 radioisotope heater units (RHUs). Please see Attachment 1 for a more detailed explanation of MMRTGs and RHUs and their associated radiological profile.

3. Through the environmental review process, NASA has determined that there would be no impacts to federally-listed species or designated critical habitat from using a single MMRTG and up to 43 RHUs under normal operating conditions (successful launch). For potential impacts occur, there would have to be a launch mishap that results in the release of some of the Plutonium-238 (Pu-238) fuel from the MMRTG and/or RHUs, which is extremely unlikely (1 in 10,000 to 1 in 1,000,000), given the safety features designed into the MMRTG and RHUs. Additionally, due to the limited exposure pathways and the relatively insoluble composition of Pu-238, there would only be discountable impacts to federally-listed or designated critical habitat. Please see Attachment 2 for the US Fish and Wildlife Service's Information for Planning and Consultation report for the federally-listed species in Brevard County, Florida.

4. We appreciate your review and concurrence of this proposed action. Please contact Mr. Donald Dankert, KSC NEPA Manager, at (321) 861-1196 for additional information regarding the Dragonfly mission. Please address any written comments to donald.j.dankert@nasa.gov.

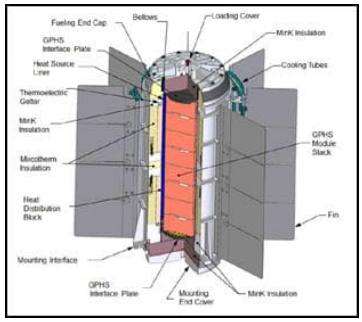
Attachment-1: MMRTG and RHU Descriptions and Radiological Risk Profile

Attachment-2: Federally-listed Species

Attachment 1: RHU and MMRTG Overview and Radiological Risk Profile

MMRTG Description

MMRTGs, a type of Radioisitope Thermoelectric Generator (RTG), are space nuclear power systems that convert heat into electricity without using moving parts; instead, MMRTGs directly convert heat from the natural decay of Pu-238 into electricity. A single MMRTG would be used for the Dragonfly mission as the source of heat and electrical power for its systems and instruments.



MMRTGs have been successfully used on 32 space missions since the 1960s and have been analyzed in previous NEPA documents including the Mars 2020 Perseverance Rover launch most recently. There have been no radiological incidents in the history of using RTGs in spacecraft.

The integrity and durability of MMRTGs have been well documented by the Department of Energy (DOE). MMRTGs are designed with safety features to withstand potential accidents from a wide-range of space missions without the release of Pu-238.

A MMRTG includes eight General Purpose Heat Source (GPHS), which are considered the essential building block of an MMRTG, as they contain and protect the Pu-238 fuel. The GPHS is engineered and constructed with multiple protective design features that substantially mitigate the risk of a release and dispersal of nuclear material in an accident situation. These safety features include the ceramic form of the Pu-238 heat source material, iridium metal alloy cladding, graphite sleeves that protect the fuel, and the rugged carbon-fiber material that forms the shell (see figure).

The majority of any release would remain on the launch pad.

For more information on MMRTGs, please visit: https://rps.nasa.gov/resources/86/multi-mission-radioisotope-thermoelectric-generator-mmrtg/?category=fact_sheets

RHU Description

RHUs are small devices that use the natural decay of Pu-238 to provide thermal energy to heat electronics for a mission.

RHUs have flown on 9 NASA missions since the 1960s and have been analyzed in approximately eight Environmental Impact Statements since 1988. There have been no radiological incidents in the history of using RHUs in spacecraft.

The integrity and durability of RHUs have been well documented by the DOE; RHUs are designed to withstand the potential accidents of a wide range of space missions without the release of Pu-238.

RHUs include multiple layers of protection. The outermost layer of protection is composed of fine-weave, pierced fabric carbon-carbon composite material. The innermost level of protection is the

platinum-rhodium metal alloy. Finally, the hot-pressed ceramic fuel pellet itself ensures the Pu-238 is in its most stable form to minimize risk of release in the event of an accident. The fuel pellet has the highest melting point of all the materials used in the RHU. It is resistant to fracture and, in the extremely unlikely event of a lauch mishap, the ceramic form could break into pieces rather than fine dust, thereby limiting the potential airborne release of Pu-238. Additionally, NASA designs their missions to avoid this potential.

For more information on RHUs, please visit: https://rps.nasa.gov/power-and-thermal-systems/thermal-systems/light-weight-radioisotope-heater-unit/

Associated Risks from MMRTG and RHU systems

There are no inherent environmental effects associated with MMRTGs or RHUs operating in a normal environment (successful launch). Consequently, the only potential risks to the Endangered Species Act or Marine Mammal Protection Act relates to the potential inhalation of radioactive material after a launch mishap and the resulting impact from the cleanup of any contaminated land. For this to occur, there would have to be a launch accident that results in the release of some of the Pu-238 fuel from the MMRTG and/or RHUs, which is extremely unlikely (1 in 10,000 to 1 in 1,000,000), given the safety features designed into the MMRTG and RHUs.

The calculated radiation dose to a member of the public after a launch incident that results in release from a single MMRTG and up to 43 RHUs ranges from 2.98 to 21.4 rem, depending on the distance from the incident and meteorological conditions. However, these dose consequences represent a conservative estimate of release which is beyond extremely unlikely. Therefore, it is doubtful that the potential radiation exposure after an event would result in a health effect to a protected species, as the radiation exposure would be within the range of what species are typically subjected and adapted to.

Attachment 2: Federally-listed Species List

Federally Threatened and Endangered Species Documented to Occur at CCSFS or KSC

Species Type	Common Name	Scientific Name	Federal Status
Reptiles and Amphibians	American Alligator	*Alligator mississippiensis*	Threatened
Reptiles and Amphibians	Atlantic (Kemp's) Ridley Sea Turtle	*Lepidochelys kempi*	Endangered
Reptiles and Amphibians	Atlantic Green Sea Turtle	*Chelonia mydas*	Endangered
Reptiles and Amphibians	Atlantic Salt Marsh Snake	*Nerodia clarkia taeniata*	Threatened
Reptiles and Amphibians	Eastern Indigo Snake	*Drymarchon corais couperi*	Threatened
Reptiles and Amphibians	Gopher Tortoise	*Gopherus polyphemus*	Candidate for Federal Listing
Reptiles and Amphibians	Hawksbill Sea Turtle	*Eretmochelys imbricata*	Endangered
Reptiles and Amphibians	Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered
Reptiles and Amphibians	Atlantic Loggerhead Sea Turtle	*Caretta caretta*	Threatened
Mammals	Northern Atlantic Right Whale	*Eubalaena glacialis*	Endangered
Mammals	Southeastern Beach Mouse	*Peromyscus polionotus niveiventris*	Threatened
Mammals	West Indian Manatee	*Trichechus manatus latirostris*	Endangered
Fishes	Smalltooth Sawfish	*Pristis pectinata*	Endangered
Fishes	Nassau grouper	*Epinephalus striatus*	Threatened
Birds	Auburn's Crested Caracara	*Polyborus plancus audubonii*	Threatened
Birds	Crested Caracara	*Caracara cheriway*	Threatened
Birds	Eastern Black Rail	*Laterallus jamaicensis* ssp. *Jamaicensis*	Proposed Threatened
Birds	Everglade Snail Kite	*Rostrhamus sociabilis pumbeus*	Endangered
Birds	Florida Scrub Jay	*Aphelocoma coerulescens*	Threatened
Birds	Piping Plover	*Charadrius melodus*	Threatened
Birds	Red Knot	*Calidris canutus rufa*	Threatened
Birds	Red-cockaded Woodpecker	*Picoides borealis*	Endangered
Birds	Roseate Tern	*Sterna dougallii*	Threatened
Birds	Wood Stork	*Mycteria americana*	Endangered
Birds	Bald Eagle	*Haliaeetus leucocephalus*	Protected under the Bald and Golden Eagle Protection Act
Plants	Carter's Mustard	*Warea carteri*	Endangered
Plants	Four-petal Pawpaw	*Asimina tetramera*	Endangered
Plants	Florida Perforate Lichen	*Cladonia perforafa*	Endangered
Plants	Lakela's Mint	*Dicerandra immaculata*	Endangered
Plants	Lewton's Polygala	*Polygala lewtonii*	Endangered
Plants	Johnson's Seagrass	*Halophila johnsonii*	Threatened
Plants	Beach jacquemontia	*Jacquemontia reclinate*	Endangered
Plants	Tiny Polygala	*Polygala smallii*	Endangered

U.S. Fish and Wildlife Service (USFWS). 2020. "Information for Planning and Consultation" (IPac), Version 1.4. Brevard County.
U.S. Air Force (USAF). 2020. *Integrated Cultural Resources Management Plan for the 45th Space Wing*. Final. July.

From: Lewis, Christina M <christina_lewis@fws.gov> on behalf of FLESRegs, FW4 <FW4FLESRegs@fws.gov>
Sent: Tuesday, April 26, 2022 5:23 AM
To: Dankert, Donald J. (KSC-SIE30)
Cc: Dziergowski, Annie
Subject: [EXTERNAL] NASA Dragonfly

Thank you for contacting the U.S. Fish and Wildlife Service, Florida Ecological Services Office. Please do not reply to this automated response. This message simply confirms that we received your request for consultation. The project has been entered into our system and has been assigned the ECOSphere reference number 2022-0035719. Please include that number in all subsequent correspondence.

A staff biologist will contact you directly should we require additional information. If you have not heard from us within 60 days, please submit a status request via e-mail to FW4FLESRegs@fws.gov.

Thank you.

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
Florida Ecological Services Field Office

July 20, 2022

Mr. Donald Dankert
Environmental Management Branch
SI-E3, NASA Kennedy Space Center

Service Consultation Code: 2022-0035719
Date Received: April 25, 2022
Consultation Date: June 22, 2022
Project: Dragonfly Mission
Applicant: NASA
Counties: Brevard

Dear Mr. Dankert:

The U.S. Fish and Wildlife Service (Service) has reviewed the informal consultation request and the supporting Environmental Assessment (EA) for the Dragonfly Mission for the launching of radioisotope power systems (RPSs) from Kennedy Space Center (KSC) and Cape Canaveral Space Force Station (CCSFS). The National Aeronautics Space Agency (NASA) has prepared an EA in accordance with the National Environmental Policy Act and pursuant to section 7 of the Endangered Species Act of 1973 (Act) (16 U.S.C. 1531 *et seq*.) are requesting our concurrence for the determination of "may affect, but is not likely to adversely affect" for all federally listed species at these properties.

The applicant (NASA) is proposing to launch multiple space missions from KSC and CCSFS using a specific type of RPS, multi-mission radioisotope thermoelectric generator (MMRTG). This type of radioisotope thermoelectric generator (RTG) is able to generate electrical output from radioactive isotopes without the use of mechanical parts, allowing mission planners to allocate electrical power to operate spacecraft systems and instruments instead of heating. All proposed launch activities are located in Brevard County, Florida.

MMRTGs are small devices that use the natural decay of plutonium-238 (Pu-238) to provide thermal energy to heat payloads in space missions. The need for MMRTGs in space missions is expected to increase as the space program expands; therefore, KSC has programmatically analyzed the use of MMRTGs for launches at CCSFS and KSC complexes within the EA. The proposed action for consultation under the Act is the extremely unlikely release scenario outlined in the EA.

Space missions have flown RTGs since the 1960s with no radiological incidents in the history of using RTGs in spacecraft. NASA analyzed the increase utilization and the likelihood of Pu-238 exposure to humans and wildlife if a catastrophic accident occurs. MMRTGs have several safety mechanisms designed to withstand launch mishaps and extreme heat. The units are designed to preclude the release of radioactive materials in the unlikely event there is an unintentional,

suborbital return to Earth. NASA reviewed several aerial release scenarios and the highest potential Roentgen Equivalent Man (rem) exposure. Sensitivity analysis, which factors distance from an incident and wind speeds, found that the potential public exposure level rates are expected to be beneath the typical annual background and man-made sources of radiation exposure rates.

Similar to humans, the exposure pathways to wildlife include possibly inhalation, ingestion and immersion. NASA determined that the effects of radiation exposure if multiple safety mechanisms fail will be temporary and minor to wildlife based on the analysis of potential public exposure and background rates and man-made exposure. NASA also analyzed the potential radiological deposition effects to wetlands if Pu-238 is released in the environment under the extreme unlikely release scenario. Responses would be conducted per the National Response Framework and any remediation dredge and fill activities would be coordinated through the U.S. Army Corps of Engineers and applicable state agencies if wetlands or state-regulated waterbodies are affected after an accidental release.

Based on the analysis presented in the EA and the response safeguards in place for the extreme unlikely release scenario, the Service concurs with the NASA determination of "may affect, but is not likely to adversely affect" all federally listed species for the programmatically covered launch facilities at the CCSFS and KSC properties. If there is an unforeseen, unpredicted, catastrophic failure that results in a higher than predicted value of Pu-238 exposure to humans and wildlife, the Service and NASA have agreed to follow the procedures outlined for emergency consultations, 50 CFR §402.05.

Although this does not represent a biological opinion as described in section 7 of the Act, it does fulfill the requirements of the Act and no further action is required. Reinitiation of consultation is required if modifications are made to the project that were not previously considered and may adversely affect all federally listed species found on these properties or their habitats; if additional information involving potential effects to listed species not previously considered becomes available; or if take of listed species occurs.

If you have any questions regarding this response, please contact Mr. Brendan Myers by e-mail at brendan_myers@fws.gov or by calling (850) 348-6560.

Sincerely,

Digitally signed by
CHRISTOPHER PUTNAM
Date: 2022.07.20 14:29:09
-04'00'

Christopher Putnam
Environmental Review Division Supervisor
Florida Ecological Services Office

Appendix 3.5A
National Historic Preservation Act (NHPA) Consultation Documents

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National Aeronautics and Space Administration

John F. Kennedy Space Center
Kennedy Space Center, FL 32899

Reply to Attn of: SI-E3

Florida Division of Historical Resources
& State Historic Preservation Officer
Attn: Jennifer Tobias
500 S. Bronough Street
R. A. Gray Building
Tallahassee, Florida 32399-0250

Subject: National Historic Preservation Act Section 106 Consultation for the Dragonfly Mission from Cape Canaveral Space Force Station (CCSFS) and Kennedy Space Center (KSC), Florida

The National Aeronautics and Space Administration (NASA) requests your concurrence on a "no adverse effect" determination for National Register of Historic Places (NRHP)-listed and eligible sites at CCSFS and KSC for the launch of the Dragonfly Mission, a planetary mission sending a multi-rotor vehicle to visit Saturn's largest moon, Titan.

NASA prepared an environmental assessment (EA) per the National Environmental Policy Act (NEPA) regulations at Title 40 *Code of Federal Regulations* (CFR) for NASA's upcoming Dragonfly mission. As part of this EA, NASA is analyzing the environmental impacts of launching the Dragonfly mission, which would use a single multi-mission radioisotope thermoelectric generator (MMRTG) and up to 43 radioisotope heater units (RHUs).

Through the environmental review process, NASA has determined that there would be no impacts to NRHP-listed or eligible sites at CCSFS or KSC from using a single MMRTG and up to 43 RHUs under normal operating conditions (i.e., successful launch). The only potential risks to NRHP-listed and eligible sites relate to the potential cleanup activities that would occur after a launch mishap. However, for this to occur, there would have to be a launch mishap that results in the release of some of the Pu-238 fuel from the MMRTG and/or RHUs, which is extremely unlikely (1 in 10,000 to 1 in 1,000,000), given the safety features designed into the MMRTG and RHUs.

Pu-238 is relatively insoluble and will typically remain on the top 2 inches of surface soil

after a release. Consequently, the potential for impacting a known or unknown archeological site present in a contaminated area is limited. In the unlikely event that cleanup activities require the excavation of soil on or near a NRHP-listed or eligible archeological resource, the Florida State Historic Preservation Officer will be notified prior to any non-emergency response activities at the site, and appropriate mitigation measures will be developed in accordance with the National Historic Preservation Act (NHPA). If a new archeological site is identified during decontamination activities, the respective KSC Cultural Resource Manager (CRM) or CCSFS Historic Preservation Officer (HPO) will be notified immediately. The CRM or HPO will determine if the site is eligible for listing on the NRHP; if it is deemed eligible, the Florida State Historic Preservation Officer will be notified before any other response activities are conducted at that site to determine appropriate mitigation measures.

Numerous NRHP-listed and eligible historic sites, as well as National Historic Landmarks, are located on CCSFS and KSC. These significant historic resources include the launch complexes where the Dragonfly spacecraft could be launched. MMRTG- and RHU-specific impacts could involve potential cleanup activities, primarily on the exterior of structures. If a historic structure were identified as part of a response activity, the Florida State Historic Preservation Officer would be notified beforehand, and appropriate mitigations measures would be developed in accordance with the NHPA.

We appreciate your review of this proposed action. Please contact Mr. Donald Dankert, KSC NEPA Manager, at (321) 861-1196 for additional information regarding the Dragonfly mission. Please address any written comments to donald.j.dankert@nasa.gov.

Sincerely,

DONALD DANKERT

Digitally signed by DONALD DANKERT
Date: 2022.04.25 15:57:50 -04'00'

Donald Dankert
KSC NEPA Manager

Enclosure:
RHU Description

cc:
HQS FPO/R. Klein
KSC/AD/S. Gilmore
KSC/CC/A. Vinson
KSC/SI-C2/R. Griffin
FWS/T. Penn
NPS/J. Grass
NPS/K. Kneifl

FLORIDA DEPARTMENT of STATE

RON DESANTIS
Governor

LAUREL M. LEE
Secretary of State

Mr. Donald Dankert
KSC NEPA Manager
John F. Kennedy Space Center
Kennedy Space Center, Florida 32899

April 29, 2022

Re: DHR Project No.: 2022-2362
Draft Environmental Assessment for the Dragonfly Mission
Cape Canaveral Space Force Station (CCSFS) and Kennedy Space Center (KSC)
Brevard County

Dear Mr. Dankert:

This office reviewed the referenced project for possible impact to historic properties listed, or eligible for listing, in the *National Register of Historic Places.* The review was conducted in accordance with Section 106 of the *National Historic Preservation Act of 1966*, as amended and *36 CFR Part 800: Protection of Historic Properties*.

We reviewed Sections 3.5, which discusses Cultural Resources in the above referenced environmental assessment. Based on the information provided in the document, it is the opinion of this office that cultural resources have adequately been addressed. Therefore, we concur with your finding that the proposed undertaking should have no adverse effect on historic properties.

If you have any questions concerning our comments, please contact Scott Edwards, Historic Preservationist, by electronic mail *scott.edwards@dos.myflorida.com*, or at 850.245.6333 or 800.847.7278.

Sincerely,

Kelly L Chase
For

Timothy A. Parsons, Ph.D.
Director, Division of Historical Resources
and State Historic Preservation Officer

From: Ryba, Jeanne M. (KSC-SIE30) <jeanne.m.ryba@nasa.gov>
Sent: Monday, April 25, 2022 1:26 PM
To: Tobias, Jennifer L.; Edwards, Scott
Cc: CompliancePermits@DOS.MyFlorida.com; Dankert, Donald J. (KSC-SIE30); Ryba, Jeanne M. (KSC-SIE30); Klein, Rebecca A (HQ-LD020); Murdock, Nicholas A. (KSC-SIE30); Gilmore, Steven (KSC-ADA00); Vinson, Alex (KSC-CC000); Griffin, Richard T. (KSC-SIC20); Kristen_Kneifl@nps.gov; Simone_Monteleone@nps.gov; Gwilym_Rankin@nps.gov; PENDERS, THOMAS E GS-12 USAF AFSPC 45 CES/CEIE; roz@callhenry.com; vmcoperationsmgr@gmail.com; thomas.penders@spaceforce.mil; james.draper@spaceforce.mil; Lopetz, Laura A. (KSC-BOSS-4540)[PAE - SGT Partners LLC]
Subject: Section 106 Consultation for the Dragonfly Mission Involving a Single Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) and Radioisotope Heater Units (RHUs)
Attachments: 106 Consultation Letter for Dragonfly EA_Signed[3].pdf; dragonfly_draft_ea_noa_april_2022.pdf; dragonfly_public_draft_ea_april_2022.pdf

Good afternoon Jennifer,

As NASA's Kennedy Space Center (NASA KSC) processes the Dragonfly Mission for launch, the agency has prepared a Draft Environmental Assessment (EA) for the use a single multi-mission radioisotope thermoelectric generator (MMRTG) and radioisotope heater units (RHUs) to support this effort.

Attached is the consultation letter, the Notice of Availability, and the draft EA explaining in detail the MMRTG and RHUs use and what we may expect in the unlikely event of a mishap on launch.

We believe we are covered as stated in 36 CPR Part 800.12 (b1), and under KSC's Programmatic Agreement, **VII. Emergency Situations,** which states:

> In those situations where unanticipated and sudden events, including, but not limited to, floods, fires, and/or hurricanes that result in or that cause or effect the alterations of the structural stability of a historic property and/or structure, rendering it an immediate health and safety hazard, NASA-KSC will take the necessary steps to comply with the ACHP's regulations for emergency situations (36 CPR Part 800.12) and make the historic property and/or structure safe and secure. Within ten (10) days, or as soon as practicable, NASA-KSC shall notify the SHPO or the ACHP of such actions, providing a brief description of the nature of the emergency and corrective work.

I'm also including the April 25, 2022 response from Chris Stahl, Coordinator from the Florida State Clearinghouse, "While it is covered by EO 12372, the Florida State Clearinghouse does not select the project for review. You may proceed with your project."

Please let us know if KSC's Programmatic Agreement is sufficient to move forward on this project or if your office requires additional information or documentation.

Sincerely,

Jeanne Ryba
321.867.7824
KSC Cultural Resource Manager

From: Cerny, Alesha K <alesha_cerny@nps.gov> **On Behalf Of** SER National Historic Landmarks, NPS
Sent: Wednesday, May 25, 2022 10:35 AM
To: Ryba, Jeanne M. (KSC-SIE30) <jeanne.m.ryba@nasa.gov>; Dankert, Donald J. (KSC-SIE30) <donald.j.dankert@nasa.gov>
Cc: thomas.penders@spaceforce.mil
Subject: [EXTERNAL] Re: Section 106 Consultation for the Dragonfly Mission

Hi Jeanne,

Thank you for sending the consultation letter, the Notice of Availability, and the draft EA for the Dragonfly Mission.

We have reviewed the documents and agree KSC's Programmatic Agreement is sufficient to move forward on this project. Our office requires no additional information or documentation at this time and we have no comments or concerns.

Please send future correspondence to ser_nhl@nps.gov as it is accessible by multiple staff.

Thank You,
Alesha Cerny

National Historic Landmarks Program
National Park Service, Interior Region 2 (Legacy Southeast Region)
100 Alabama St. SW, Atlanta, GA 30303
Office: (404) 507-5791
ser_nhl@nps.gov

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