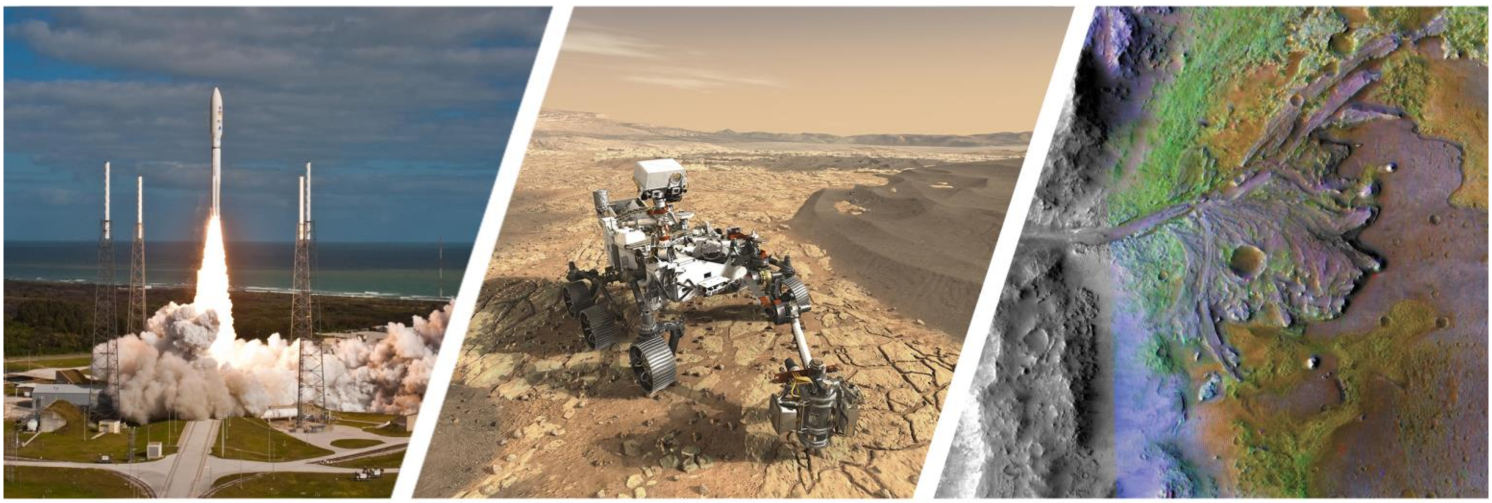
National Aeronautics and Space Administration



DRAFT

Supplemental Environmental Impact Statement for the Mars 2020 Mission

October 2019

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

www.nasa.gov

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SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT (SEIS) FOR THE MARS 2020 MISSION

ABSTRACT

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DATE:	October 2019

This Supplemental Environmental Impact Statement (SEIS) has been prepared by the National Aeronautics and Space Administration (NASA) in accordance with the National Environmental Policy Act (NEPA) of 1969, as amended, to assist in the decision-making process for the Mars 2020 mission. This SEIS provides information related to updates to the potential environmental impacts associated with the Mars 2020 mission as outlined in the *Final Environmental Impact Statement for the Mars 2020 Mission* (the "2014 FEIS") and associated NASA Record of Decision (ROD) issued in January 2015. The ROD identified Alternative 1 as the chosen alternative based on analysis presented in the 2014 FEIS. Alternative 1 involved deployment of a rover using a radioisotope power system to conduct scientific work on the Mars surface.

The environmental analysis presented in the 2014 FEIS was based on the best available information on mission-specific parameters and candidate expendable launch vehicles.

Since publication of the 2014 FEIS and issuance of the ROD in 2015, NASA has actively advanced the mission. Investments have been made that constitute irrevocable commitment of funds, resources, and decisions, including the Mars 2020 rover and payload design, power system fueling, Mars landing site selection, selection of the launch vehicle, and selection of the launch period. Additionally, NASA and DOE have completed a more detailed risk analysis that incorporates new and updated information, which affected the risk estimate results as compared to what was presented in the 2014 FEIS. Based on the new and updated information associated with postulated launch vehicle accident scenarios, NASA determined that the purposes of NEPA will be furthered by conducting this additional environmental analysis and documentation.

This SEIS therefore 1) identifies substantive changes in the affected environment since the November 2014 FEIS, to include important regulatory and/or physical changes to resources within the affected environment, and 2) analyzes potential radiological impacts to the updated affected environment associated with launch vehicle–related accidents.

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ABBREVIATIONS AND ACRONYMS

Acronym	Definition
2014 FEIS	*Final Environmental Impact Statement for the Mars 2020 Mission*
2014 NRA	*Nuclear Risk Assessment for the Mars 2020 Mission Environmental Impact Statement*
2019 NRA Update	*Nuclear Risk Assessment 2019 Update for the Mars 2020 Mission Environmental Impact Statement*
ACS	American Community Survey
AFB	Air Force Base
APE	area of potential effects
BCC	Birds of Conservation Concern
BCGs	Biota Concentration Guides
BLS	Bureau of Labor Statistics
°C	degrees Celsius
CCAFS	Cape Canaveral Air Force Station
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CH_4	methane
CNCPP	Center for New Crops and Plant Products
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
DHS	Department of Homeland Security
DIL	Derived Intervention Level
DOE	U.S. Department of Energy
EFH	Essential Fish Habitat
ELV	expendable launch vehicle
EO	Executive Order
ESA	Endangered Species Act
FDA	Food and Drug Administration
FDEP	Florida Department of Environmental Protection
FGDC	Federal Geographic Data Committee
FR	Federal Register
FSAR	Final Safety Analysis Report
FSII	full stack intact impact
FTS	flight termination system
FWC	Florida Fish and Wildlife Conservation Commission
GHG	greenhouse gas
GPHS-RTG	General Purpose Heat Source-Radioisotope Thermoelectric Generator
GWP	global warming potential
INSRP	Interagency Nuclear Safety Review Panel
IPaC	Information for Planning and Consultation
ISCORS	Interagency Steering Committee on Radiation Standards
km	kilometers
km^2	square kilometers

Acronym	**Definition**
KSC	Kennedy Space Center
Low Altitude FTS	low-altitude flight termination system
LWRHU	Light-Weight Radioisotope Heater Unit
$\mu Ci/m^2$	microcuries per square meter
$\mu g/m^3$	microgram per cubic meter
mi	miles
mi^2	square miles
MMRTG	Multi-Mission Radioisotope Thermoelectric Generator
NAAQS	National Ambient Air Quality Standards
NASA	National Aeronautics and Space Administration
NSPM	National Security Presidential Memorandum
NEI	National Emissions Inventory
NEPA	National Environmental Policy Act of 1969
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOA	Notice of Availability
NOAA	National Oceanic and Atmospheric Administration
NO_x	nitrogen oxides
NRF	National Response Framework
NRHP	National Register of Historic Places
ODS	ozone-depleting substances
pH	potential of hydrogen (a measure of acidity)
PLF	payload fairing
PM_{10} and $PM_{2.5}$	particulate matter with a diameter of less than or equal to 10 micrometers and 2.5 micrometers, respectively
ppm	parts per million
rem	roentgen equivalent in man
ROD	Record of Decision
ROI	region of influence
SEIS	Supplemental Environmental Impact Statement
SHPO	State Historic Preservation Officer
SLC	Space Launch Complex
SLC-41	Space Launch Complex 41
SO_2	sulfur dioxide
Stage 2/SV	intact stage 2 and space vehicle impact
SVII	space vehicle intact impact
USAF	U.S. Air Force
U.S.C.	United States Code
USCB	U.S. Census Bureau
USFWS	U.S. Fish and Wildlife Service
VOC	volatile organic compound

COMMON METRIC/BRITISH SYSTEM EQUIVALENTS

Length

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

Area

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

Volume

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

Weight

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

Energy

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

Pressure

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

Force

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

Radiation

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

1. PURPOSE AND NEED FOR THE ACTION

This Supplemental Environmental Impact Statement (SEIS) has been prepared by the National Aeronautics and Space Administration (NASA) and its cooperating agencies, the United States (U.S.) Department of Energy (DOE) and U.S. Air Force (USAF), to assist in the decision-making process as required by the National Environmental Policy Act of 1969, as amended (NEPA) (42 United States Code [U.S.C.] 4321 et seq.); Executive Order (EO) 12114, *Environmental Effects Abroad of Major Federal Actions*; Council on Environmental Quality (CEQ) regulations (40 Code of Federal Regulations [CFR] parts 1500–1508); and NASA policies and procedures at 14 CFR 1216. This is a Tier 2 mission-specific document under NASA's *Final Programmatic Environmental Impact Statement for the Mars Exploration Program* (NASA 2005).

This SEIS provides information related to updates to the potential environmental impacts associated with preparing for and launching the Mars 2020 mission as outlined in the *Final Environmental Impact Statement for the Mars 2020 Mission* (the "2014 FEIS") (NASA 2014) and associated Record of Decision (ROD) issued in January 2015 (NASA 2015).

The DOE's cooperating agency role stems from its responsibility in developing and producing special nuclear material and nuclear power systems used by NASA. The USAF, 45th Space Wing, Patrick Air Force Base (AFB), Florida, operates the Eastern Range, which includes NASA's Kennedy Space Center (KSC) and USAF's Cape Canaveral Air Force Station (CCAFS). The USAF serves as a cooperating agency due to their jurisdictional authority over the CCAFS launch site and range safety for the Mars 2020 mission, as well as their staff's technical expertise in launch operations and launch vehicle accident response.

1.1 BACKGROUND

NASA completed the 2014 FEIS in support of the Mars 2020 mission. The Proposed Action, as described in the 2014 FEIS, would employ scientific instrumentation to seek signs of past life in situ, select and store a compelling suite of samples in a returnable cache, and demonstrate technologies for future robotic and human exploration of Mars. The Mars 2020 spacecraft would deliver a large, mobile science laboratory (known as a "rover") with advanced instrumentation to a scientifically interesting location on the surface of Mars in February 2021.

The 2014 FEIS identified reasonable alternatives to implement the Proposed Action that would meet the underlying purpose and need for the Mars 2020 mission. It also described the potential environmental impacts from the launch of the mission payload onboard an expendable launch vehicle (ELV) from either KSC or CCAFS. Those alternatives were:

- **Proposed Action (Alternative 1) (NASA's Preferred Alternative):** NASA proposed to continue preparations for and implement the Mars 2020 mission to the surface of Mars. The proposed Mars 2020 spacecraft would be launched onboard an ELV from KSC or CCAFS, Brevard County, Florida, during a 20-day launch opportunity that runs from July through August 2020 and inserted into a trajectory toward Mars. Should the mission be delayed, the proposed Mars 2020 mission would launch during the next available launch opportunity in August through September 2022. The rover proposed for the Mars 2020 mission would use a Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) to continually provide heat and electrical power to the rover's battery so that the rover could operate and conduct scientific work on the planet's surface.

- **Alternative 2:** Under this alternative, NASA would discontinue preparations for the Proposed Action (Alternative 1) and implement a different power system for the Mars rover. The rover would use solar power to operate instead of a MMRTG. The spacecraft would still be launched onboard an ELV from KSC or CCAFS, Brevard County, Florida, during a 20-day launch opportunity that runs from July through August 2020 and inserted into a trajectory toward Mars. As with Alternative 1, should the mission be delayed, the proposed Mars 2020 mission would launch during the next available opportunity in August through September 2022.
- **Alternative 3:** Under this alternative, NASA would discontinue preparations for the Proposed Action (Alternative 1) and implement an alternative power and heating system for the Mars 2020 mission to Mars. Like Alternative 2, the rover would use solar power as its source of electricity. But in addition, the rover would use heat output from Light-Weight Radioisotope Heater Units (LWRHUs) to help keep its onboard systems at proper operating temperatures. The Mars 2020 spacecraft would still be launched onboard an ELV from KSC or CCAFS, Brevard County, Florida, during a 20-day launch opportunity from July through August 2020 in a trajectory toward Mars. Should the mission be delayed, the Mars 2020 mission would launch during the next available opportunity in August through September 2022.
- **No Action Alternative:** Under this alternative, NASA would discontinue preparations for the Mars 2020 mission and would not launch the spacecraft.

Analysis presented in the 2014 FEIS focused on environmental impacts from a normal launch and potential launch vehicle accidents. The potential for launch vehicle–related accidents was estimated to be unlikely. Analysis was conducted to determine the extent of potential environmental impacts from 1) a catastrophic launch vehicle accident resulting in release of nuclear material (should the rover's MMRTG become damaged) and 2) a launch vehicle accident that does not release nuclear material (provided the rover's MMRTG was not damaged).

The environmental analysis presented in the 2014 FEIS (NASA 2014) was based on DOE's *Nuclear Risk Assessment for the Mars 2020 Mission Environmental Impact Statement* (SNL 2014) ("the 2014 NRA"). The 2014 NRA was based on mission-specific parameters and ELV estimates that NASA provided to DOE in 2013 and the best available information on how radiological material could be released and transported in an accident.

In January 2015, NASA issued a ROD that identified Alternative 1 as the chosen alternative based on analysis presented in the 2014 FEIS. Alternative 1 was chosen because it would enable the best return of scientific and technical information and make the most effective use of fiscal, human, and material resources. Alternatives 2 and 3 were not selected because, under these alternatives, the solar-powered rover would not be capable of performing all the science experiments planned for a full Mars year at certain latitudes. The solar-powered rover cannot generate sufficient power at extreme cold temperatures.

Updates and Changes to the Action Since 2014

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:** Based on the 2015 ROD to implement Alternative 1, NASA designed the rover and scientific payload (including instrumentation) to use an MMRTG. As a result, the solar options under Alternatives 2 and 3 are no longer viable. NASA has committed irrevocable resources in this regard, including proceeding with the MMRTG fueling process.
- **Mars landing site selection:** Based on the 2015 ROD to implement Alternative 1, NASA selected the landing site based on the use of an MMRTG. In November 2018, NASA identified the Jezero Crater as the Mars rover landing site. As a result, this further limits rover design options because, under Alternative 2, the rover could not operate during most of the spring and summer (about 50 to 55 percent of the operational lifetime compared to the MMRTG), and under Alternative 3, the rover could not operate for part of the summer (about 60 percent of the operational lifetime compared to the MMRTG).
- **Selection of launch vehicle:** The 2014 FEIS analyzed the potential impacts associated with use of three different ELVs: the Atlas V, the Delta IV, and Falcon Heavy. Since the 2015 ROD, NASA selected the Atlas V as the ELV. As a result, the mission will launch from SLC-41 at CCAFS because it is the only location that can support the Atlas V ELV.
- **Launch period:** NASA has identified the launch period to begin as early as July 17, 2020, and end in mid-August 2020. If the launch does not occur during this launch period, the alternate launch period of 2022 presented in the 2014 FEIS would apply.

The potential environmental impacts associated with normal launches or launch-related accidents that do not result in release of nuclear materials, as described in the FEIS, have not changed.

Since the 2015 ROD, NASA and DOE have completed a more detailed analysis of the risks associated with launch accident scenarios that do result in the release of nuclear material (as described in Section 4.7 of the 2014 FEIS and explained below). The potential for launch vehicle–related accidents remains unlikely. The DOE's *Nuclear Risk Assessment 2019 Update for the Mars 2020 Mission Environmental Impact Statement* (the "2019 NRA Update") reflects new and updated information and presents the risk estimate results as compared to the 2014 NRA used for the 2014 FEIS. Based on the new and updated information associated with postulated launch vehicle accident scenarios resulting in potential release of nuclear materials, NASA determined that the purposes of NEPA will be furthered by conducting this additional environmental analysis and documentation. The new information that drove the different results includes:

- new knowledge gained about how the MMRTG is affected by accident scenarios;
- updated analytical models and computer simulation input parameters, informed by best available knowledge as well as lessons learned from other missions; and
- updates to account for specific design features of the selected launch vehicle.

The analysis showed that the most likely outcome is a successful launch of the spacecraft toward Mars. If the launch is unsuccessful (about a 1.25 percent probability), the most probable outcome is an accident without a release of radioactive material. In the unlikely event an accident does result in release of radioactive material, the probability and extent of potential consequences have increased since the 2014 FEIS and 2015 ROD, as described in Section 2.4.3 (Environmental Impacts of Potential Launch Accident with Radiological Release); however, the overall probability of a release of radiological material remains small.

The recently published National Security Presidential Memorandum #20 (NSPM-20) (2019) on the Launch of Spacecraft Containing Space Nuclear Systems requires that Federal agencies sponsoring a launch of space nuclear systems ensure compliance with requirements under NEPA. Separately, but related to the NEPA processes, the nuclear launch authorization process provides a rigorous, risk-informed safety analysis to ensure that public safety is adequately maintained. NSPM-20 updates the authorization process for launches of spacecraft containing space nuclear systems and includes safety guidelines focused on the maximum individual dose that are consistent with other regulatory structures employed throughout the U.S. government. The overall results presented in the 2019 NRA Update are within the established NSPM-20 safety guidelines for launch of spacecraft containing nuclear systems.

Updates and New Information Incorporated in the 2019 Risk Analysis

In March 2016, NASA initiated the nuclear safety review process required for launch authorization, in compliance with Presidential/National Security Council directives. As part of this process, DOE prepared a nuclear safety analysis that includes a complete, detailed risk analysis. This risk analysis followed procedures and used techniques similar to those used in risk analyses performed for earlier NASA missions using radioisotope devices. An Interagency Nuclear Safety Review Panel (INSRP) was formed to evaluate the nuclear safety analysis. The panel consisted of representatives from NASA, DOE, the Department of Defense, the Environmental Protection Agency (EPA), and the Nuclear Regulatory Commission. The DOE's 2019 NRA Update documents the results and methodology of the safety analysis conducted under this process (SNL 2019).

Improvements to the modeling for the 2019 NRA Update are based on prior INSRP Safety Evaluation Report recommendations for the 2011 Mars Science Laboratory mission, NASA and DOE safety testing program data, and the Mars 2020 INSRP recommendations. The new model includes the most relevant information, which accounts for a better understanding of how the MMRTG's iridium cladding responds to impact forces in accident conditions (see Section 2.1.3, Rover Electrical Power, for more detail on the iridium cladding within the MMRTG's general purpose heat source).

The updated safety analysis accounts for the specific design features of the Mars 2020 Atlas V 541 launch vehicle that was selected on August 25, 2016, after the 2014 FEIS ROD was issued (January 27, 2015). It incorporates current mission launch parameters as well as lessons learned and modeling data updates derived from previous missions, updated analytical models, and computer simulation input parameters, including:

- Solid propellant fragmentation and trajectory information:
    - The solid propellant fragment model has been updated since the 2014 FEIS. The new fragmentation model used for this SEIS generates fragments with higher speeds that travel farther than in the previous model.
    - To model solid propellant fragment velocities in the early launch phase, the force imparted to the solid propellant fragments due to the common core explosion was incorporated, compared to its exclusion from the previous analysis for the Mars Science Laboratory mission conducted in 2011.
- Plutonium release model:
    - The plutonium release model was updated to incorporate the module and iridium cladding response to impact forces, as well as to better capture the material release statistics, compared to the 2014 FEIS (see the fuel clad discussion in Section 2.1.3 of the FEIS and Section 3.5.2.2.3, MMRTG Response to Accident Environments, in this SEIS).
- Potential debris impact area:
    - In the presence of the new crew tower, the potential debris impact area has changed since the 2014 FEIS.
- Blast model information:
    - The solid propellant blast model was updated, using test information and new analysis since the 2014 FEIS.
- Solid propellant fire:
    - The solid propellant fire model was updated since the 2014 FEIS, using recent multi-year test data and analysis models. For example, the maximum flame temperature is lower and the aluminum agglomerate size distribution is revised.

- Atmospheric transport modeling, weather data, propellant plume rise, and the particle tracking in plumes, including:
  - Incorporating the international standard 4D Lagrangian particle tracking model jointly developed by the National Oceanic and Atmospheric Administration (NOAA) and the Australian Meteorological Service;
  - Using updated gridded meteorological data for all possible release locations, elevations, and particle sizes, versus global means based on sparse observations that were used previously;
  - Performing complex dispersion and deposition simulations based on a proven dispersion model rather than the previous curve fits to limited data.
- Health effects modeling changes, including:
  - Age-specific dose and risk calculation improvements;
  - Health effects calculations, using specific risk coefficients for plutonium-238 and exposure pathways; and
  - Use of region-specific crop information.

The analysis conservatively assumes no mitigation actions, such as sheltering and keeping people out of potentially affected land areas.

Relationship Between the 2014 FEIS and This SEIS

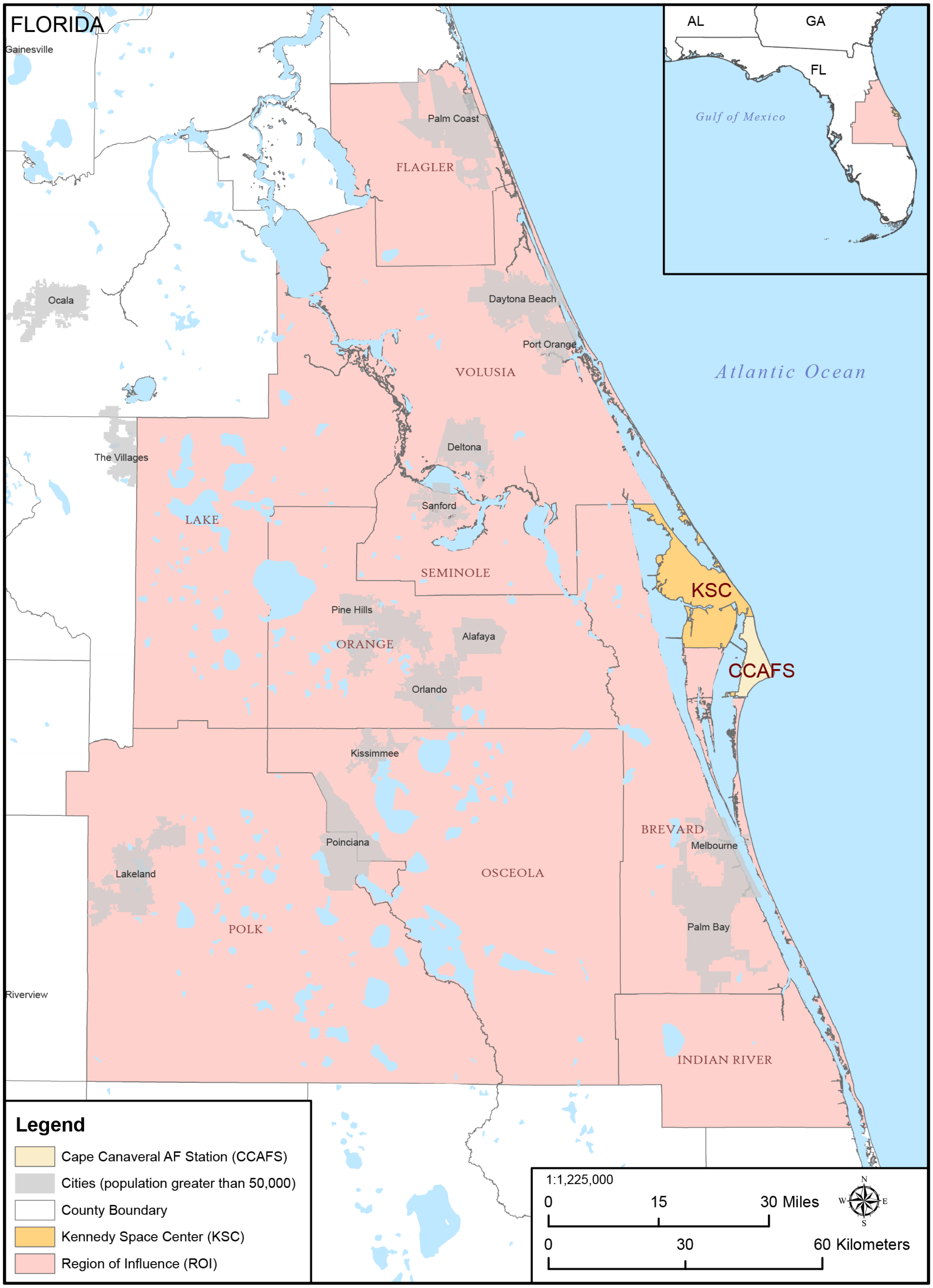
This SEIS serves to address the potential environmental impacts associated with the updated mission risk presented in the 2019 NRA Update. Because other mission parameters have not changed since the 2015 ROD and were previously analyzed in the 2014 FEIS (e.g., use of CCAFS as a launch site), this SEIS does not address potential impacts associated with normal launch activities or launch vehicle–related accidents that do not result in the release of nuclear material. As a result, the analysis of potential impacts conducted in the 2014 FEIS associated with these activities is incorporated throughout the SEIS.

This SEIS does not address Alternatives 2 or 3 as presented in the 2014 FEIS. NASA has made the decision, as documented in the 2015 ROD, to proceed with Alternative 1, including use of the MMRTG power system on the Mars rover.

Therefore, this SEIS addresses the Proposed Action (which is Alternative 1 as defined in the 2014 FEIS and 2015 ROD) as well as a No Action Alternative as required by NEPA.

Consequently, this SEIS is intended to:

- Identify changes in the affected environment since the November 2014 FEIS, to include any regulatory and/or physical changes to resources within the affected environment. The affected environment, or region of influence (ROI), consists of counties with areas within 100 kilometers (km) (62 miles [mi]) of Space Launch Complex 41 (SLC-41) located in the northernmost section of CCAFS, Brevard County, Florida. The counties that lie within the ROI include Brevard, Indian River, Orange, Osceola, Seminole, and Volusia and small portions of Flagler, Lake, and Polk Counties. These counties were identified as part of the affected environment in the 2014 FEIS and are shown in Figure 1.1-1.



1
2 **Figure 1.1-1. 2019 SEIS Region of Influence**

- Analyze potential radiological impacts to the updated affected environment associated with launch vehicle–related accidents that result in a release of nuclear material.

Throughout this document, where information from the 2014 FEIS is incorporated by reference, specific sections of the 2014 FEIS are identified for simplified cross-referencing.

1.2 PURPOSE OF THE ACTION

The purpose of the Mars 2020 mission has not changed since the 2014 FEIS (see Section 1.2 of the 2014 FEIS).

The purpose of this SEIS is to address potential radiological impacts associated with launch vehicle–related accidents that result in radiological releases from implementation of Alternative 1 as defined in the 2015 ROD for the Mars 2020 mission.

1.3 NEED FOR THE ACTION

The need for the Mars 2020 mission has not changed since the 2014 FEIS (see Section 1.3 of the 2014 FEIS).

1.4 NEPA PLANNING AND SCOPING ACTIVITIES

2014 FEIS

The NEPA planning and scoping activities for the 2014 FEIS are described in Section 1.4 of the 2014 FEIS.

2019 SEIS

Title 40 CFR 1502.9 (c)(4) does not require scoping for an SEIS. However, in order to inform the public, NASA did publish a Notice of Intent to conduct this SEIS in the Federal Register on September 26, 2019 (84 Federal Register [FR] 50860). No formal scoping process or scoping meetings were conducted for this SEIS.

1.5 RESULTS OF PUBLIC REVIEW OF THE EIS

2014 FEIS

The public review process for the 2014 FEIS is described in Section 1.5 of the 2014 FEIS.

2019 SEIS

NASA published a Notice of Availability (NOA) for this SEIS in the Federal Register on October 25, 2019, as well as advertisements in local newspapers notifying the local community of the availability of the SEIS and the time and location of public meetings. This SEIS will be made available for public and agency review for 45 calendar days.

This section will be updated upon the conclusion of the public and agency review. Chapter 7 provides a more detailed discussion of the public involvement process for this SEIS.

1.6 CHANGES TO THE DRAFT SEIS

The SEIS will be updated based on comments received during the Draft SEIS public/agency review process. This section will be updated to summarize any associated changes made between the Draft SEIS and the Final SEIS.

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2. DESCRIPTION AND COMPARISON OF ALTERNATIVES

This section provides a description and comparison of the Proposed Action and No Action Alternative presented in the 2014 FEIS (Sections 2.1 and 2.4, respectively, in the 2014 FEIS) versus the Proposed Action and No Action Alternative as updated since the 2015 ROD was signed.

As discussed in Section 1.1 (Background) of this SEIS, Alternatives 2 and 3 described in the 2014 FEIS are not addressed in this SEIS because the decision to proceed with Alternative 1 was documented in the 2015 ROD. As a result, NASA has made significant irrevocable progress toward advancing the Mars 2020 mission utilizing the MMRTG.

Additional information regarding the baseline operational capabilities for the Mars 2020 mission can be found in the introductory section of Chapter 2 of the 2014 FEIS.

The No Action Alternative addressed in this SEIS is the same as that described in Section 2.4 of the 2014 FEIS. NASA would discontinue preparations for any Mars 2020 mission, and the spacecraft would not be launched.

Additional information regarding the Proposed Action addressed in this SEIS is provided below in Section 2.1 (Description of the Proposed Action).

2.1 DESCRIPTION OF THE PROPOSED ACTION

2.1.1 Mission Description

The description of the Mars 2020 mission is generally the same as that presented in the 2014 FEIS. The subsections below describe the mission according to the 2014 FEIS and the mission as updated since issuance of the 2015 ROD.

2014 FEIS

As described in the 2014 FEIS, the Mars 2020 spacecraft would be launched from KSC or CCAFS onboard an Atlas V, Delta IV, or Falcon Heavy class of ELVs. The launch would occur within an approximate 20-day launch period, opening in July 2020 and closing in August 2020.

2019 SEIS

After signing the 2015 ROD, NASA selected the Atlas V as the ELV. Therefore, because KSC cannot support the Atlas V, the launch site would be CCAFS, previously assessed as part of the 2014 FEIS. Additionally, NASA has narrowed the launch period from summer 2020, as described in the 2014 FEIS, to an approximate 20-day launch period, opening in July 2020 and closing in August 2020.

2.1.2 Spacecraft Description

The description of the spacecraft presented in Section 2.1.2 of the 2014 FEIS has not substantively changed since issuance of the 2015 ROD. There was an addition of a small robotic helicopter technology demonstration as a secondary payload on the rover. This addition was accounted for in the risk analysis presented in the 2019 NRA Update.

2.1.3 Rover Electrical Power

The description of the rover's electrical power system (the MMRTG) is the same as presented in Section 2.1.3 of the 2014 FEIS. Updated analytical models, new testing information, updated computer simulation input parameters, and lessons learned from other missions resulted in a revised understanding of the MMRTG response to accidents (see Section 3.5.2.2.3, MMRTG Response to Accident Environments).

2.1.4 Operational Considerations

Operational considerations are the same as described in Section 2.1.4 of the 2014 FEIS and have not changed since issuance of the 2015 ROD.

2.1.5 Spacecraft Processing

The subsections below describe spacecraft processing according to the 2014 FEIS and as updated since issuance of the 2015 ROD.

2014 FEIS

As described in the 2014 FEIS, the spacecraft would be inspected and comprehensive tests would be performed, including flight and mission simulations. DOE would deliver the MMRTG to a KSC storage facility. Once the spacecraft tests are completed, the MMRTG would be moved to the Payload Hazardous Servicing Facility, where it would be fitted to the rover for a pre-flight systems check. After completing these checks, the MMRTG would be returned to storage. The spacecraft would then be fueled with a total of about 460 kilograms (1,014 pounds) of hydrazine (SNL 2014), the currently estimated propellant load capability for the cruise stage and descent stage.

After a systems check and other tests, the spacecraft would be enclosed within the launch vehicle payload fairing (PLF), and the PLF, containing the spacecraft, would then be transported from the Payload Hazardous Servicing Facility to the launch complex at KSC or CCAFS and attached to the vehicle's second stage.

2019 SEIS

Because NASA has now identified CCAFS as the launch site, the PLF would be transported to the launch complex at CCAFS. All other aspects of spacecraft processing would be the same as described in Section 2.1.5 of the 2014 FEIS.

2.1.6 Representative Launch Vehicle Configurations for the Mars 2020 Mission

The subsections below describe representative launch vehicle configurations for the Mars 2020 mission according to the 2014 FEIS and as updated since issuance of the 2015 ROD.

2014 FEIS

The evaluations of potential environmental consequences for the 2014 FEIS were prepared before NASA selected the launch vehicle for the Mars 2020 mission. The evaluations were based upon representative configurations of the Atlas V and Delta IV class vehicles (the Delta IV class vehicle representing the liquid-fueled Delta IV and Falcon Heavy launch vehicles) that would have the performance capabilities necessary for the mission.

The Space Launch Complex (SLC) that supports the Atlas V vehicle is SLC-41, which is located in the northernmost section of CCAFS. The launch complex consists of a launch pad, an umbilical mast, propellant and water storage areas, an exhaust flume, catch basins, security services, fences, support buildings, and facilities necessary to prepare, service, and launch Atlas V vehicles (NASA 2014).

Security at SLC-41 is ensured by a perimeter fence, guards, and restricted access. Since all operations in the launch complex would involve or would be conducted in the vicinity of liquid or solid propellants and explosive devices, the number of personnel permitted in the area, safety clothing to be worn, the type of activity permitted, and equipment allowed would be strictly regulated. The airspace over the launch complex would be restricted at the time of launch.

2019 SEIS

NASA selected the Atlas V launch vehicle in August 2016, after completing the ROD in 2015. Descriptions of the Delta IV and Falcon Heavy launch vehicles as presented in Section 2.1.6.2 and 2.1.6.3 of the 2014 FEIS, respectively, are no longer applicable to the Proposed Action. A description of the Atlas V launch vehicle is provided in Section 2.1.6.1 and associated subsections of the 2014 FEIS. Since the 2014 FEIS, the Atlas V 541 vehicle has undergone evolutionary changes that include the avionics and second stage engine. The models for launch vehicle accident probabilities and accident environments have been updated to account for all modifications.

As described in the 2014 FEIS, the launch site that supports the Atlas V ELV is CCAFS SLC-41. SLC-41 has undergone changes to support Vulcan and Commercial Crew since the 2014 FEIS. These changes include the addition of a crew access tower, ground storage propellant tanks and associated infrastructure.

2.1.6.1 Flight Termination System

The flight termination system is the same as described Section 2.1.6.4 of the 2014 FEIS.

2.1.6.2 Range Safety Considerations

Range safety considerations at CCAFS are the same as those described in Section 2.1.6.5 of the 2014 FEIS.

2.1.6.3 Electromagnetic Environment

The electromagnetic environment is the same as described in Section 2.1.6.6 of the 2014 FEIS.

2.1.7 Radiological Contingency Response Planning

2014 FEIS

The 2014 FEIS addressed general radiological contingency response planning as well as specifics for CCAFS, KSC, the city of Cape Canaveral, and Brevard County. Additionally, the 2014 FEIS addressed radiological contingency response planning for accidents outside the jurisdiction of the United States.

2019 SEIS

Radiological contingency response planning would include coordination with appropriate agencies in the following locations: CCAFS, KSC, the city of Cape Canaveral, and Brevard, Indian River, Orange, Osceola, Seminole, Volusia, Flagler, Lake, and Polk Counties. Additionally, this SEIS addresses radiological contingency response planning for accidents outside the jurisdiction of the United States.

2.2 DESCRIPTION OF THE NO ACTION ALTERNATIVE

The No Action Alternative within the context of this SEIS would be the same as that described in Section 2.4 of the 2014 FEIS. NASA would discontinue preparations for the Mars 2020 mission.

2.3 ALTERNATIVES CONSIDERED BUT NOT EVALUATED FURTHER

There are no alternatives considered but not evaluated further in this SEIS; the purpose of this SEIS is to address changes in the Proposed Action since issuance of the ROD in 2015.

Alternatives previously considered but not evaluated further are described in Section 2.5 of the 2014 FEIS.

2.4 SUMMARY OF ENVIRONMENTAL IMPACTS FROM THE PROPOSED ACTION – 2014 VS. 2019

This section summarizes potential environmental impacts associated with the Proposed Action identified in the 2014 FEIS as compared to the potential environmental impacts associated with the Proposed Action identified in this SEIS.

A comparison of alternatives previously analyzed (i.e., Alternatives 2 and 3) can be found in Section 2.6 of the 2014 FEIS. However, as stated previously, this SEIS only addresses the Proposed Action and the No Action Alternative.

2.4.1 Environmental Impacts of a Normal Launch

Proposed Action – The potential impacts associated with a normal launch would be the same as those described in Sections 2.6.2.1 and 4.1.2 of the 2014 FEIS. Updates to the Proposed Action as described in Chapters 1 and 2 of this SEIS would not result in any new or additional impacts from those identified in the 2014 FEIS.

No Action Alternative – As in the 2014 FEIS, under the No Action Alternative, a launch would not occur. Therefore, there would be no impacts associated with the No Action Alternative.

2.4.2 Environmental Impacts of Potential Launch Accident with No Radiological Release

Proposed Action – The potential non-radiological impacts associated with launch accidents would be the same as those described in Sections 2.6.2.2 and 4.1.3 of the 2014 FEIS. Updates to the Proposed Action as described in Chapters 1 and 2 of this SEIS would not result in any new or additional impacts from those identified in the 2014 FEIS.

No Action Alternative – As in the 2014 FEIS, under the No Action Alternative, a launch would not occur. Therefore, there would be no impacts associated with the No Action Alternative.

2.4.3 Environmental Impacts of Potential Launch Accident with Radiological Release

This section presents a comparison of the potential launch-related probabilities and impacts as presented in the 2014 FEIS versus those probabilities and impacts identified in this SEIS. More detailed information on the risk assessment methodology can be found in Section 4.1.4 of the 2014 FEIS.

Table 2.4-1 presents a summary comparison of launch-related probabilities for the Proposed Action from the 2014 FEIS versus this SEIS (rounded to a one-tenth percentage point). For the 2014 FEIS, the launch vehicle accident probabilities were derived by combining the estimated failure probabilities for the Atlas V and Delta IV launch vehicles from the *Mars 2020 Representative Databook* (NASA 2013). As such, the estimated probabilities from the 2014 FEIS do not reflect the reliability of any single launch vehicle. The 2014 FEIS estimated an overall probability of a launch accident at 2.5 percent.

Table 2.4-1. Comparison of Total Launch-Related Probabilities – Early Launch Through Earth Escape (2014 FEIS vs. 2019 SEIS)

Document	Successful Launch (Earth Escape) Probability (%)	Overall Launch Accident Probability (%)[a]	Launch Accident No Release of Plutonium Dioxide Probability (%)[a]	Launch Accident Release of Plutonium Dioxide Probability (%)[a]
2014 FEIS	97.5	2.5	2.4	0.04
2019 SEIS	98.7	1.3	1.2	0.10

Notes:

Difference in launch accident probability and sum of accident probabilities is due to rounding.

(a) Per launch attempt

Key: FEIS = Final Environmental Impact Statement; SEIS = Supplemental Environmental Impact Statement.

The SEIS utilizes launch vehicle accident probabilities associated with the Atlas V (a specific launch vehicle). Therefore, the estimated probabilities for this SEIS reflect the reliability of the Atlas V. Both the 2014 FEIS and this SEIS present the release probabilities estimated in their respective NRAs. The 2019 NRA Update used for this SEIS estimated an overall probability of a launch accident at 1.25 percent, representing a decrease of 1.25 percent probability from 2.50 percent as presented in the 2014 FEIS. The probability of a launch accident with a release of plutonium dioxide is estimated at 0.10 percent, an increase of 0.06 percent probability from 0.04 as presented in the 2014 FEIS. Figure 2.4-1 and Figure 2.4-2 provide graphical representations of the accident probabilities as presented in Table 2.4-1 from the 2014 FEIS and this SEIS, respectively.

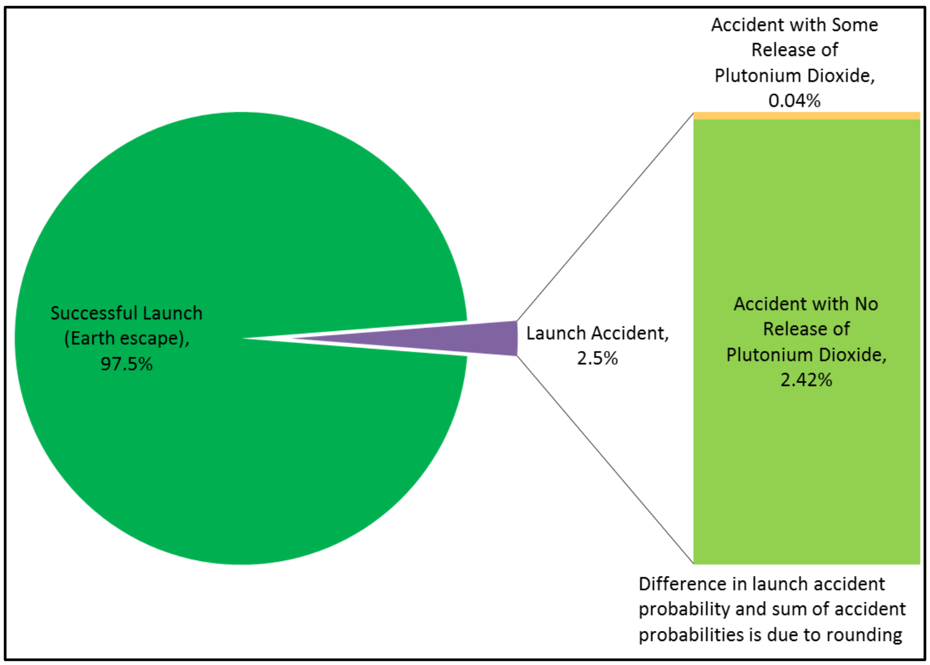


Figure 2.4-1. 2014 FEIS Total Launch Profile Accident Probabilities

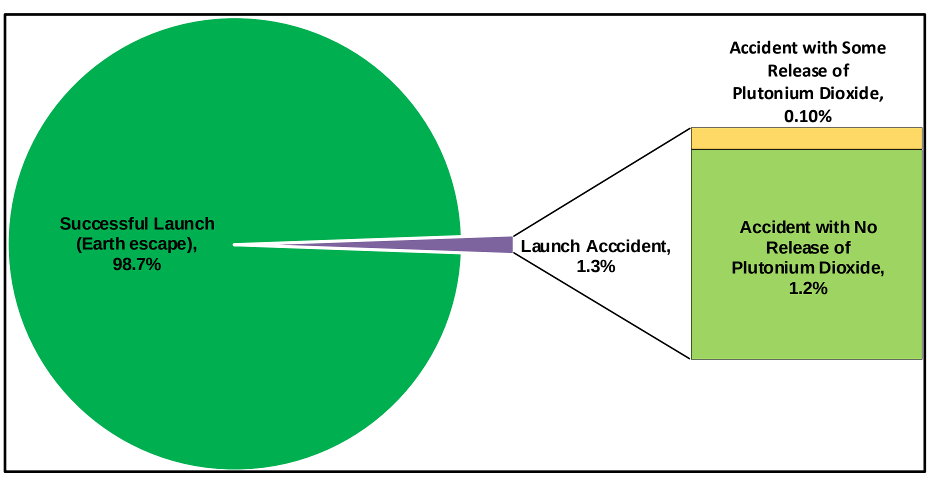


Figure 2.4-2. 2019 SEIS Total Launch Profile Accident Probabilities

2014 FEIS

The 2014 FEIS identified that the most likely outcome of implementing the proposed Mars 2020 mission, with over a 97 percent probability, would be a successful launch to Mars. The unsuccessful launches (about a 2.5 percent probability) would result from either a malfunction or a launch accident. Most malfunctions would involve trajectory control malfunctions, which would occur late in the ascent profile. This type of malfunction would place the spacecraft on an incorrect trajectory escaping from Earth but leading to failure of the spacecraft to reach Mars. Most launch accidents result in destruction of the launch vehicle but would not result in damage to the MMRTG sufficient to cause a release of some plutonium dioxide. The analysis estimated that for less than about 0.04 percent of the time (a probability of 1 in 2,600), a launch could result in an accident with the release of plutonium dioxide (see Section 2.6.2.3.2 of the 2014 FEIS).

2019 SEIS

This SEIS identifies that the most likely outcome of implementing the Mars 2020 mission, with nearly a 99 percent probability, would be a successful launch to Mars. An unsuccessful launch (a 1.25 percent probability) would result from either a malfunction or a launch accident. Most malfunctions would involve trajectory control malfunctions, which would occur late in the ascent profile. This type of malfunction would place the spacecraft on an incorrect trajectory escaping from Earth but leading to failure of the spacecraft to reach Mars. Across all mission phases, most launch accidents would result in destruction of the launch vehicle but would not result in damage to the MMRTG sufficient to cause a release of some plutonium dioxide. For accidents in the launch area, the probability of a release of plutonium dioxide in an accident is 52 percent. For the overall mission, the analysis estimates that about 0.10 percent of the time (a probability of 1 in 960), a launch could result in an accident with the release of plutonium dioxide (see Section 2.4.3.1.1, Accident Probabilities and Consequences, of this SEIS).

2.4.3.1 The 2014 FEIS NRA and 2019 SEIS NRA Update

Discussion of the 2014 NRA for the proposed Mars 2020 mission that was used in the 2014 FEIS is found in Section 2.6.2.3.1 of the 2014 FEIS. The risk assessment approach for the 2019 NRA Update was the same but incorporated the modeling updates described previously and used information based on the selected Atlas V 541 launch vehicle for estimating accident probabilities, potential releases of plutonium dioxide in case of an accident (called “source terms”), radiological consequences, and mission risks.

The 2019 NRA Update for the Mars 2020 mission considered 1) potential accidents associated with the launch and their probabilities and accident environments, 2) the response of the MMRTG to such accidents in terms of the amount of radioactive materials released and their probabilities, and 3) the radiological consequences and mission risks associated with such releases. The risk assessment was based on a MMRTG radioactive material inventory of about 59,000 curies of primarily plutonium-238 (an alpha-emitter with an 87.7-year half-life).

The risk assessment for the Mars 2020 mission began with the identification of the initial launch vehicle system malfunctions or failures and the subsequent chain of accident events that could ultimately lead to the accident environments (e.g., explosive overpressures, fragments, fire) that could threaten the MMRTG. These launch vehicle system failures were based on launch vehicle system reliabilities and estimated failure probabilities provided to DOE by NASA (SNL 2019).

Failure of the launch vehicle has the potential to create accident environments that could damage the MMRTG and result in the release of plutonium dioxide. Based on analyses performed for earlier missions that carried radioisotope devices (RTGs and LWRHUs), DOE identified the specific accident environments that could potentially threaten the MMRTG. DOE then determined the response of the MMRTG and its components to these accident environments and estimated the amount of radioactive material that could be released.

2.4.3.1.1 Accident Probabilities and Consequences

Section 4.1.4 of the 2014 FEIS provides a detailed quantitative discussion of the accident probabilities and associated potential consequences for the proposed Mars 2020 mission. Section 4.1.4 of the 2014 FEIS also describes the risk assessment with the results presented for both mean and 99th percentile values.

Section 3.5 (Health and Safety) of this SEIS provides a detailed quantitative discussion of the accident probabilities and associated potential consequences for the Mars 2020 mission as outlined in the 2019 NRA Update used for this SEIS. Section 3.5 also describes the risk assessment, with the results presented for both mean and 99th percentile values.

For both the 2014 NRA and the 2019 NRA Update, the Mars 2020 mission was divided into phases, which reflect principal launch events:

- **Phase 0 – Pre-Launch:** from the installation of the MMRTG to just prior to the start of the first stage main engine
- **Phase 1 – Early Launch:** from the start of the first stage main engines to just prior to the time after which there would be no potential for debris or an intact vehicle configuration to impact land in the launch area, and water impact would occur
- **Phase 2 – Late Launch:** from the end of Phase 1 to when the launch vehicle reaches an altitude of about 30 km (100,000 feet), an altitude above which reentry heating could occur
- **Phase 3 – Suborbital Reentry:** from an altitude of about 30 km (100,000 feet) to the first engine cutoff of the second stage
- **Phase 4 – Orbit Reentry:** from the first engine cutoff of the second stage to separation of the spacecraft from the second stage
- **Phase 5 – Long-term Reentry:** from spacecraft separation to no chance of spacecraft reentry

Accident scenarios were assessed over all launch phases—from pre-launch operations through escape from Earth orbit—and consequences were assessed for both the regional population near the launch site and the global population.

- **Phase 0 (Pre-Launch) and Phase 1 (Early Launch):** A launch-related accident during these periods could result in ground impact in the launch area.
- **Phase 2 (Late Launch):** A launch accident during this period would lead to impact of debris in the Atlantic Ocean.
- **Phase 3 (Suborbital):** A launch accident during this period prior to reaching Earth parking orbit could lead to prompt suborbital reentry within minutes.
- **Phase 4 (Orbital) and Phase 5 (Long-Term Reentry):** A launch accident that occurs after attaining parking orbit could result in orbital decay reentries from minutes to years after the accident.

The radiological consequences of a given accident that results in a release of radioactive material have been calculated in terms of radiation doses, potential health effects, and land area potentially impacted at or above specified levels. The radiological consequences have been estimated from atmospheric transport and dispersion simulations incorporating both worldwide and launch-site specific meteorological and population data.

The estimated radiological consequences by launch phase and for the overall mission are summarized below. For consistency, the accident consequences and associated risks identified in the 2014 FEIS and this SEIS are presented in terms of the mean (see Section 3.5, Health and Safety, for detailed information regarding this discussion).

Consequences of Radiological Release on Human Health

Human health consequences are expressed in terms of maximum individual dose, collective dose to the potentially exposed population, and the associated health effects. The maximum individual dose is the maximum dose, typically expressed in units of rem (roentgen equivalent in man), delivered to a single individual assumed to be outside without shelter during the time of radiological exposure for each accident. Collective dose (also called a population dose) is the sum of the radiation dose received by all individuals exposed to radiation from a given release, assuming no mitigations, such as sheltering in place. Health effects represent statistically estimated additional latent cancer fatalities resulting from an exposure to a release of radioactive material calculated over a 50-year period following the exposure and are determined based on Interagency Steering Committee on Radiation Standards (ISCORS) health effects estimators (DOE 2002a).

Table 2.4-2 provides a summary of the human health consequences for all phases as presented in the 2014 FEIS versus those identified in this SEIS.

Table 2.4-2. Summary of Estimated Mean Radiological Health Consequences – 2014 FEIS vs. 2019 SEIS

Document	Consequence Contributing Source	Launch Area Accident		Accidents Beyond the Launch Area				Overall Mission Accidents
		Pre-Launch	Early Launch	Late Launch	Sub-Orbital	Orbital	Long-term Reentry	
2014 FEIS	Probability of Accident with Release[(a)]	1 in 93,000	1 in 11,000	1 in 130,000	1 in 67,000	1 in 3,800	1 in 11,000,000	1 in 2,600
2019 SEIS	Probability of Accident with Release[(a)]	1 in 16,000	1 in 1,100	1 in 390,000	1 in 140,000	1 in 15,000	1 in 120,000	1 in 960
2014 FEIS	Max Individual Dose, rem	0.00029	0.06	0.000016	0.043	0.0005	0.0008	0.016
2019 SEIS	Max Individual Dose, rem	0.14	0.21	0.048	2.4	1.6	1.0	0.31
2014 FEIS	Latent Cancer Fatalities[(b)]	0.0014	0.29	0.000078	0.20	0.0026	0.0038	0.076
2019 SEIS	Latent Cancer Fatalities[(b)]	0.20	0.52	0.017	0.32	0.14	0.068	0.47

Notes:
(a) Per launch attempt
(b) A latent cancer fatality of less than 1.0 can be interpreted as the probability of the occurrence of one latent cancer fatality within the exposed population. For example, a value of 0.25 would be a one in four chance that the accident would result in one latent cancer fatality within the exposed population.
Key: FEIS = Final Environmental Impact Statement; rem = roentgen equivalent in man; SEIS = Supplemental Environmental Impact Statement.

2014 FEIS

For the Proposed Action as described in the 2014 FEIS, an accident resulting in the release of plutonium dioxide from the MMRTG occurs with a probability of 1 in 2,600. The mean mission human health consequences are estimated at:

- maximum dose received by an individual would have a mean of 0.016 rem, which is equivalent to about 5 percent of the natural annual background dose received by each member of the population of the United States during a year[1]; and
- a mean collective dose resulting in about 0.076 additional latent cancer fatalities within the entire group of potentially exposed individuals.

For individual phases of the mission, the mean maximum dose received by an individual ranges from 0.000016 to 0.060 rem, and the additional latent cancer fatalities range from 0.000078 to 0.29. The largest values are both associated with accidents with releases that occur during the Early Launch Phase (Phase 1). The range of accidents have specific probabilities associated with them and are not the same (refer to Table 2.4-2).

[1] An average of about 0.3 rem per year is received by an individual in the United States from natural sources. The dose from man-made sources, such as medical diagnosis and therapy, could be as high as an additional 0.3 rem. See Section 3.2.6 of the 2014 FEIS for further information.

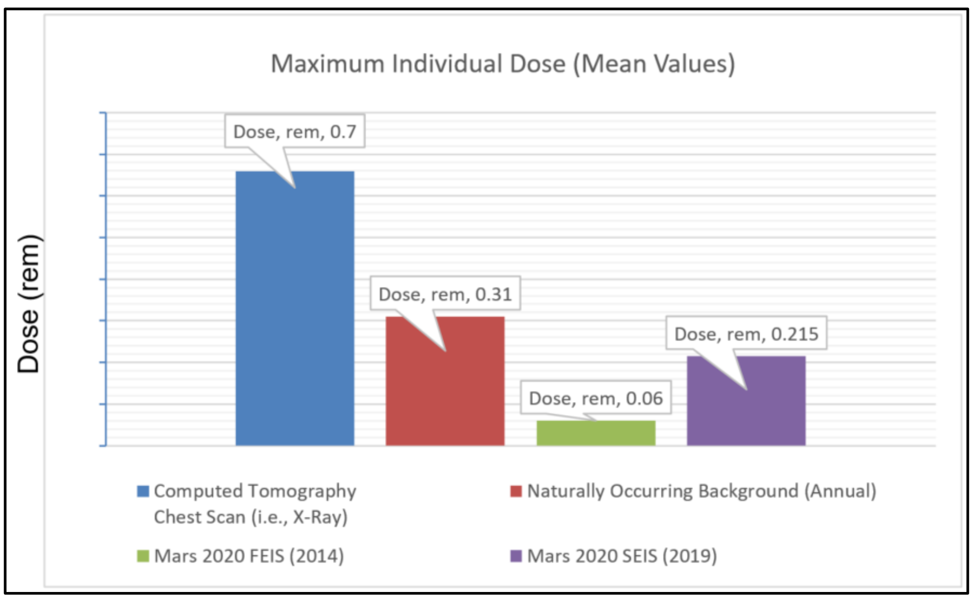
2019 SEIS

For the Proposed Action as described in this SEIS, an accident resulting in the release of plutonium dioxide from the MMRTG occurs with a probability of 1 in 960. The mean mission human health consequences are:

- mean maximum dose received by an individual would have a mean of 0.31 rem, which is nearly equivalent to the natural annual background dose received by each member of the population of the United States during a year; and
- a mean collective dose resulting in about 0.47 additional latent cancer fatalities within the entire group of potentially exposed individuals.

For individual phases of the mission, the mean maximum dose received by an individual ranges from 0.048 to 2.4 rem, and the additional latent cancer fatalities range from 0.017 to 0.52. The largest maximum doses to an individual are associated with accidents with releases that occur in later launch phases, while the largest latent cancer fatality value is associated with early launch accidents with impacts in the launch area. The range of accidents have specific probabilities associated with them and are not the same (refer to Table 2.4-2).

Figure 2.4-3 provides a graphical comparison of the maximum individual dose, given an accident with release of radioactive material.



Note: See Section 3.5 (Health and Safety) for more discussion regarding the maximum individual dose.

Figure 2.4-3. Maximum Individual Dose Given an Accident with Release of Radioactive Material (Launch Area Accident – Early Launch)

Impacts of Radiological Releases on the Environment

In addition to the potential human health consequences of launch accidents that could result in a release of plutonium dioxide, environmental impacts could also include contamination of natural vegetation, wetlands, agricultural land, cultural, archaeological and historic sites, urban areas, inland water, and the ocean, as well as impacts on wildlife.

As described in Section 2.6.2.3.2 of the 2014 FEIS, potential environmental contamination was evaluated in terms of areas that may potentially exceed various screening levels and dose rate–related criteria considered in evaluating the need for land cleanup/mitigation if an accident involving a radiological release occurred. In the NRA for the 2014 FEIS and this 2019 SEIS, land areas that could potentially exceed a screening level of 0.2 microcuries per square meter (μCi/m^2) have been identified. This is a screening level used in prior NASA environmental documentation based on proposed guidance to Federal agencies by the EPA in 1977 (EPA 1977). However, this screening level was never formally adopted by the EPA; rather, that agency has historically assessed the need for action (such as monitoring or cleanup) on a case-by-case basis. While the 0.2 μCi/m^2 screening level has been used in prior NASA environmental documentation (NASA 2014) to identify areas potentially needing further action, it is not considered definitive, as event- or site-specific factors must be considered. Therefore, this screening value is included in this SEIS for comparative purposes to the 2014 FEIS and prior missions. For the purposes of determining land area that could potentially require investigative or remedial actions in the event of release of radiological material, NASA's contingency response plans will establish specific screening values appropriate for the Mars 2020 launch from CCAFS to ensure the timely identification and implementation of appropriate protective actions.

In addition to the potential direct costs of radiological surveys, monitoring, and potential cleanup following an accident, there are potential secondary societal costs associated with the decontamination and mitigation activities due to launch area accidents. Those costs may include: temporary or longer term relocation of residents; temporary or longer term loss of employment; destruction or quarantine of agricultural products, including citrus crops; land use restrictions; restriction or bans on commercial fishing; and public health effects and medical care.

The areas that could be potentially affected to the extent that these secondary costs would be incurred are not necessarily the same as the area potentially affected above 0.2 μCi/m^2. For example, the Food and Drug Administration (FDA) has provided guidelines for crop contamination intended to ensure contaminated foodstuffs would not endanger the health and safety of the public. These guidelines, in the form of Derived Intervention Levels (DILs), identify the level of impact above which some action (decontamination, destruction, quarantine, etc.) is required. The DIL for cropland used within the context of the 2019 NRA Update and this SEIS is 7.3 μCi/m^2 (for launch Phases 0, 1, and 2) (SNL 2019).

The results for the mean land area potentially affected at or above a level of 0.2 μCi/m^2 or 7.3 μCi/m^2 and thus potentially requiring additional evaluation are summarized in Table 2.4-3 and shown graphically in Figure 2.4-4. For potential launch area accidents, DOE has estimated that the crop area potentially affected above the DIL for which some action is required would be over 100 times smaller than the area potentially affected above 0.2 μCi/m^2.

Table 2.4-3. Estimated Mars 2020 Mission Land Area Potentially Exceeding 0.2 or 7.3 μCi/m^2 for Accident with Radiological Release (Mean Maximum Values) – 2014 FEIS vs. 2019 SEIS

Launch Phase	2014 FEIS		2019 SEIS		
	Release Probability[a]	Land Area	Release Probability[a]	Land Area	Cropland Area[b]
Pre-launch[c]	1 in 93,000	0.035 km^2 (0.014 mi^2)	1 in 16,000	7.4 km^2 (2.9 mi^2)	0.00076 km^2 (0.00029 mi^2)
Early launch[c]	1 in 11,000	7.4 km^2 (2.9 mi^2)	1 in 1,100	79 km^2 (31 mi^2)	0.014 km^2 (0.0053 mi^2)
Late launch	1 in 130,000	0.0020 km^2 (0.00077 mi^2)	1 in 390,000	25 km^2 (9.7 mi^2)	0.010 km^2 (0.0039 mi^2)
Suborbital	1 in 68,000	5.2 km^2 (2.0 mi^2)	1 in 140,000	76 km^2 (29 mi^2)	0.0049 km^2 (0.0019 mi^2)
Orbital	1 in 3,800	0.066 km^2 (0.025 mi^2)	1 in 15,000	5.9 km^2 (2.3 mi^2)	0.0058 km^2 (0.0022 mi^2)
Long-term Reentry	1 in 11 million	0.097 km^2 (0.037 mi^2)	1 in 120,000	4.9 km^2 (1.9 mi^2)	0.0048 km^2 (0.0019 mi^2)
Overall Mission	**1 in 2,600**	**1.94 km^2 (0.75 mi^2)**	**1 in 960**	**69 km^2 (27 mi^2)**	**0.012 km^2 (0.0048 mi^2)**

Notes:
(a) Per launch attempt
(b) Indicates a Derived Intervention Level of 7.3 microcuries per square meter (μCi/m^2) for launch Phases 0, 1, and 2.
(c) Accidents during these launch phases are relevant to a region of influence associated with the United States (e.g., an area 7.4 km^2 to 79 km^2 from the launch accident location). Accidents during subsequent launch phases would be associated with a region of influence considered outside the United States as the "global environment" because these launch phases occur outside the jurisdiction of the United States.
Key: FEIS = Final Environmental Impact Statement; km^2 = square kilometers; mi^2 = square miles; SEIS = Supplemental Environmental Impact Statement.

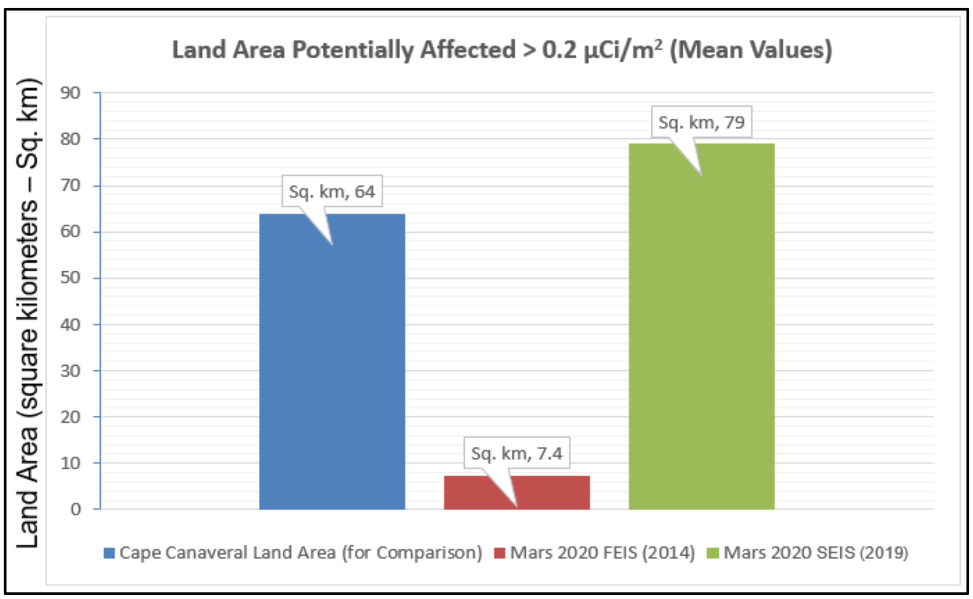


Figure 2.4-4. Land Area Potentially Exceeding 0.2 μCi/m^2 in the Event of a Launch Accident with Radiological Release (Launch Area Accident – Early Launch)

2.4.3.1.2 Mission Risks

To place the estimates of potential health effects due to launch accidents for the Mars 2020 mission into a perspective that can be compared with other human undertakings and events, it is useful to use the concept of risk. Risk is commonly viewed as the possibility of harm or damage. For the Mars 2020 mission, public risk is characterized in terms of the expectation of health effects in a statistical sense. The risk for each launch phase and for the overall mission is estimated by multiplying the total probability of a release by the health effects resulting from that release. Risk calculated in this manner can also be interpreted as the probability of one or more health effects occurring in the exposed population.

Population Risks

2014 FEIS

The 2014 FEIS identified the Proposed Action's estimated overall population health effects risk from the release of plutonium dioxide to be about 1 in 34,000, that is, one chance in 34,000 of an additional health effect (i.e., a health effect occurring outside of normal statistical health effect probabilities; see Section 3.5, Health and Safety, for more detailed information). For accidents that may occur in the launch area, not everyone within 100 km (62 mi) of the launch site would be potentially exposed. Who would be potentially exposed is dependent upon several factors, including the weather conditions at the time of the accident as well as any response actions taken (i.e., shelter in place). The total probability of a health effect within the regional population is about 1 in 61,000, or about 57 percent of the total risk of the entire launch event (i.e., all phases combined). For the global population (excluding those exposed in the launch area region), the risk would be due to the potential for accidental release occurring from pre-launch through Mars trajectory insertion and was estimated to be about 1 in 79,000, or about 43 percent of the entire launch event (i.e., all phases combined).

2019 SEIS

This SEIS identifies the Proposed Action's estimated overall population health effects risk from the release of plutonium dioxide to be about 1 in 2,000—that is, one chance in 2,000 of an additional health effect. For accidents that may occur in the launch area, not everyone within 100 km (62 mi) of the launch site would be potentially exposed. Similar to analysis in the 2014 FEIS, who would be potentially exposed is dependent upon several factors, including the weather conditions at the time of the accident and response actions (i.e., shelter in place). The total probability of a health effect within the regional population is about 1 in 3,000, or about 66 percent of the total risk for the overall mission. For the global population (excluding those exposed in the launch area region), the risk would be due to the potential for accidental release occurring from pre-launch through Mars trajectory insertion and was estimated to be about 1 in 6,000, or about 34 percent of the total risk for the mission.

Individual Risks (Maximum Individual Risks)

Both the 2014 FEIS and this SEIS find that those individuals within the population that might receive the highest radiation exposures, such as those very close to the launch area, would face very small risks. The 2014 FEIS found that the risk to the maximally exposed individual within the regional population was estimated to be less than 1 in 300 million for the Mars 2020 mission. This SEIS estimates that the risk to the maximally exposed individual within the regional population is estimated to be less than 1 in 9 million for the Mars 2020 mission. Most people in the potentially exposed population would have much lower risks.

These risk estimates are miniscule compared to other risks. Annual fatality statistics indicate that in the year 2017 the average individual risk of accidental death in the United States was about 1 in 1,900 per year, while the average individual risk of death due to any disease, including cancer, was about 1 in 150 (see Section 3.5, Health and Safety, of this SEIS for additional details).

2.4.4 Summary Comparison of the Proposed Action and No Action Alternative

In terms of environmental impacts, normal implementation of the Proposed Action would primarily yield short-term impacts to air quality from the launch vehicle's exhaust. Should a launch accident occur, potential environmental impacts would be primarily associated with combustion products from released propellants and from falling debris. As stated in Sections 2.4.1 (Environmental Impacts of a Normal Launch) and 2.4.2 (Environmental Impacts of Potential Launch Accident with No Radiological Release), these impacts were addressed in the 2014 FEIS and are not addressed in detail in this SEIS because they do not substantively differ from the analysis and associated consequences identified in the 2014 FEIS.

Although the probability of such accidents occurring is unlikely, it is possible that a launch accident could result in a release of some of the plutonium dioxide from the MMRTG, which could potentially result in consequences to human health and the environment. These potential impacts are summarized in Section 2.4.3 (Environmental Impacts of Potential Launch Accident with Radiological Release) and addressed in detail in Chapter 3, Affected Environment and Environmental Consequences) of this SEIS.

For the No Action Alternative, no environmental impacts would occur since there would be no launch. The No Action Alternative is discussed in detail in the 2014 FEIS. Implementation of the No Action Alternative would not meet the purpose and need for the Mars 2020 mission because none of the planned science would be achieved.

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3. AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

3.1 INTRODUCTION

This chapter corresponds to Chapters 3 and 4 of the 2014 FEIS. In this SEIS, the affected environment and environmental consequences discussions for each resource area have been combined for easier understanding. As discussed in Chapter 1 (Purpose and Need for the Action), this SEIS identifies changes to the affected environment since the 2014 FEIS was published. In addition, this report discusses potential environmental impacts from postulated launch vehicle accidents causing a release of radioactive materials. The 2014 FEIS addressed such scenarios, but this SEIS includes an updated analysis using new modeling results. Spatial dispersion of radiological contamination levels within the ROI that could potentially occur from a launch vehicle accident with a release of radioactive materials is dependent on specifics of the accident. Such variables that affect spatial dispersion include the launch phase (i.e., where the accident occurs, elevation of the launch vehicle at the time of the accident, etc.), how the launch vehicle reacts to the accident, the weather, and the wind conditions at the time of the event. Specific impacts and associated mitigations as a result of such an unlikely occurrence would need to be evaluated as part of response activities as outlined in Section 3.5 (Health and Safety) of this SEIS.

The 2014 FEIS addressed impacts associated with normal launch activities, including accidents that would not release radioactive materials. Those potential impacts remain the same, so this SEIS does not repeat that information.

Also, this SEIS does not address some resource areas that were included in the 2014 FEIS. Section 3.2 below explains the rationale for not including those resource areas from the 2014 FEIS. Section 3.3 identifies any incomplete or unavailable information needed to describe the affected environment or conduct the environmental analysis. Sections 3.5 through 3.15 describe the affected environment for environmental resources analyzed for this SEIS, as well as environmental effects as they correspond to the 2014 FEIS and changes as of 2019.

3.2 RESOURCES CONSIDERED BUT NOT CARRIED FORWARD

Table 3.2-1 lists the environmental resources that were not carried forward from the 2014 FEIS for analysis in this SEIS and explains why they were not carried forward.

Table 3.2-1. Resources Considered But Not Carried Forward

Resource Area	Rationale
Noise	The noise environment and potential noise-related impacts from launch activities remain the same as that described in the 2014 FEIS. With the exception of sonic booms associated with booster landings, the noise environment within the ROI has remained largely unchanged since 2014 (there are no booster landings associated with the Mars 2020 mission). Other NEPA documents address the effects of launch activities on the affected environment (NASA 2016). A launch accident resulting in

Table 3.2-1. Resources Considered But Not Carried Forward

Resource Area	Rationale
	a radiological release would have no additional noise consequences than those resulting from a launch accident that does not release radioactive materials.
Aesthetics	The aesthetic environment and potential impacts from launch activities remain the same as that described in the 2014 FEIS. Aside from typical development activities within the ROI, the aesthetic environment has remained largely unchanged since 2014. A launch accident resulting in a radiological release would have no more impacts to the aesthetic environment than those from a launch accident that does not release radioactive materials.
Hazardous Materials and Hazardous Waste	Hazardous materials and waste management, pollution prevention, and spill management at CCAFS/KSC remain the same as described in the 2014 FEIS. The hazardous materials or potential wastes associated with the Proposed Action as described in the 2014 FEIS have not changed. Hazardous wastes associated with accidents (both non-radiological release and radiological release) and associated management would be the same as described in the 2014 FEIS. Hazardous materials and hazardous wastes would continue to be managed under Federal and state regulations. All CCAFS/KSC launch sites have established operating plans to implement these regulations. These plans clearly define responsibilities and procedures for managing hazardous materials and hazardous wastes. Any hazardous materials remaining after processing would be properly stored for future use or disposed of in accordance with applicable regulations. All hazardous waste would be properly containerized, stored, labeled, manifested, shipped, and disposed of so as to comply with regulations.

Key: CCAFS/KSC = Cape Canaveral Air Force Station/Kennedy Space Center; FEIS = Final Environmental Impact Statement; NEPA = National Environmental Policy Act; ROI = region of influence.

3.3 INCOMPLETE OR UNAVAILABLE INFORMATION

As with the 2014 FEIS (Section 4.7), this SEIS has been developed before final preparations could be completed for the Mars 2020 mission. However, the design is complete, the hardware is built, and the system is undergoing testing. At this time, there are no expected changes that might substantively affect the environmental evaluations presented in this SEIS.

3.4 ENVIRONMENTAL COMPLIANCE AT CCAFS

This section corresponds to Sections 3.1 and 4.10 of the 2014 FEIS, which presented environmental laws, regulations, reviews, and consultation requirements applicable to CCAFS, including permits, licenses, and approvals. No substantive changes in CCAFS operations, permits, licenses, and/or approvals have been identified that would substantively affect the analysis from the 2014 FEIS.

3.5 HEALTH AND SAFETY

This section corresponds to Section 3.1.10 of the 2014 FEIS, which described regional and onsite (CCAFS/KSC) safety associated with payload processing, transport, and launches.

3.5.1 Affected Environment

Changes to ROI Since 2014 FEIS

Regional Safety

Regional safety aspects of the baseline environment as described in the 2014 FEIS remain the same. CCAFS, KSC, the City of Cape Canaveral, and Brevard County still maintain a mutual-aid agreement in the event of an on- or off-station emergency. During launch activities, CCAFS maintains communication with KSC, Brevard County Emergency Management, the Florida Marine Patrol, the U.S. Coast Guard, and the State coordinating agency, the Florida Division of Emergency Management. Range Safety monitors launch viewing areas to ensure that risks to people, aircraft, and surface vessels do not exceed acceptable limits. NASA closes control areas and airspace to the public as needed.

Since the issuance of the 2015 ROD, NASA has made contingency plans for the unlikely event that a launch accident would cause release of radioactive material. Before launching any spacecraft that includes radioisotope power systems, NASA develops plans to make sure it can effectively respond to a launch accident. NASA develops these plans under the Department of Homeland Security's (DHS) National Response Framework (NRF) (DHS 2016a) and the NRF Nuclear/Radiological Incident Annex (DHS 2016b). In making these plans, NASA coordinates with other organizations that would respond in a radiological emergency. These organizations include DOE and other Federal agencies, the State of Florida, Brevard County, and local governmental organizations. In addition, in 2019, DOE's National Nuclear Safety Administration conducted a radiological emergency response exercise as part of the efforts to ensure that local, state, and Federal authorities are trained and prepared in the event of an accident.

3.5.2 Environmental Consequences

This section compares the environmental impacts of potential accidents involving radioactive materials as presented in the 2014 FEIS with results from more recent analysis. For additional details, see the 2014 FEIS and Appendix A (Health and Safety Supporting Information) of this SEIS.

3.5.2.1 No Action Alternative

The No Action Alternative would be the same as described in Section 2.4 of the 2014 FEIS. Under this alternative, NASA would discontinue preparations for the Mars 2020 mission, and thus no health and safety impacts would occur outside of normal ongoing operations within the CCAFS or the larger nine-county ROI.

3.5.2.2 Proposed Action

NASA and DOE assessed the potential environmental impacts of postulated launch accidents involving release of plutonium dioxide. Results show the most likely outcome is a successful launch of the spacecraft toward Mars. But in the case of an unsuccessful launch, it is unlikely to cause a release of plutonium dioxide.

For the 2014 FEIS, NASA estimated the launch success probability for a "composite" launch vehicle to complete all pre-launch operations, first stage flight, second stage flight, and insertion of the spacecraft into the proper trajectory. NASA calculated the accident probabilities by combining the estimated accident probabilities for the Atlas V and Delta IV launch vehicles as stated in the *Mars 2020 Representative Databook* (NASA 2013). As such, these estimated probabilities did not reflect the reliability of any single launch vehicle.

For the updated analysis, NASA estimated the accident probabilities for the selected Atlas V 541 launch vehicle. The probabilities for the Atlas V 541 differ from those of the composite vehicle reported in the 2014 FEIS, as follows:

- The 2014 FEIS reported a 97.5 percent chance of a successful launch of the composite vehicle; the 2019 analysis reports a 98.8 percent chance of a successful launch of the Atlas V 541.
- The 2014 FEIS reported a 2.5 percent chance of a launch vehicle accident; the 2019 analysis reports a 1.25 percent chance of a launch vehicle accident.

DOE's updated analysis estimated accident release probabilities and source terms for the selected Atlas V 541 launch vehicle, as stated in the 2019 NRA Update. The probability of release and consequences following an accident for the Atlas V 541 differs from those of the composite vehicle reported in the 2014 FEIS as follows:

- The 2014 FEIS reported an unlikely[2] chance (1 in 2,600) for the overall mission of a launch vehicle accident that would release plutonium dioxide; the 2019 analysis reports a larger but still unlikely chance (1 in 960) for the overall mission of a launch vehicle accident with release.
    - The 2014 FEIS reported the very unlikely chance (1 in 11,000) of a launch vehicle accident that would result in a release of plutonium dioxide within the launch area; the 2019 analysis reports a larger unlikely chance (1 in 1,100).
    - The 2014 FEIS reported an unlikely (1 in 3,500) chance of a launch vehicle accident that would result in a release of plutonium dioxide outside the launch area; the 2019 analysis reports a smaller very unlikely (1 in 12,000) chance.
- The 2014 FEIS reported that no radiologically related fatalities would be expected as a result of any launch accident. The 2019 NRA Update analysis found that some accidents, while very or extremely unlikely (see Section 3.5.2.2.5, Radiological Consequences), could result in long-term latent cancer fatalities. For example, a full stack intact impact (FSII) accident in Phase 1 (early

[2] As in the 2014 FEIS, for this SEIS, the total probabilities of an accident with a release of plutonium dioxide are grouped into categories that reflect the likelihood of each accident:

- unlikely: 10^{-2} to 10^{-4} (1 in 100 to 1 in 10,000);
- very unlikely: 10^{-4} to 10^{-6} (1 in 10,000 to 1 in 1 million); and
- extremely unlikely: less than 10^{-6} (less than 1 in 1 million).

launch), with a less than 1 in 1 million probability of occurrence, is estimated to result in an estimated seven latent cancer fatalities (over 50 years). For comparison, according to the National Institutes of Health's National Cancer Institute, of the population in the nine counties surrounding KFC/CCAFS (estimated at 4,633,191 in 2020) about 1 in 5 (National Cancer Institute 2019), or about 900,000 people, will die of cancer from other causes.

- The 2014 FEIS reported that an accident in the launch area that releases radioactive material would cause an average maximum dose of radiation equal to about two months of exposure to natural background radiation for a person in the United States. The 2019 NRA Update reports an average maximum dose equal to about eight months of exposure to natural background radiation under the same scenario.
- The 2014 FEIS reported that the average land area that would require further evaluation for potential contamination from a launch vehicle accident resulting in a release affecting U.S. land areas would be between 0.035 square kilometer (km^2) (0.014 square mile [mi^2]) during Phase 0 (pre-launch) and 7.4 km^2 (2.9 mi^2) from a launch vehicle accident with release in Phase 1 (early launch). This is the land area that would need to be evaluated to determine potential impact levels above 0.2 $\mu Ci/m^2$. Land areas above this level would be considered to be potentially impacted to the point of requiring detailed characterization for potential cleanup actions. The 2019 NRA Update analysis found that the average land area requiring further evaluation from a launch vehicle accident resulting in a release affecting U.S. land areas would be between 7.4 km^2 (2.9 mi^2) during Phase 0 and 79 km^2 (31 mi^2) from a launch vehicle accident with release in Phase 1 (early launch). A Phase 0 launch vehicle accident resulting in a release is a very unlikely event, and a Phase 1 launch vehicle accident resulting in release is an unlikely event with probabilities of occurrence per launch of less than 1 in 16,000 and 1 in 1,100, respectively.

The consequences and their probabilities in the 2014 FEIS and this SEIS are based on these launch vehicle accident probabilities and estimated release probabilities in the 2014 NRA and 2019 NRA Update, respectively.

3.5.2.2.1 Risk Assessment Method

The risk methodology has not changed significantly (see Chapter 4 of the 2014 FEIS). However, many of the models used have undergone revision. These revisions incorporate increased understanding of the phenomena associated with plutonium release from the MMRTG under accident conditions and the transport and uptake of plutonium.

3.5.2.2.2 Launch Accidents and Accident Probabilities

In the 2019 NRA Update, the method for calculating accident probabilities is the same as that used in the 2014 FEIS. But two factors result in differences between the probabilities used for the 2014 FEIS and the 2019 NRA Update. Since the publication of the ROD for the 2014 FEIS, NASA selected the Atlas V 541 as the mission launch vehicle. Accident probabilities used in the 2019 analysis reflect the selected vehicle. The Atlas V 541 vehicle has undergone evolutionary changes that include the avionics and second stage engine. The models for launch vehicle accident probabilities and accident environments have been updated to account for all modifications. Additional launches have occurred in the five years since the 2014 FEIS analysis was performed. DOE incorporated data from these more recent launches in its analysis of accident probabilities. As stated in the 2014 FEIS and in Section 3.3 (Incomplete or Unavailable Information) of this SEIS, NASA continues to evaluate the reliability of launch vehicles (NASA 2014).

2014 FEIS

The 2014 FEIS reported a total mission failure probability of 2.5 x 10^{-2}. Phase 3 had the highest probability of an accident followed by Phase 4. Accidents were slightly less likely in Phases 1 and 2 than Phase 4. Table 3.5-1 compares the accident end-state probabilities for each launch phase.

Table 3.5-1. Accident End-State and Release Probabilities (per Launch Attempt)

Launch Phase	2014 FEIS			2019 NRA Update		
	Accident Probability	Conditional Release Probability	Total Release Probability	Accident Probability	Conditional Release Probability	Total Release Probability
Phase 0	Very Unlikely ($3.3x10^{-5}$)	$3.3x10^{-1}$	Very Unlikely ($1.1x10^{-5}$)	Unlikely ($1.0 x10^{-4}$)	$6.0x10^{-1}$	Very Unlikely ($6.2x10^{-5}$)
Phase 1	Unlikely ($3.1x10^{-3}$)	$2.8x 10^{-2}$	Very Unlikely ($8.8x10^{-5}$)	Unlikely ($1.7x10^{-3}$)	$5.2x 10^{-1}$	Unlikely ($9.0x10^{-4}$)
Phase 2	Unlikely ($3.6x10^{-3}$)	$2.1x10^{-3}$	Very Unlikely ($7.7x10^{-6}$)	Unlikely ($2.5x10^{-3}$)	$1.0x10^{-3}$	Very Unlikely ($2.6x10^{-6}$)
Phase 3	$1.3x10^{-2}$	$1.3x10^{-3}$	Very Unlikely ($1.5x10^{-5}$)	Unlikely $6.8x10^{-3}$	$1.1x10^{-3}$	Very Unlikely ($7.3x10^{-6}$)
Phase 4	Unlikely ($4.7x10^{-3}$)	$5.6x10^{-2}$	Unlikely ($2.6x10^{-4}$)	Unlikely ($1.2x10^{-3}$)	$5.5x10^{-2}$	Very Unlikely ($6.6x10^{-5}$)
Phase 5	Very Unlikely ($1.0x10^{-6}$)	$9.4x10^{-2}$	Extremely Unlikely ($9.4x10^{-8}$)	Unlikely ($1.4x10^{-4}$)	$6.0x10^{-2}$	Very Unlikely ($8.5x10^{-6}$)
Total Probability	**$2.5x10^{-2}$**	**$1.6x10^{-2}$**	**Unlikely ($3.8x10^{-4}$)**	**$1.3x10^{-2}$**	**$8.4x10^{-2}$**	**Unlikely ($1.0x10^{-3}$)**

Key: FEIS = Final Environmental Impact Statement; NRA = Nuclear Risk Assessment.

Phase 1 consists of five accident groups: on-pad explosions, full stack intact impact (FSII) (the entire launch vehicle impacts the ground), space vehicle intact impact (SVII) (the entire space vehicle impacts the ground), Stage 2/SV (the intact stage 2 and the space vehicle impact the ground), and low-altitude flight termination system (Low Altitude FTS) (the vehicle is destroyed at low altitude and debris impacts the ground). Probabilities for the release of plutonium differ for each group, and source terms also differ. (For the purpose of this SEIS, “source term” is defined as the quantity of radioisotope that is released from the fuel clads in the GPHS modules and that becomes airborne.) The most probable accident is the Low Altitude FTS.

The methodology presented in Section 4.1.4.1 of the 2014 FEIS includes the basis for identifying accident probabilities. Different mechanical failures result in accidents in different phases, and these failures have different probabilities over a phase. Also, in Phase 1, how the accident progresses also depends on variables that have unique probabilities. For example, the FTS is more likely to succeed (resulting in Low Altitude FTS) than fail and the other end states (FSII, Stage 2/SV, SVII) require FTS failure for an accident to occur.

2019 SEIS

The 2019 NRA Update reports a total mission failure probability of 1.3×10^{-2}. Phase 3 has the highest probability of an accident, followed by Phases 2 and 1. The probability of a Phase 3 accident dropped by a factor of 2. The probability of a Phase 4 accident dropped by a factor of 4. The Phase 5 accident probability increased but remains less likely than the accident probability for all phases except for Phase 0. The Low Altitude FTS remains the most probable accident in Phase 1. Table 3.5-1 lists phase accident, conditional release, and total release probabilities.

For additional details on mission failure probabilities and development of the data, see the 2014 FEIS and Appendix A (Health and Safety Supporting Information) of this SEIS.

3.5.2.2.3 MMRTG Response to Accident Environments

2014 FEIS

For details on potential responses of the MMRTG and its components in an accident, see the 2014 FEIS Sections 2.1.3 and 4.1.4.3.

2019 SEIS

The 2019 NRA Update and this SEIS reflect a better understanding of how the iridium in the MMRTG fuel clads responds to impacts (as described on page 2-23 of the 2014 FEIS) when the MMRTG is operating at lower temperatures during 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. Using this new test information and previous older bare clad test data, the models used to predict clad failure under various accident conditions were updated. Because of the reduced fuel clad ductility, combined with changes in the air dispersion modeling and accident analysis techniques, the updated models predict increased radiological impact estimates, due to the increased frequency and magnitude of releases of plutonium dioxide.

This updated analysis indicates that the chances of some types of launch accidents resulting in a release of radioactive material are higher than estimated in the 2014 NRA and that the chances of potential radiological environmental impacts from those accidents are higher than estimated in the 2014 FEIS. For additional details, see Appendix A (Health and Safety Supporting Information), Section A.3.1.

3.5.2.2.4 Accident Probabilities and Source Terms

NASA and DOE evaluated each of the identified end states and estimated the accident environments to which the MMRTG would likely be exposed. From that information, DOE developed conditional probabilities that a release would occur and estimated source terms, based on the known response of GPHS modules to various accident environments.

The probability of a launch accident involving any release of plutonium dioxide is very small, estimated to be unlikely in both the 2014 FEIS analysis and analysis for this SEIS: approximately 1 in 10,000 for the 2014 FEIS analysis and 1 in 1,000 for this SEIS analysis. The most severe accident environments would occur during launch area accidents that might expose the MMRTG to mechanical impacts, explosion overpressures and fragments, and fire from burning liquid and solid propellants.

Appendix A (Health and Safety Supporting Information) summarizes the accident (both an accident without a release and an accident with a release) and source term probabilities by mission phase, along with mean and 99th percentile source terms for the 2014 FEIS and this SEIS.

In the 2019 NRA Update, conditional probabilities of release increased in Phases 0 and 1 compared to those of the 2014 FEIS. These probabilities decreased slightly in Phases 2 through 5 in the 2019 analysis. With the changes in accident probabilities, a greater fraction of launch accidents that could result in a release would occur in Phases 0 and 1.

The 2019 NRA Update indicates that, of the launch accidents resulting in a release (a mission total probability of 1.04×10^{-3}), 92 percent would occur within the launch area (a total probability of 9.6×10^{-4} for Phase 0 and Phase 1 accidents), while the 2014 FEIS reported 26 percent of launch accidents with a release (a mission total probability of 3.8×10^{-4}) would occur within the launch area (a total probability 9.9×10^{-5} for Phase 0 and Phase 1 accidents).

Within the launch area, for Phase 0 and Phase 1 accidents, the release probability increased by about a factor of 10 in the 2019 analysis (e.g., Phase 1 increased from 2.8 percent to 52 percent). Overall, the probability of an accident with a release increased by a factor of 3 for the mission ($1.04 \times 10^{-3}$from 3.8×10^{-4}). Table 3.5-2 provides the phase and mission release probabilities as well as the release probabilities for the Phase 1 accident scenarios.

Table 3.5-2. 2014 FEIS and 2019 NRA Update Summary of Release Probabilities and Source Terms

Mission Phase[a]	2014 FEIS			2019 NRA Update		
	Total Probability of a Release[b]	Mean Source Term (given a release) (Curies)	99th Percentile Source Term[c],[d] (given a release) (Curies)	Total Probability of a Release[b]	Mean Source Term (given a release) (Curies)	99th Percentile Source Term[c],[d] (given a release) (Curies)
0: Pre-Launch[e]	Very Unlikely ($1.1x10^{-5}$)	0.28	6.7	Very Unlikely ($6.2x10^{-5}$)	52.3	1,080
1: Early Launch[e]						
On-Pad Explosion	Very Unlikely ($8.3x10^{-6}$)	23	40	Very Unlikely ($3.2x10^{-5}$)	1,330	10,000
FSII	Very Unlikely ($3.2x10^{-6}$)	110	1,800	Extremely Unlikely ($8.8x10^{-7}$)	6,540	20,200
Stage 2/SV	Very Unlikely ($1.8x10^{-6}$)	77	910	Very Unlikely ($1.6x10^{-5}$)	2,650	13,700
SVII	Extremely Unlikely ($3.4x10^{-8}$)	50	580	Extremely Unlikely ($8.8x10^{-7}$)	1,190	8,610
Low Altitude FTS	Very Unlikely ($7.5x10^{-5}$)	61	620	Unlikely ($8.5x10^{-4}$)	1,090	5,550
Overall Phase 1	Very Unlikely ($8.8x10^{-5}$)	59	630	Unlikely ($9.0x10^{-4}$)	1,130	6,970
2: Late Launch	Very Unlikely ($7.7x10^{-6}$)	0.016	0.23	Very Unlikely ($2.6x10^{-6}$)	79.8	621
3: Suborbital	Very Unlikely ($1.5x10^{-5}$)	42	930	Very Unlikely ($7.3x10^{-6}$)	371	3,820
4: Orbital	Unlikely ($2.6X10^{-4}$)	0.53	6.2	Very Unlikely ($6.6X10^{-5}$)	46.1	414
5: Long-term Reentry	Extremely Unlikely ($9.4x10^{-8}$)	0.77	7.8	Very Unlikely ($8.5x10^{-6}$)	48.7	423
Overall Mission[f]	**Unlikely ($3.8x10^{-4}$)**	**16**	**340**	**Unlikely ($1.0x10^{-3}$)**	**979**	**6,290**

Source: (NASA 2014, SNL 2019)

Notes:

Differences in multiplications and summations are due to rounding of results as reported in the 2014 NRA. Probability categories (e.g., unlikely, very unlikely) are as defined by NASA.

(a) The table presents a composite of the results for the Atlas V 551 and the Delta IV Heavy, which were used for the 2014 FEIS, determined by taking the probability-weighted value of the two sets of results, treating the conditional probability of having a given launch vehicle as 0.5; and for the Atlas V 541 for the 2019 NRA Update.

(b) Per launch attempt.

(c) Total source terms given. The source term is that portion of the release that becomes airborne that would represent the amounts of plutonium dioxide released that are no more than 100 micrometers (100 microns) in diameter. Particles larger than this do not generally become airborne and would remain in the vicinity of the accident.

(d) The 99th percentile values would be expected to occur at a probability of about 100 times lower than the mean probability of release.

(e) Accidents during these launch phases are relevant to a region of influence associated with the United States. Accidents during subsequent launch phases would be associated with a region of influence considered outside the United States as the "global environment" because these launch phases occur outside the jurisdiction of the United States.

(f) Overall mission values are weighted by the total probability of release for each mission phase.

Key: FEIS = Final Environmental Impact Statement; NRA = Nuclear Risk Assessment; FSII = full stack intact impact (the entire launch vehicle impacts the ground); Low Altitude FTS = flight termination system (the vehicle is destroyed at low altitude and debris impacts the ground); Stage 2/SV = stage 2 and space vehicle (the intact stage 2 and the space vehicle impact the ground); SVII = space vehicle intact impact (the entire space vehicle impacts the ground).

As can be seen from the data in Table 3.5-2, generally, mean source terms (given a release) increased by a factor of 10 to less than a factor of 200 for each launch phase and accident scenario (with the exception of Phase 2 [Late Launch], which releases increase from very small to similar to Phases 3, 4, and 5). (Additional information is provided in Appendix A, Health and Safety Supporting Information, Table A-3 and Table A-4. Those tables provide mean and 99th percentile source terms given an accident *and* given a release. The mean source terms *given a release* were used to generate the consequence and risk estimates for this mission.) The mean source terms (given a release) for Phase 1 and all of individual Phase 1 accident scenarios increased by a factor of between 18 and 60. Source terms for Phases 3, 4, and 5 increased by a factor of less than 100, and Phase 1 by a factor of about 200. The Phase 2 source term, which was much less than 1 curie in the 2014 NRA, increased to 79.8 curies in the 2019 analysis.

Differences in Source Terms

Differences in conditional release probabilities and source terms are the result of the changes to the analytical models identified above (e.g., changes made to reflect the results of MMRTG accident environment tests). Improved understanding of the response of the MMRTG materials (especially the fuel cladding) to those environments (e.g., impacts, temperature) resulted in the increases to the conditional release probabilities. These factors resulted in the source term changes.

In general, consequence measures increase as source terms increase, but the increase is not necessarily one to one. Furthermore, the increase in consequence measures are less than the increase in the overall mission source term for the 2019 NRA Update due to the updates to the consequence modeling.

3.5.2.2.5 Radiological Consequences

As in the 2014 FEIS, the radiological consequences of an accident that results in a radiological release, assuming no post-accident mitigation, were calculated in terms of maximum individual dose, collective dose, health effects, and land area potentially requiring further evaluation for impacts at or above specified levels. The 2014 FEIS provides more information on the definitions of these consequences. See Appendix B of the 2014 FEIS for more information on the behavior of plutonium dioxide in the environment (environmental transport and health impact mechanisms).

Changes Since the 2014 FEIS

Using the best available information, DOE updated models and parameter inputs that are used for conducting the nuclear safety analysis, including models addressing MMRTG response to accident environments, radiological transport mechanisms within those environments, and potential health effects. Appendix A (Health and Safety Supporting Information) of this SEIS provides more details.

Discussion of the Consequence Results

Table 3.5-3 and Table 3.5-4 summarize DOE's risk assessment radiological consequences of an accident with a release for each of the mission phases for the 2014 FEIS and this SEIS, respectively. The radiological consequences were estimated by mission phase in terms of both the mean and 99th percentile values. Appendix A (Health and Safety Supporting Information) discusses the 99th percentile values.

DOE developed the radiological consequences based on detailed characteristics of the material released, that is the source terms, listed in Table 3.5-2.

The following subsections summarize key results for the mean estimates.

Maximum Individual Doses

The maximum individual dose is the maximum dose potentially delivered to a single individual for each accident. In the 2014 FEIS, mean maximally exposed individual doses for all phases of the launch are a fraction of the average dose that an individual might receive annually from natural background radiation,[3] generally less than 100 millirem. Only for a Phase 1 FSII accident is the average maximally exposed individual dose greater than 100 millirem, with a value of 110 millirem. This is about a third of the average annual natural background dose to someone living in the United States.

The results of the 2019 NRA Update show that the maximum exposed individual doses are generally approximately a magnitude factor of 10 or more higher than that calculated in the 2014 FEIS. In the 2014 FEIS, the maximum individual dose for Phases 2, 4, and 5 are much smaller than the Phase 1 doses. In the 2019 NRA Update, these Phase 2, 4, and 5 doses increased significantly more than the Phase 1 dose did. These doses, while still smaller, are now much closer to the doses estimated for Phase 1. During Phase 1, the predicted mean radiation dose to the maximally exposed individual ranges from about 0.19 rem (190 millirem) for Low Altitude FTS and SVII launch area accidents up to about 1.2 rem (1,200 millirem) for an extremely unlikely FSII in combination with burning solid propellant. No near-term radiological health effects would be expected from any of these exposures. Unlike the results of the 2014 FEIS, the dose to the maximally exposed individual for the FSII is not the largest single maximally exposed individual dose for any accident. Rather, the Phase 3 suborbital failure and a hard surface impact yields a maximally exposed individual dose of 2.4 rem (2,400 millirem), which is the highest individual dose from any accident. This lifetime dose of 2.4 rem is equal to approximately eight years of exposure to natural background radiation.

[3] An average of about 0.31 rem per year for an individual in the United States from natural sources. Man-made sources add an additional 0.060 to 0.31 rem. The dominant man-made contribution is from medical radiological diagnosis and therapy. See Section 3.2.6 of the 2014 FEIS for further information.

Table 3.5-3. 2014 FEIS Summary of Estimated MMRTG Accident Radiological Consequences

Mission Phase[(a)]	Total Probability of Release[(b)]	Maximum Individual Dose (rem)		Health Effects[(d)]		Potentially Affected Land Area[(e)] (km^2)	
		Mean	99th Percentile[(c)]	Mean	99th Percentile[(c)]	Mean	99th Percentile[(c)]
0: Pre-Launch[(f)]	Very Unlikely ($1.1x10^{-5}$)	0.00029	0.0068	0.0014	0.033	0.035	0.83
1: Early Launch[(f)]							
On-Pad Explosion	Very Unlikely ($8.3x10^{-6}$)	0.024	0.040	0.11	0.19	2.9	4.9
FSII	Very Unlikely ($3.2x10^{-6}$)	0.11	1.9	0.52	8.9	13	230
Stage 2/SV	Very Unlikely ($1.8x10^{-6}$)	0.079	0.93	0.38	4.5	9.7	110
SVII	Extremely Unlikely ($3.4x10^{-8}$)	0.051	0.59	0.25	2.9	6.3	73
Low Altitude FTS	Very Unlikely ($7.5x10^{-5}$)	0.062	0.63	0.30	3.0	7.6	77
Overall Phase 1	Very Unlikely ($8.8x10^{-5}$)	0.060	0.65	0.29	3.1	7.4	79
2: Late Launch	Very Unlikely ($7.7x10^{-6}$)	$1.6x10^{-5}$	0.0002	$7.8x10^{-5}$	0.0011	0.0020	0.029
3: Suborbital	Very Unlikely ($1.5x10^{-5}$)	0.043	0.95	0.20	4.6	5.2	120
4: Orbital	Unlikely ($2.6x10^{-4}$)	0.0005	0.0063	0.0026	0.030	0.066	0.77
5: Long-term Reentry	Extremely Unlikely ($9.4x10^{-8}$)	0.0008	0.0080	0.0038	0.038	0.097	0.98
Overall Mission[(g)]	**Unlikely ($3.8x10^{-4}$)**	**0.016**	**0.35**	**0.076**	**1.7**	**1.9**	**43**

Source: (NASA 2014)

Notes:

Differences in multiplications and summations are due to rounding of results as reported in the 2014 NRA. Probability categories (e.g., unlikely, very unlikely) are as defined by NASA.

(a) The table presents a composite of the results for the Atlas V 551 and the Delta IV Heavy, which were used for the 2014 FEIS, determined by taking the probability-weighted value of the two sets of results, treating the conditional probability of having a given launch vehicle as 0.5.

(b) Per launch attempt.

(c) The 99th percentile values would be expected to occur at a probability of about 100 times lower than the mean probability of release.

(d) Based on ISCOR health effects recommendation of $6 x 10^{-4}$ health effects per person-rem for the general population.

(e) Land area potentially exceeding 0.2 $\mu Ci/m^2$; 1 km^2 = 0.386 mi^2.

(f) Accidents during these launch phases are relevant to a region of influence associated with the United States. Accidents during subsequent launch phases would be associated with a region of influence considered outside the United States as the "global environment" because these launch phases occur outside the jurisdiction of the United States.

(g) Overall mission values weighted by total probability of release for each mission phase.

Key: $\mu Ci/m^2$ = microcuries per square meter; FEIS = Final Environmental Impact Statement; FSII = full stack intact impact (the entire launch vehicle impacts the ground); ISCOR = Interagency Steering Committee on Radiation; km^2 = square kilometers; Low or High Altitude FTS = flight termination system (the vehicle is destroyed at low or high altitude and debris impacts the ground); mi^2 = square miles; MMRTG = Multi-Mission Radioisotope Thermoelectric Generator; NRA = Nuclear Risk Assessment; rem = roentgen equivalent in man; Stage 2/SV = stage 2 and space vehicle (the intact stage 2 and the space vehicle impact the ground); SVII = space vehicle intact impact (the entire space vehicle impacts the ground).

Table 3.5-4. 2019 NRA Update Summary of Estimated MMRTG Accident Radiological Consequences

Mission Phase[a]	Total Probability of Release[b]	Maximum Individual Dose[c] (rem)		Health Effects[e]		Land Area Potentially Affected[f] (km^2)		Cropland Potentially Affected[g] (km^2)	
		Mean	99th Percentile[d]	Mean	99th Percentile[d]	Mean	99th Percentile[d]	Mean	99th Percentile[d]
0: Pre-Launch[h]	Very Unlikely ($6.2x10^{-5}$)	0.14	2.4	0.20	4.7	7.4	180	0.00076	0.00
1: Early Launch[h]									
On-Pad Explosion	Very Unlikely ($3.2x10^{-5}$)	0.36	8.1	1.1	21	140	2,200	0.025	0.58
FSII	Extremely Unlikely ($8.8x10^{-7}$)	1.2	26	7.0	130	660	6,400	0.12	1.7
Stage 2/SV	Very Unlikely ($1.6x10^{-5}$)	0.39	6.2	1.7	22	260	4,300	0.042	0.85
SVII	Extremely Unlikely ($8.8x10^{-7}$)	0.19	3.6	0.61	9.4	88	1,400	0.017	0.42
Low Altitude FTS	Unlikely ($8.5x10^{-4}$)	0.19	2.9	0.47	6.2	73	940	0.013	0.27
Overall Phase 1	Unlikely ($8.9x10^{-4}$)	0.21	4.1	0.52	7.1	79	1,200	0.014	0.32
2: Late Launch	Very Unlikely ($2.6x10^{-6}$)	0.048	1.3	0.017	0.39	25	410	0.010	0.27
3: Suborbital	Very Unlikely ($7.3x10^{-6}$)	2.4	55	0.32	4.1	76	970	0.0049	0.065
4: Orbital	Very Unlikely ($6.6x10^{-5}$)	1.6	19	0.14	2.7	5.9	52	0.0058	0.10
5: Long-term Reentry	Very Unlikely ($8.5x10^{-6}$)	1.0	19	0.068	1.3	4.9	41	0.0048	0.068
Overall Mission[i]	**Unlikely ($1.0x10^{-3}$)**	**0.31**	**5.8**	**0.47**	**6.8**	**69**	**1,000**	**0.012**	**0.28**

Source: (SNL 2019)

Notes:

Differences in multiplications and summations are due to rounding of results as reported in the 2019 NRA Update. Probability categories (e.g., unlikely, very unlikely) are as defined by NASA.

(a) The table presents the results for the Atlas V 541 as reported in the 2019 NRA Update.

(b) Per launch attempt.

(c) Based on ISCOR-60 modeling of age and organ-specific doses from exposure to plutonium.

(d) The 99th percentile values would be expected to occur at a probability of about 100 times lower than the mean probability of release.

(e) Based on ISCOR-60 modeling of health effects based on organ-specific doses from exposure to plutonium.

(f) Land area contaminated above 0.2 $\mu Ci/m^2$; 1 km^2 = 0.386 mi^2.

(g) Cropland area exceeding Food and Drug Administration Derived Intervention Level, which is approximately 7.3 $\mu Ci/m^2$ (per the 2019 NRA Update).

(h) Accidents during these launch phases are relevant to a region of influence associated with the United States. Accidents during subsequent launch phases would be associated with a region of influence considered outside the United States as the "global environment" because these launch phases occur outside the jurisdiction of the United States.

(i) Overall mission values weighted by total probability of release for each mission phase.

Key: $\mu Ci/m^2$ = microcuries per square meter; FSII = full stack intact impact (the entire launch vehicle impacts the ground); ISCOR = Interagency Steering Committee on Radiation; km^2 = square kilometers; Low or High Altitude FTS = flight termination system (the vehicle is destroyed at low or high altitude and debris impacts the ground); mi^2 = square miles; MMRTG = Multi-Mission Radioisotope Thermoelectric Generator; NRA = Nuclear Risk Assessment; rem = roentgen equivalent in man; Stage 2/SV = Stage 2 and space vehicle (the intact Stage 2 and the space vehicle impact the ground); SVII = space vehicle intact impact (the entire space vehicle impacts the ground).

Population Exposures

In the 2014 FEIS, the average health effects for all launch phases and for the overall mission is less than 1. Phase 1 accidents result in an estimated 0.29 mean health effects, the largest average health effects of any phase. The average mission health effects is 0.076.

In this SEIS, the average health effects are larger than predicted in the 2014 FEIS, with the largest increases associated with the phases with the lowest average health effect (e.g., the Phase 1 health effects increased from 0.29 to 0.52). The range of average health effects for the mission phases in this SEIS is much smaller than in the 2014 FEIS, ranging from a low of 0.068 to a high of 0.53 (Phase 1). The largest population dose would be associated with a Phase 1 release. The average mission health effects was calculated to be 0.47.

For each of the analyzed Phase 1 accidents in the 2014 FEIS, the mean expected health effects was also less than 1. This means that, given that any accident occurs, no latent cancer fatalities would be expected.

As in the 2014 FEIS, the 2019 NRA Update analysis shows that the Low Altitude FTS remains the most likely accident scenario, although the probability of this scenario is a factor of 10 higher in the 2019 NRA Update than in the 2014 FEIS. The probability for this unlikely scenario with a release is 8.5×10^{-4} (or 1 in 1,200). Assuming no mitigation actions, such as sheltering and exclusion of people from affected land areas, the 2019 NRA Update predicts that the radiation dose to the potentially exposed population results in less than 1 additional health effect over the long term. The mean estimate for this release scenario is 0.47 health effects, slightly higher than what was calculated for the 2014 FEIS.

In the 2019 NRA Update analysis, the mean health effects for the very and extremely unlikely accidents in Phase 1 and 2 were much higher (by about a factor of 10) than for a Low Altitude FTS accident, which contrasts with the 2014 NRA, where the mean health effects for the very and extremely unlikely accidents in Phase 1 and 2 were about the same as a Low Altitude FTS accident. Assuming no mitigation actions (e.g., sheltering), estimated mean health effects in the 2019 NRA Update range from a low of less than 0.2 to a high of 7 (from an FSII accident). The probability of release that results in an estimated 7 latent cancer fatalities has a probability of 1 in 1,100,000.

Impacts of Radiological Releases on the Environment

The 2019 NRA Update uses the same methodology to assess impacts to the environment as the 2014 FEIS, which is described in Section 4.4 of the 2014 FEIS. (Models used to implement the methodology were updated after the 2014 FEIS.)

Potential environmental contamination was evaluated in terms of:

- areas that may potentially exceed various screening levels and dose rate–related criteria considered in evaluating the need for land cleanup following potential radioactive contamination; and

- areas exceeding FDA guidelines for food contamination.

These two measures of environmental contamination serve two different purposes. Estimates of potential land areas affected are intended to identify areas where additional actions may be required to protect the public in the affected ROI. As discussed below, areas contaminated below the screening level are assumed not to require any cleanup. Any actions to address areas contaminated above this level would be determined through an assessment performed in response to an accident. Estimates of potential land area affected above the FDA guidelines are intended to identify crops for which additional action may need to be taken to protect the public at large. Actions required to address potential cropland impacts would also be performed in response to an accident.

The results from the 2014 FEIS and 2019 NRA Update are summarized in Table 3.5-3 and Table 3.5-4. The 2019 NRA Update shows that the intentional destruction of all the vehicle stages (i.e., the most likely type of launch area accident with a release), would require further evaluation of an area about 73 km^2 (28 mi^2) in size to determine the extent of land area potentially exceeding 0.2 μCi/m^2. This value is about a factor of 10 higher than calculated in the 2014 FEIS. However, this value is not based on a regulatory limit and was only included for comparison. The 2019 NRA Update also shows that in at least one very unlikely ground impact configuration, an FSII with a total estimated probability of 8.8×10^{-7} (1 in 1,100,000), a mean area of 660 km^2 (about 260 mi^2) could potentially exceed 0.2 μCi/m^2 and would thus require additional evaluation. While this is about a factor of 50 higher than the value from the 2014 FEIS, the probability of this land area being affected is lower than previously estimated. Detectable levels below 0.2 μCi/m^2 would be expected over an even larger area.

There may be some land areas that would potentially need further action, such as monitoring or cleanup.

The FDA has established DILs (i.e., Derived Intervention Levels) (FDA 1998) designed to limit the dose to an individual from consuming contaminated foodstuffs. These DILs identify recommended levels of contamination above which individuals consuming the contaminated foodstuffs would receive an unacceptable dose. The DIL varies depending upon the receptor (the individual consuming the foodstuffs) primarily based upon the age of the individual. In the case of plutonium-238, the limiting DIL (i.e., the highest allowable concentration) of 7.3 μCi/m^2 was selected by DOE (SNL 2019).

For the 2019 NRA Update, DOE performed an analysis to determine the extent of cropland that could be affected in excess of this DIL. The results of that analysis show that for all phases and for all accidents, the potential area affected above the DIL is consistently more than 1,000 times lower than (less than 0.1 percent) the area potentially exceeding the 0.2 μCi/m^2 level, as shown in Table 3.5-3. For example, in assessing a Phase 1 accident with Low Altitude FTS (the most probable Phase 1 accident), DOE calculated that the DIL value of 7.3 μCi/m^2 would be exceeded in an area of 0.013 km^2 (0.005 mi^2 or about 3.2 acres) (SNL 2019); this area would require further evaluation to determine the scope of potential impacts. This is the mean value for the cropland area where some mitigation measures could be required to limit the public health impact from the consumption of food contaminated by a release from this accident. This value is about 0.02 percent of the calculated potentially affected land area using the 0.2 µCi/m^2 value.

3.5.2.2.6 Mission Risks

Summaries of the mission risks as calculated for the 2014 FEIS and this SEIS are presented in Table 3.5-5. As in the 2014 FEIS, "risk" is defined as the expectation of health effects in a statistical sense (i.e., the product of total probability times the mean health effects resulting from a release, and then summed over all conditions leading to a release). The risk of health effects in the potentially exposed populations is determined for each mission phase and the overall mission.

Table 3.5-5. 2014 FEIS and 2019 NRA Update Summary of MMRTG Mean Health Effect Mission Risks

Mission Phase[a]	2014 FEIS			2019 NRA Update		
	Total Probability of a Release[b]	Mean Health Effects (given a release)	Mission Risks	Total Probability of a Release[b]	Mean Health Effects (given a release)	Mission Risks
0: Pre-Launch[c]	Very Unlikely ($1.1x10^{-5}$)	0.0014	$1.5x10^{-8}$	Very Unlikely ($6.2x10^{-5}$)	0.20	$1.2x10^{-5}$
1: Early Launch[c]	Very Unlikely ($8.8x10^{-5}$)	0.29	$2.5x10^{-5}$	Unlikely ($8.9x10^{-4}$)	0.52	$4.7x10^{-4}$
2: Late Launch	Very Unlikely ($7.7x10^{-6}$)	$7.8x10^{-5}$	$6.0x10^{-10}$	Very Unlikely ($2.6x10^{-6}$)	0.017	$4.3x10^{-8}$
3: Suborbital	Very Unlikely ($1.5x10^{-5}$)	0.20	$3.0x10^{-6}$	Very Unlikely ($7.3x10^{-6}$)	0.32	$2.4x10^{-6}$
4: Orbital	Unlikely ($2.6x10^{-4}$)	0.0026	$6.8x10^{-7}$	Very Unlikely ($6.6x10^{-5}$)	0.14	$9.1x10^{-6}$
5: Long-term Reentry	Extremely Unlikely ($9.4x10^{-8}$)	0.0038	$3.6x10^{-10}$	Very Unlikely ($8.5x10^{-6}$)	0.068	$5.8x10^{-7}$
Overall Mission	**Unlikely ($3.8x10^{-4}$)**	**0.076**	**$2.9x10^{-5}$**	**Unlikely ($1.0x10^{-3}$)**	**0.47**	**$4.9x10^{-4}$**

Sources: (SNL 2019, NASA 2014)

Notes:

Differences in multiplications and summations are due to rounding of results.

Probability categories (e.g., unlikely, very unlikely) are as defined by NASA.

(a) For the 2014 FEIS results, this table presents a composite of the results for the Atlas V 551 and the Delta IV Heavy, which were used for the 2014 FEIS, determined by taking the probability-weighted value of the two sets of results, treating the conditional probability of having a given launch vehicle as 0.5. Accident probabilities are the average of individual values for the two vehicles. Based on the current state of knowledge, the specific accident probabilities for the accident conditions for each vehicle are expected to be similar. For the 2019 NRA Update, this table presents the results for the Atlas V 541.

(b) Per launch attempt.

(c) Accidents during these launch phases are relevant to a region of influence associated with the United States. Accidents during subsequent launch phases would be associated with a region of influence considered outside the United States as the "global environment" as well as within the United States because these launch phases occur outside the jurisdiction of the United States.

Key: FEIS = Final Environmental Impact Statement; MMRTG = Multi-Mission Radioisotope Thermoelectric Generator; NRA = Nuclear Risk Assessment.

Since the health effects resulting from a release equals the sum of the probability of a health effect for each individual in the exposed population, risk can also be interpreted as the total probability of one health effect, given the mission.

The overall radiological risk for the Mars 2020 mission is estimated to be 4.9×10^{-4}, based on the 2019 NRA Update. Thus, the total probability of one health effect for the Proposed Action is about 1 in 2,000, approximately 20 times higher than estimated in the 2014 FEIS. The increase in risk is primarily attributable to the increase in the risk of Phase 1 accidents.

The risk contribution from Phase 1 accidents, 4.7×10^{-4} (or a probability of about 1 in 2,100 that a health effect will occur), represents 96 percent of the radiological risk for the Mars 2020 mission, a higher percentage than presented in the 2014 FEIS. The primary contributors to the Phase 1 risk in order of significance are 1) Low Altitude FTS, 2) On-Pad Explosion, and 3) Stage2/SVII. While the absolute value of the risk from other phases also increased between the 2014 and 2019 analyses, no other phase contributes more than 2 percent to the overall risk.

The contributions to risk within 100 km (62 mi) of the launch site and in the global area are summarized in Table 3.5-6. Due to the increase in the Phase 1 contribution to risk in the 2019 NRA Update, the launch area risk is about 67 percent of the overall mission risk (compared to the estimate of 57 percent in the 2014 FEIS), while the risk to global areas is 33 percent. The launch area risks are due entirely from accidents during Phases 0 and 1, with Phase 1 being the primary contributor. The global risks are due to accidents in all mission phases, with Phase 1 being the primary contributor due to the atmospheric transport of small particles beyond 100 km (62 mi) from the launch site.

Table 3.5-6. 2014 FEIS and 2019 NRA Update MMRTG Health Effect Mission Risk Contributions by Affected Region

Mission Phase[a]	2014 FEIS			2019 NRA Update		
	Launch Area Mission Risk[b]	Global Area Mission Risk[c]	Total	Launch Area Mission Risk[b]	Global Area Mission Risk[d]	Total
0: Pre-Launch	8.9×10^{-9}	5.9×10^{-9}	1.5×10^{-8}	8.3×10^{-6}	3.9×10^{-6}	1.2×10^{-5}
1: Early Launch	1.7×10^{-5}	8.9×10^{-6}	2.5×10^{-5}	3.2×10^{-4}	1.5×10^{-4}	4.7×10^{-4}
2: Late Launch	—	6.0×10^{-10}	6.0×10^{-10}	3.0×10^{-8}	1.3×10^{-8}	4.3×10^{-8}
3: Suborbital	—	3.0×10^{-6}	3.0×10^{-6}	5.0×10^{-10}	2.4×10^{-6}	2.4×10^{-6}
4: Orbital	—	6.8×10^{-7}	6.8×10^{-7}	—	9.1×10^{-6}	9.1×10^{-6}
5: Long-term Reentry	—	3.6×10^{-10}	3.6×10^{-10}	—	5.8×10^{-7}	5.8×10^{-7}
Overall Mission	1.7×10^{-5}	1.3×10^{-5}	2.9×10^{-5}	3.3×10^{-4}	1.6×10^{-4}	4.9×10^{-4}

Sources: (NASA 2014, SNL 2019)
Notes:
Differences in summations may be due to rounding.
(a) For the 2014 FEIS, this table presents a composite of the results for the Atlas V 551 and the Delta IV Heavy, which were used for the 2014 FEIS, determined by taking the probability-weighted value of the two sets of results, treating the conditional probability of having a given launch vehicle as 0.5. For the 2019 NRA Update, this table presents results for the Atlas V 541.
(b) Phases 0 and 1: within 100 kilometers (62 miles) of the launch site.
(c) Phase 3: southern Africa; Phase 4: land impacts between 29° north and 29° south latitude.
(d) Phase 3: southern Africa; Phase 4: land impacts between 35° north and 35° south latitude.
Key: FEIS = Final Environmental Impact Statement; MMRTG = Multi-Mission Radioisotope Thermoelectric Generator; NRA = Nuclear Risk Assessment.

Individual Risks (Maximum Exposed Individual)

Individual risk from the Mars 2020 mission can be interpreted as the probability of a particular individual in the exposed population incurring a fatal cancer over 50 years. For an accident near the launch site, not everyone within the regional area would be expected to receive a dose as a result of the accident. Due to meteorological conditions prevailing at the time of launch, only a portion of the total regional population is estimated to receive some measurable radiological exposure if an accident occurs.

Even individuals within the exposed population, such as those very close to the launch area that might receive the highest exposures, would face very small risks. The risk to the maximally exposed individual (Table 3.5-7) is estimated to be less than 1 in 9 million for the Mars 2020 mission, based on the results of the 2019 NRA Update compared to the less than 1 in 300 million estimate from the 2014 FEIS. Most people in the potentially exposed population would have much lower risks.

Table 3.5-7. MMRTG Maximum Individual Risk

Mission Phase[(a)]	2014 FEIS			2019 SEIS		
	Release Probability[(b)]	Maximum Individual Dose (rem)	Maximum Individual Risk[(c),(d)]	Release Probability[(b)]	Maximum Individual Dose (rem)	Maximum Individual Risk[(c),(d)]
0: Pre-Launch[(e)]	Very Unlikely ($1.1x10^{-5}$)	0.00029	$1.9x10^{-12}$	Very Unlikely ($6.2x10^{-5}$)	0.14	$5.0x10^{-9}$
1: Early Launch[(e)]	Very Unlikely ($8.8x10^{-5}$)	0.060	$3.2x10^{-9}$	Unlikely ($8.9x10^{-4}$)	0.21	$1.1x10^{-7}$
2: Late Launch	Very Unlikely ($7.7x10^{-6}$)	$1.6x10^{-5}$	$7.6x10^{-14}$	Very Unlikely ($2.6x10^{-6}$)	0.048	$7.4x10^{-11}$
3: Suborbital	Very Unlikely ($1.5x10^{-5}$)	0.043	$3.8 x10^{-10}$	Very Unlikely ($7.3x10^{-6}$)	2.4	$1.0 x10^{-8}$
4: Orbital	Unlikely ($2.6x10^{-4}$)	0.0005	$8.5 x10^{-11}$	Very Unlikely ($6.6x10^{-5}$)	1.6	$6.3 x10^{-8}$
5: Long-term Reentry	Extremely Unlikely ($9.4x10^{-8}$)	0.0008	$4.5 x10^{-14}$	Very Unlikely ($8.5x10^{-6}$)	1.0	$5.1 x10^{-9}$

Sources: (NASA 2014, SNL 2019)

Notes:

Probability categories (e.g., unlikely, very unlikely) are as defined by NASA.

(a) For the 2014 FEIS, this table presents a composite of the results for the Atlas V 551 and the Delta IV Heavy, which were used for the 2014 EIS, determined by taking the probability-weighted value of the two sets of results, treating the conditional probability of having a given launch vehicle as 0.5. For the 2019 NRA Update, this table presents results for the Atlas V 541.

(b) Per launch attempt.

(c) Determined as the product of total probability of release, maximum individual dose (mean value), and a health effects estimator of $6 x 10^{-4}$ latent cancer fatalities per rem.

(d) The individuals associated with the maximum individual risk in Phases 0 and 1 are assumed to be the same individual, so the two risks are additive. The individuals associated with the maximum individual risk in Phases 3, 4, and 5 would not be the same individual due to different global regions potentially affected.

(e) Accidents during these launch phases are relevant to a region of influence associated with the United States. Accidents during subsequent launch phases would be associated with a region of influence considered outside the United States as the "global environment" because these launch phases occur outside the jurisdiction of the United States.

Key: FEIS = Final Environmental Impact Statement; MMRTG = Multi-Mission Radioisotope Thermoelectric Generator; NRA = Nuclear Risk Assessment; rem = roentgen equivalent in man; SEIS = Supplemental Environmental Impact Statement.

The revised individual risk estimates, based on the 2019 NRA Update, are still small compared to other risks. These risk estimates are lifetime risks. Data show that in 2017, the average annual individual risk of accidental death in the United States was about 1 in 1,900 per year, while the average individual risk of death due to any disease, including cancer, was about 1 in 150 per year (more detail is presented in Appendix A, Health and Safety Supporting Information, of this SEIS).

3.5.2.2.7 Uncertainty

An uncertainty analysis to estimate uncertainties in probabilities, source terms, radiological consequences, and mission risks has been performed and used in the 2019 NRA Update. The uncertainty in the risk values is a function of the uncertainty in accident probabilities, conditional release probabilities, and the probability of a consequence, given a release. Two measures of uncertainty help to describe the uncertainty associated with the mission risk estimates.

The mean values provided in this document are values in a probability distribution and are used to express “best value” mission risks. Additional points in the distribution, the 95th and 5th percentiles, provide information that help to describe the variability in the risk estimate.

Based on experience with analyses in the risk assessment of previous missions (e.g., for the Cassini, Mars Exploration Rover, New Horizons, and Mars Science Laboratory missions), this uncertainty in the estimated mission risk for the Mars 2020 mission can be approximated. The safety and risk analyses for those missions indicate that the uncertainty is dominated by the uncertainty associated with the launch vehicle accident probabilities. The 5th and 95th percentile accident probabilities are about a factor of 25 lower and higher, respectively, than the accident median probabilities.

The Mars 2020 mission health effect risk estimate from the 2019 NRA Update of 4.9×10^{-4} (or a probability of about 1 in 2,000 that a health effect would occur) can be treated as the median of the uncertainty probability distribution (i.e., it is equally probable that the mission health effect risk could be higher or lower than this value). Applying the factor of 25 from the accident median probabilities, the mission risks at the 5th and 95th percent confidence levels are then estimated to be 2.0×10^{-5} (or a probability of about 1 in 50,000 that a health effect would occur) and 1.2×10^{-2} (or a probability of about 1 in 80 that a health effect would occur), respectively. These high and low values of this uncertainty range are about an order of magnitude (approximately 10 times) higher than that identified in the 2014 FEIS.

Uncertainty limits provide insight into how precisely the accident risks can be estimated. While the uncertainty described above deals with the distribution of risk estimates associated with an estimated mean, there is also uncertainty associated with the mean value itself. The 90 percent uncertainty interval around the mean mission risk (human health and land contamination) was calculated. With the 90 percent uncertainty interval, most estimates of the mean are believed to lie between two values; the estimate of the mean is less than the lower limit 5 percent of the time, between the two values 90 percent of the time, and above the upper limit 5 percent of the time.

For this analysis, these uncertainty limits are based on the mean human health risk values of 4.9 x 10^{-4} with a land contamination risk of 0.072 km^2 (0.028 mi^2). The lower and upper bounds of the 90 percent uncertainty interval for human health mission risk are 2.2 x 10^{-4} (the mean estimate would be below this value 5 percent of the time) and 1.2 x 10^{-3} (the mean estimate would be above this value 5 percent of the time), respectively. The lower and upper bounds of the 90 percent uncertainty interval for mission land contamination risk are 0.032 km^2 (0.012 mi^2) and 0.18 km^2 (0.07 mi^2), respectively. The uncertainty in the overall mission health effect risk is dominated by the uncertainty in the probability of an accident.

3.5.2.3 Radiological Contingency Response Planning

NASA's Radiological Contingency Response Planning would remain similar to what was described in the 2014 FEIS. But due to the increase in the area potentially impacted by a launch accident, NASA would coordinate with a larger number of county and local entities. In addition to Brevard County, NASA would coordinate with appropriate agencies in Flagler, Indian River, Lake, Orange, Osceola, Polk, Seminole, and Volusia Counties.

NASA's plans would be developed under the NRF (DHS 2016a) and the NRF Nuclear/Radiological Incident Annex (DHS 2016b) in coordination with DOE and other Federal agencies, the State of Florida, the potentially affected counties, and local governmental organizations. The NRF Annex provides the nationwide framework for radiological response planning.

3.6 LAND USE

This section corresponds to Section 3.1.1 of the 2014 FEIS. It briefly describes KSC and CCAFS and nearby surrounding areas but focuses on overall land use and management of a larger nine-county area where mission-related impacts could occur. This area includes Brevard, Flagler, Indian River, Lake, Orange, Osceola, Polk, Seminole, and Volusia Counties.

3.6.1 Affected Environment

The 2014 FEIS examined the effects of the Mars 2020 mission on land use in and immediately around CCAFS and KSC. Section 3.1.1 of the 2014 FEIS describes the land use and administration of these areas. For more information about land use and recreation at KSC and the surrounding area, see the *KSC Center-wide Operations Master Plan Programmatic Final Environmental Impact Statement* (NASA 2016).

Changes to ROI Since 2014 FEIS

As shown in Figure 3.6-1, CCAFS is located on the east coast of Florida in Brevard County on a barrier island called the Canaveral Peninsula. The installation is bounded on the west by the Banana River, on the north by KSC, on the east by the Atlantic

Ocean, and on the south by Port Canaveral. CCAFS encompasses an area of about 63.9 km^2 (15,800 acres; 24.7 mi^2) (NASA 2014). The area is subdivided into various mission-related uses. The land is managed by the USAF 45th Space Wing, primarily to support the operational mission (NASA 2014). The uses and administration are essentially unchanged from the description in the 2014 FEIS.

Launch operations at CCAFS are arranged along the Atlantic Ocean shoreline, with launch and range support immediately adjacent to the west. The area to the west of the launch areas is divided by the airfield into southern and northern portions. A port area with commercial and industrial uses occupies the southern portion. The northern portion has a mixture of industrial, administrative, range support, and recreation areas interspersed with open space. There are no public beaches on CCAFS. The Mars 2020 launch would occur at the north end of CCAFS at site SLC-41 (NASA 2014).

KSC is located on the east coast of Florida in Brevard County on the north end of Merritt Island adjacent to Cape Canaveral. KSC is bordered on the west by the Indian River and on the east by the Atlantic Ocean and CCAFS. The northernmost end of the Banana River separates Merritt Island and CCAFS and is included as part of KSC submerged lands. More detailed description of land use and management on KSC is provided in the *KSC Center-wide Operations Master Plan Programmatic Final Environmental Impact Statement*, Section 3.11 (NASA 2016).

At KSC, a small portion of the land is developed for industrial and operational functions, and most of the land is in a natural, undeveloped state. NASA manages the developed areas that support its mission. Most of KSC land provides an open space buffer for the space mission and includes the Merritt Island National Wildlife Refuge, created by an agreement with the U.S. Fish and Wildlife Service (USFWS) in 1972. Public Law 93-626 designated the Canaveral National Seashore, leading to an agreement with the Department of the Interior in 1975 for Canaveral National Seashore land within KSC. Public access to much of this land is managed by the USFWS and the National Park Service. Visitation fluctuates due to variations in weather and other factors, but hovers around 1 million visitors annually to both Merritt Island National Wildlife Refuge and Canaveral National Seashore (NASA 2016).

Land areas immediately surrounding KSC include a seaport, recreation and wildlife management areas, agricultural land, and two major municipal areas within 10 miles of KSC operational areas: the cities of Titusville and Cape Canaveral (NASA 2016).

The land area beyond KSC and CCAFS potentially influenced by the Mars 2020 launch event includes portions of nine counties: Brevard, Indian River, Osceola, Orange, Seminole, and Volusia Counties, and more peripherally, Flagler, Lake, and Polk Counties. Figure 3.6-2 presents the generalized land use in this area of interest. The nine-county area encompasses almost 23,750 km^2 (9,170 mi^2). It includes 13 cities and census-designated places with populations over 50,000 (see Figure 3.6-2), the largest being Orlando in Orange County, with a population of about 270,000.

This region in east central Florida is a mixture of developed and natural/undeveloped land. Broadly speaking, the far eastern coastline includes barrier islands and intercoastal waterway with beaches, small communities, industrial activities, conservation areas, and military land (including CCAFS and Patrick AFB). Immediately to the west is the mainland shoreline with a combination of developed areas interspersed with rural agricultural land and conservation land. To the west of the coastal land is a broad north/south band of marshland, upland forests, lakes, and wetland with interspersed agriculture and pockets of development. Further west and north (of CCAFS and KSC) is a highly developed urbanized band stretching from Daytona Beach in Volusia County to Kissimmee in Osceola County.

The rest of the interior land is a mix of urban, suburban, and rural agricultural land, with pockets of forest and marsh. A generalized categorization of the land use in the nine-county area is presented in Table 3.6-1, urban areas support a range of land development for residential, industrial, commercial, industrial, institutional, conservation, recreation, and public infrastructure use. The developed footprint in the nine-county area is about 17 to 20 percent (Table 3.6-1).

Table 3.6-1. Generalized Land Use/Land Cover in the Nine-County Region

Land Use Category[a]	Area (square kilometers)	Percent of Total
Agricultural[b]	8,472	36%
Industrial	177	1%
Institutional[c]	153	1%
Mining	791	3%
Public/Semi-Public[d]	6,550	28%
Recreation[e]	836	4%
Residential	3,075	13%
Retail/Office[f]	398	2%
Right-of-Way[g]	22	0%
Vacant Non-Residential	436	2%
Vacant Residential	1,001	4%
Water[h]	98	0%
Undefined[i]	1,460	6%
Total	**23,469**	**100%**

Source: (FGDC 2018a)

Notes:

(a) Land use categories derived from 99 categories in source data.
(b) Agricultural land includes crops, timberland, grazing land, dairies, and ornamental/floriculture uses.
(c) Institutional includes schools, private hospitals, clubs, cultural organizations, colleges, and military uses.
(d) Public and semi-public land includes public hospitals and government-owned lands, such as municipal, county, state, and Federal land (most of which is open undeveloped land reserved for conservation, recreation, and other public uses).
(e) Recreation land includes forest, park, and outdoor recreational areas (non-commercial).
(f) Retail/office includes mixed use areas, shopping areas, offices, outdoor commercial recreation, services, airports terminals and marinas, night clubs, auditoriums, tourist attractions, private camp sites, animal race tracks, hotels, and restaurants.
(g) Right-of-way is land used for streets, roads, and canals.
(h) Water includes lakes, rivers, and submerged lands.
(i) Undefined is composed of land categorized as “acreage not zoned for agriculture” and “parcels with no value.”

The population in the nine-county area is about 4.6 million (USCB 2017a). The population fluctuates somewhat due to the seasonal influx of “snowbirds,” seeking warmer winter weather, and the popularity of the region for vacationing year-round. The area hosts a high number of visitors and tourists attracted by the vacation opportunities along the ocean and abundant businesses catering to outdoor recreation. Large numbers of visitors are drawn by major attractions such as Walt Disney World in Orlando, numerous other theme parks and resorts, the Monument of States historical site near Kissimmee in Osceola County, and Brevard County attractions such as the KSC visitor center and cruise terminals at the port (NPS 2014).

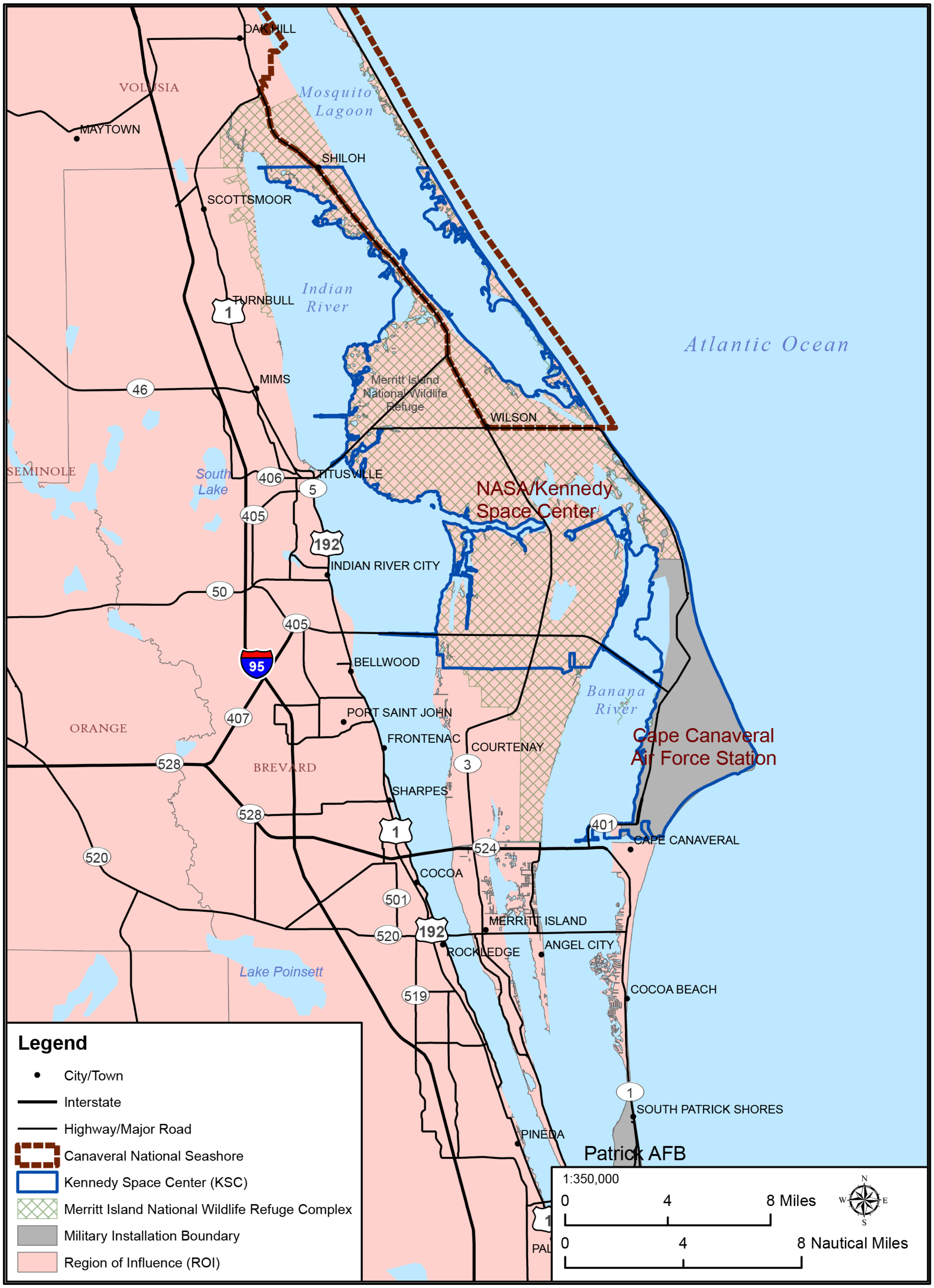


Figure 3.6-1. General Land Use and Administration at KSC and CCAFS

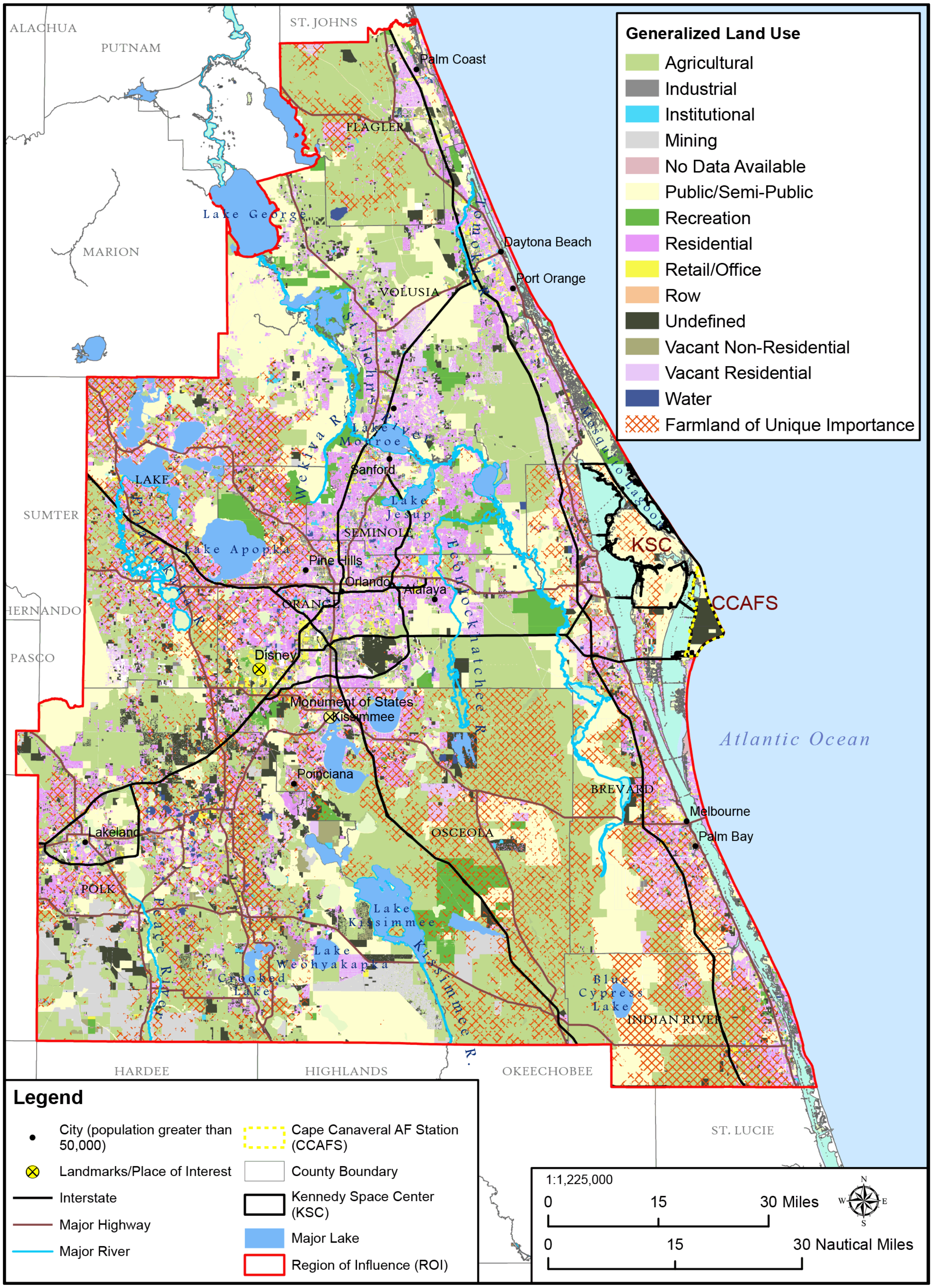


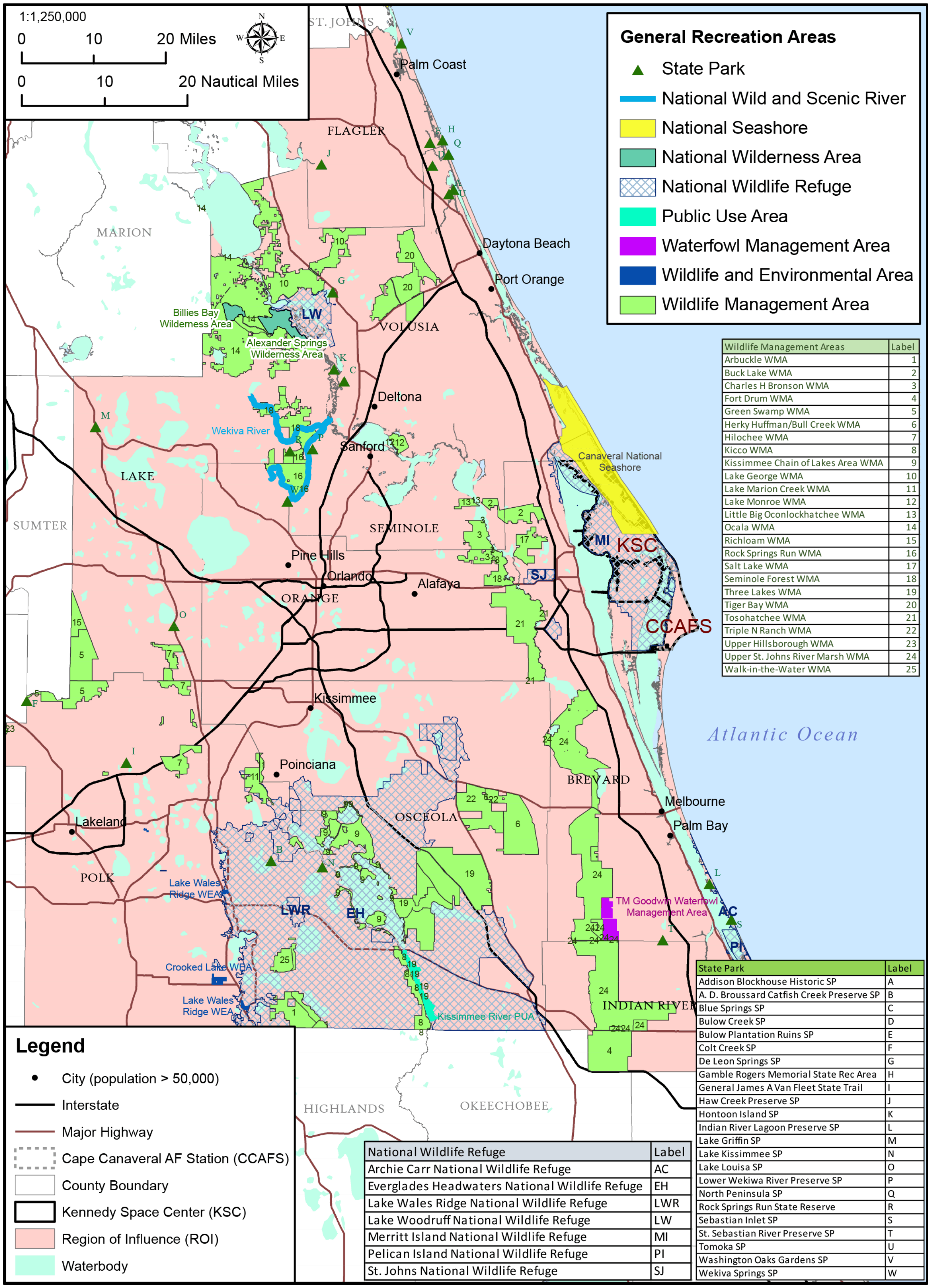
Figure 3.6-2. General Land Use in the Nine-County Region

Agriculture is a major industry in the nine-county region, with about 36 percent of the land area (almost 8,500 km^2) dedicated to a broad spectrum of agricultural products (see Table 3.6-1). Information from the Purdue University Center for New Crops and Plant Products (CNCPP) shows that citrus growing is extensive in Polk, Lake, and Indian River Counties, and nursery products grown under glass occupy large areas in Volusia, Lake, Polk, Orange, and Seminole Counties (CNCPP 2019). Some of the counties specialize in particular vegetables, citrus types (oranges, lemons, tangerines, grapefruit, limes), or small fruits (CNCPP 2019). About 5,408 km^2 (2,088 mi^2) (31 percent) of the nine-county area consists of farmland of unique importance (Natural Resources Conservation Service 2019). Unique farmland is land other than prime farmland that is used for the production of specific high-value crops. No prime or unique farmland is present at CCAFS (NASA 2014).

The Florida coastal areas provide a variety of opportunities for outdoor recreation. The Merritt Island National Wildlife Refuge and Canaveral National Seashore (both discussed in detail in Section 3.1.5 of the 2014 FEIS) have around 1 million visitors annually, with some fluctuation. In addition, the nine-county area has substantial amounts of public land designated for conservation and/or recreational use, including: two national wilderness areas, one national seashore, seven national wildlife refuges, 22 state parks, 25 state wildlife management areas, one waterfowl management area, one fish management area, two wildlife and environmental areas, and one national Wild and Scenic River (see Figure 3.6-3) (FGDC 2017, FGDC 2018b, FGDC 2019, USFS 2019a, USFS 2019b).

Together these areas cover about 6,800 km^2 (2,626 mi^2) (almost 30 percent of the nine-county area). These resources are extensively used by local residents and non-local visitors for fishing, boating, viewing nature, hiking and camping, beachcombing and treasure hunting, and many other outdoor sports, both natural-based and commercialized. These activities and the spending generated by them are an important part of the regional economy (see Section 3.12, Socioeconomics and Children's Environmental Health and Safety).

Each of the nine counties has a planning office and process for developing a future land use map that incorporates local goals. The plans reflecting these goals have been developed at different times and some are currently being updated. County governments also have active emergency management services, mostly focused on hurricane and weather events. Nonetheless, this translates into a widespread system, with various channels for communicating to the public about disasters and events that threaten the safety of persons and property. Brevard County, having both KSC and CCAFS within its boundaries, has a highly developed relationship with NASA and the USAF for alerting the public about future and ongoing launch events. The Brevard County Emergency Management website already is notifying the public that the Mars 2020 launch is anticipated for next summer. Preparedness for responding to accidents involves the U.S. Coast Guard, NASA, DOE, DHS, and other organizations that are needed in post-accident situations. All of this supports the ongoing feasibility of the land uses and inhabitation of this diverse and popular area. Additional information about emergency management is provided in Section 3.12 (Socioeconomics and Children's Environmental Health and Safety, Public and Emergency Systems) of this SEIS.



Wildlife Management Areas	Label
Arbuckle WMA	1
Buck Lake WMA	2
Charles H Bronson WMA	3
Fort Drum WMA	4
Green Swamp WMA	5
Herky Huffman/Bull Creek WMA	6
Hilochee WMA	7
Kicco WMA	8
Kissimmee Chain of Lakes Area WMA	9
Lake George WMA	10
Lake Marion Creek WMA	11
Lake Monroe WMA	12
Little Big Oconlockhatchee WMA	13
Ocala WMA	14
Richloam WMA	15
Rock Springs Run WMA	16
Salt Lake WMA	17
Seminole Forest WMA	18
Three Lakes WMA	19
Tiger Bay WMA	20
Tosohatchee WMA	21
Triple N Ranch WMA	22
Upper Hillsborough WMA	23
Upper St. Johns River Marsh WMA	24
Walk-in-the-Water WMA	25

State Park	Label
Addison Blockhouse Historic SP	A
A. D. Broussard Catfish Creek Preserve SP	B
Blue Springs SP	C
Bulow Creek SP	D
Bulow Plantation Ruins SP	E
Colt Creek SP	F
De Leon Springs SP	G
Gamble Rogers Memorial State Rec Area	H
General James A Van Fleet State Trail	I
Haw Creek Preserve SP	J
Hontoon Island SP	K
Indian River Lagoon Preserve SP	L
Lake Griffin SP	M
Lake Kissimmee SP	N
Lake Louisa SP	O
Lower Wekiwa River Preserve SP	P
North Peninsula SP	Q
Rock Springs Run State Reserve	R
Sebastian Inlet SP	S
St. Sebastian River Preserve SP	T
Tomoka SP	U
Washington Oaks Gardens SP	V
Wekiva Springs SP	W

National Wildlife Refuge	Label
Archie Carr National Wildlife Refuge	AC
Everglades Headwaters National Wildlife Refuge	EH
Lake Wales Ridge National Wildlife Refuge	LWR
Lake Woodruff National Wildlife Refuge	LW
Merritt Island National Wildlife Refuge	MI
Pelican Island National Wildlife Refuge	PI
St. Johns National Wildlife Refuge	SJ

Figure 3.6-3. Parks, Monuments, and Protected Areas in the Nine-County Area

3.6.2 Environmental Consequences

3.6.2.1 No Action Alternative

Under the No Action Alternative, the Mars 2020 mission would not take place. There would be no potential for a radiological accident as described in Chapter 2 (Description and Comparison of Alternatives) of this SEIS. No impacts on land use would occur.

3.6.2.2 Proposed Action

This section covers the potential impacts on land use from an accident involving release of radiological material during the Mars 2020 mission. Impacts on persons and businesses are addressed in Sections 3.5 (Health and Safety) and 3.12 (Socioeconomics and Children's Environmental Health and Safety).

Land use impacts result if an action displaces or degrades an ongoing or planned use of land for a specific purpose, reflective of its attributes for that use. The analysis considered 1) the value of the land resource, given its prevalence in the region, 2) the relative quality or uniqueness of the resource in the region, and 3) the duration of any loss of use or attributes. The area considered in the analysis encompasses nine counties that are wholly or partially within a radial distance of 100 km (62 mi) to the CCAFS launch site for the Mars 2020 mission. This area covers about 23,500 km^2 (9,073 mi^2) (see Table 3.6-1).

Estimated spatial dispersion of radiological contamination levels within the nine-county area would depend on specifics of the accident, launch phase, weather, and wind conditions at the time of the event. As described in Section 3.5 (Health and Safety), using the screening level of 0.2 μCi/m^2, an area of radiological deposition could occur within an area encompassing up to 79 km^2 (31 mi^2), depending on the stage and type of the launch accident. Should such an unlikely event occur, that area would be subject to further evaluation. Land areas impacted at levels above recommended exposure levels would potentially need further action, such as monitoring or cleanup (see Section 3.5). This conservative exposure level assumes that any exposed areas below this level would not require cleanup for any type of land use.

The 2019 NRA Update used a screening level of 7.3 μCi/m^2 for cropland to ensure that contaminated food products would not endanger public health and safety. Applying this screening criterion, the average predicted amount of cropland that would require further evaluation to determine the full scope of potential impacts could encompass between 0.00076 and 0.014 km^2 (0.19 to 3.5 acres); this may include areas of unique farmland depending on the accident and dispersion scenario.

The impact on regional allocation of land use is considered in the context of supply and opportunity for an equivalent land resource within the region. The maximum average predicted area potentially requiring further evaluation (79 km^2 or 31 mi^2) represents about one-third of 1 percent of the entire nine-county area of potential impact; about 2 percent of the residential land (vacant and developed); about 3 percent of the land used for productive and community purposes, including industry, mining, institutions (including hospitals and schools), retail and offices, recreation facilities, and infrastructure right of ways; and about 1 percent of the public/semi-public land (which includes mostly park and conservation land) (see Table 3.6-1) (FGDC 2018a). The average maximum potential evaluation footprint for croplands of 0.014 km^2 (3.5 acres) represents 0.0002 percent of the agricultural land in the nine-county area (FGDC 2018a). These are small fractions of the regional resources for these land use categories. In this context, any displacement or degradation to land use resources would be minimal. For comparative purposes, the temporary or total displacement of residential land within a 79 km^2 (31 mi^2) area would be negligible, considering that the nine-county region has about 1,000 km^2 (386 mi^2) of vacant residential land (see Table 3.6-1). Still, should such an extremely unlikely event occur, affected individuals and families could experience great inconvenience and disruption from extended access restrictions to their homes, neighborhoods, schools, and businesses. The Price-Anderson Act of 1957, as amended (42 U.S.C. 2210), established a system of financial protection for persons who may be injured in the event of a nuclear incident arising out of activities conducted by or on behalf of the DOE. In the case of the Mars 2020 mission, DOE retains title and responsibility for the MMRTG. In the extremely unlikely event that an accident were to occur resulting in release of plutonium dioxide from the MMRTG, affected property owners within or outside the United States would be eligible for compensation for damages to or loss of property or use of property arising from the nuclear incident in accordance with the provisions of the Price-Anderson Act.

If an accident occurs, Federal, state, and local emergency management operations are immediately activated. The location of the accident and potentially affected area is identified and appropriate emergency actions and restrictions are communicated to the public by local emergency planning agencies. Due to the prevalence of hurricanes in the region, an organized and well-equipped emergency response network is in place. Consistent with the 2014 FEIS, the Mars 2020 mission would also have an in-depth emergency response plan in place with clear channels of communication between all levels of government and response providers. These measures help to minimize disaster impacts on people in the area and create pathways for getting recovery efforts underway to restore normal use as soon as possible.

As noted in the 2014 FEIS, following this initial response, NASA would initiate additional surveys and monitoring to characterize the extent and level of any impact. Section 3.5 (Health and Safety) also explains that secondary societal costs associated with decontamination and mitigation activities could involve: temporary or longer term relocation of residents, temporary or longer term loss of employment, destruction of agricultural products, land use restrictions, restrictions or bans on commercial fishing, and public health effects and medical care. Based on land use, cleanup to appropriate end-state conditions would follow. Immediate post-accident measures could prevent access to affected land. This could temporarily displace persons from residential areas and prevent access to areas with a range of developed land uses, including industrial, commercial, institutional, and community-serving activities (such as schools, hospitals, arenas, and exhibition/spectator/entertainment areas). Remediation actions could extend access restrictions for a longer period, precluding use of land during that time. The most likely areas for longer-term restrictions are the most developed land areas where human health risks require the highest level of cleanup.

In general, and consistent with analysis in the 2014 FEIS, the region has diverse land use resource and capacity to absorb the maximum loss of land use displacement or degradation resulting from an accident. Particularly for this SEIS, the potentially affected area represents about one-third of 1 percent of the entire nine-county area of potential impact. However, there would be short- to long-term disruption to some localized areas recovering from an event. For example, specific producers and growers may experience an economic impact if contaminated products are quarantined or destroyed until normal conditions resume. The indirect economic effects from loss of revenues on specific industries, including agriculture, could degrade the conditions needed to use the impacted land. Similarly, if a commercial shopping mall or resort area were affected, long-term closure could cause businesses to abandon the site. Following cleanup, it is expected that redevelopment would take place, for suitable uses based on the cleanup levels. Only in unusual circumstances, cleanup to the level needed for the former use may not be possible. These impacts on local land resources could cause moderate impacts depending on the duration and local prognosis for recovery and Federal assistance.

Some areas have high value for a particular use, due to their intrinsic or societal value, and so are specifically sensitive to degradation. Examples include unique tourist areas, and state and national parks, monuments, seashore, and wildlife areas. An impact that disrupts access to these areas or their environmental qualities for longer periods could have lasting effects. If use is prevented for extended times, it can change the choices people make when selecting areas to use for vacationing and recreation, for example. These areas have distinctive qualities and contribute greatly to the regional economy. Loss or degradation of a special use area would cause anything from a minor to high impact on the particular area affected, due to high land resource value. Remediation or redevelopment could lessen the long-term impact on these special areas.

A radiological accident on land outside of the United States is very unlikely. If it occurred, NASA and the DHS would coordinate the response as described in Section 4.1.5 of the 2014 FEIS. Potential impacts on land use resources could be similar to those described above for the area surrounding CCAFS, although globally, the trajectory would traverse areas that are predominantly oceanic, rural, or sparsely inhabited. In those areas, minimal to no land use impacts are likely. NASA and DHS would assist the Department of State in coordinating the United States' response via diplomatic channels and in deploying Federal resources as requested to mitigate accident damage.

3.7 AIR RESOURCES

3.7.1 Affected Environment

This section corresponds to Section 3.1.2 of the 2014 FEIS. The affected environment, or ROI, consists of counties with areas within 100 km (62 mi) of SLC-41, located in the northernmost section of CCAFS, Brevard County, Florida. The counties that lie within the ROI include Brevard, Indian River, Orange, Osceola, Seminole, and Volusia Counties, as well as small portions of Flagler, Lake, and Polk Counties.

Changes to ROI Since 2014 FEIS

Air Quality

The 2014 FEIS, Section 3.1.2.2, stated that that CCAFS and KSC and the surrounding Brevard County attained all national and state ambient air quality standards. Currently, CCAFS, Brevard County, and all areas within 100 km (62 mi) of SLC-41 attain the National Ambient Air Quality Standards (NAAQS). The Florida Department of Environmental Protection (FDEP) repealed the Florida state ambient air quality standards in 2012 (FDEP 2012) and now only relies on the NAAQS for purposes of regulating air quality within Florida. Since the 2014 FEIS, the EPA revised a few of the NAAQS. Table 3.7-1 presents the current NAAQS.

Emissions estimated for the Proposed Action are compared to emissions developed for the nine-county ROI as part of the EPA's most recent National Emissions Inventory (NEI) effort (EPA 2019a). Table 3.7-2 presents these data, including emissions from point, area, and mobile sources.

Table 3.7-1. National Ambient Air Quality Standards

Pollutant	Average Time	Primary Standard	Secondary Standard
Carbon monoxide	8-hour[(a)] 1-hour[(a)]	9 ppm 35 ppm	N/A N/A
Lead	Rolling 3-Month average	0.15 μg/m^3 [(b)]	0.15 μg/m^3
Nitrogen dioxide	Annual 1-hour[(c)]	0.053 ppm 0.10 ppm	0.053 ppm N/A
Ozone	8-hour[(d)]	0.070 ppm	0.070 ppm
Particulate matter (PM_{10})	24-hour[(e)]	150 μg/m^3	150 μg/m^3
Particulate matter ($PM_{2.5}$)	Annual[(f)] 24-hour[(g)]	12 μg/m^3 35 μg/m^3	15 μg/m^3 35 μg/m^3
Sulfur dioxide	3-hour 1-hour[(h)]	N/A 0.075 ppm	0.5 ppm N/A

Source (EPA 2016)
Notes:
(a) Not to be exceeded more than once per year.
(b) Not to be exceeded.
(c) The 98th percentile of one-hour daily maximum concentrations, averaged over three years.
(d) Annual fourth-highest daily maximum eight-hour concentration, averaged over three years.
(e) Not to be exceeded more than once per year on average over three years.
(f) Annual mean averaged over three years.
(g) The 98th percentile, averaged over three years.
(h) The 99th percentile of one-hour daily maximum concentrations, averaged over three years.
Key: μg/m^3 = microgram per cubic meter; N/A = not applicable; ppm = parts per million.

Table 3.7-2. Existing Criteria Pollutant Emissions for the Nine-County Region of Influence

County	CO	NO_x	PM_{10}	$PM_{2.5}$	SO_2	VOCs
Brevard	114,734	15,869	15,293	5,775	1,307	49,787
Flagler	17,142	2,785	3,722	724	120	19,431
Indian River	41,179	4,333	4,807	2,197	314	20,728
Lake	79,082	7,583	22,616	5,158	317	42,679
Orange	191,337	30,218	18,075	7,688	3,822	51,475
Osceola	128,031	9,506	18,188	8,945	832	54,152
Polk	154,754	17,788	42,473	11,615	17,449	78,584
Seminole	64,224	7,227	7,843	2,442	267	20,214
Volusia	97,803	17,788	42,473	11,615	17,449	78,584
Total ROI	**888,285**	**113,097**	**175,491**	**56,159**	**41,876**	**415,636**

Source: (EPA 2019a)
Key: CO = carbon monoxide; NO_x = nitrogen oxides; PM_{10} and $PM_{2.5}$ = particulate matter with a diameter of less than or equal to 10 micrometers and 2.5 micrometers, respectively; ROI = region of influence; SO_2 = sulfur dioxide; VOC = volatile organic compound.

Ozone-Depleting Substances

Section 3.1.2.3 of the 2014 FEIS describes the regulatory drivers that promulgate the reduction and phase-out of the use of ozone-depleting substances (ODS) for both CCAFS and KSC. These regulatory drivers remain the same for the current ROI. The use of Class I ODS is prohibited at CCAFS, and the Proposed Action would not use Class II ODS (USAF 2019).

Risk Management Program 40 CFR 68

CCAFS previously developed a Risk Management Plan due to chemical holdings for hydrogen, hydrazine, and Aerozine-50. When the Titan program ended, the chemical holdings were removed from site. CCAFS does not have a current Risk Management Plan (USAF 2013).

Climate

Section 3.1.2.1 of the 2014 FEIS describes the climate of both CCAFS and KSC. That information remains the same for this SEIS, but since 2014, climate change has become a more prominent issue in the public eye.

Climate Change and Sea Level Rise

Solar irradiance, the greenhouse effect, and Earth's reflectivity interact to keep temperatures on Earth within limits conducive to life. Changes in solar irradiance due to orbital perturbations of the Earth (known as Milankovitch cycles) have forced the climate into and out of glacial cycles, with greenhouse gas (GHG) concentrations thought to provide a helpful effect. But the relatively recent increase in GHG concentrations in the atmosphere has been identified as the primary cause of current climate change (Intergovernmental Panel on Climate Change 2014, USGCRP 2018). Burning fossil fuels and other human activities cause these GHG increases in the atmosphere and speed up the rate of climate change.

The potential impacts of higher GHGs on Earth's climate include warmer temperatures, melting polar ice caps and glaciers, rising sea levels, changes in rainfall patterns, more extreme weather events (e.g., droughts, deluges, severe storms, floods, prolonged heat waves), and other associated and often interrelated effects. The *KSC Center-Wide Operations Final Programmatic Environmental Impact Statement* (NASA 2016) details other expected effects of climate change.

Over the last 20 years, erosion along the KSC coastline has increased due to frequent storm surges from nor'easters, tropical storms, and hurricanes. Erosion may have been exacerbated by effects from rising sea levels, more than 12.7 centimeters (5 inches) as measured at the Trident Pier in the adjacent Port Canaveral. As a result, FDEP has categorized the area as "critically eroded" (FDEP 2016). NASA has created more than 1.8 km (1.0 mi) of artificial dunes along the KSC coastline to protect space program assets and important wildlife habitat; an additional 9.2 km (5.7 mi) of dune creation is planned for 2018/2019. On CCAFS, the long-term trend shows that areas south of the modern cape and north of the Cape Canaveral harbor entrance are accreting. Areas north of the cape to just south of LC-37 are eroding, and areas further north are accreting (Jaeger et al. 2011).

Greenhouse Gas Emissions

Greenhouse gases include water vapor, carbon dioxide, methane, nitrous oxide, ozone, and several hydrocarbons and chlorofluorocarbons. Each GHG has an estimated global warming potential (GWP), which is a function of its lifetime and ability to trap heat in the atmosphere. The GWP rating system is standardized to carbon dioxide, which has a value of one. For example, methane has a GWP of 28, which means that it has a global warming effect 28 times greater than carbon dioxide on an equal-mass basis (USGCRP 2018). To simplify GHG analyses, total GHG emissions from a source are often expressed as a carbon dioxide equivalent (CO_2e). The CO_2e is calculated by multiplying the emissions of each GHG by its GWP and adding the results together to produce a single, combined emission rate representing all GHGs. While methane and nitrous oxide have much higher GWPs than carbon dioxide, carbon dioxide is emitted in such greater quantities that it is the overwhelming contributor to global CO_2e emissions from both natural processes and human activities.

Direct emissions of GHGs on CCAFS primarily occur from commuter vehicles, ground support operations, and launch events. But GHGs indirectly emitted by offsite power facilities due to onsite energy usage (electricity, steam, and hot water) are the main contributors to total GHGs. The direct and indirect GHGs emitted from all NASA facilities in fiscal year 2013 amounted to 959,984 metric tons of CO_2e (NASA 2016). For comparison, Table 3.7-3 lists the GHGs generated within the nine-county ROI in 2014 (EPA 2019a).

The potential effects of GHG emissions from the Proposed Action are by nature cumulative and global. Given the global nature of climate change, it is not useful at this time to attempt to link the emissions from local actions to any specific climatological change or resulting environmental impact. However, GHG emissions from the Proposed Action have been quantified in this SEIS to indicate their potential cumulative contributions to climate change effects and for comparing alternatives.

Table 3.7-3. Existing Greenhouse Gas Emissions for the Nine-County Region of Influence

County	CO_2 (tons/year)	CH_4 (tons/year)	N_2O (tons/year)	CO_2e (tons/year)
Brevard	4,003,589	1,274	106	4,067,034
Flagler	740,363	66	16	746,779
Indian River	1,378,778	864	24	1,407,587
Lake	2,301,629	1,297	60	2,351,972
Orange	8,540,149	984	208	8,626,768
Osceola	3,553,552	3,702	55	3,662,483
Polk	4,741,516	2,647	111	4,840,645
Seminole	2,656,345	363	68	2,685,716
Volusia	3,802,998	867	98	3,853,750
Total ROI	**31,718,920**	**12,063**	**746**	**32,242,734**

Source: (EPA 2019a)

Key: CH_4 = methane; CO_2 = carbon dioxide; CO_2e = carbon dioxide equivalent; N_2O = nitrous oxide; ROI = region of influence.

3.7.2 Environmental Consequences

3.7.2.1 No Action Alternative

Air Quality

Under the No Action Alternative, NASA would discontinue preparations for the Mars 2020 mission, and thus the alternative would not produce any air quality impacts.

Climate

Under the No Action Alternative, NASA would discontinue preparations for the Mars 2020 mission, and thus the alternative would not produce any climate impacts.

3.7.2.2 Proposed Action

Air Quality

Air quality impacts from normal Atlas V launch activities would be the same as those identified in Section 4.1.2.2 of the 2014 FEIS. That analysis concluded that emissions from normal Atlas V launch activities would not produce adverse short- or long-term air quality impacts within the ROI. Table 3.7-4 compares launch vehicle emissions to current baseline emissions in the ROI. These data show that proposed launch emissions would equate to very small amounts of the existing emissions within the ROI. Accordingly, emissions produced from Atlas V launch activities would not result in substantial air quality impacts within the ROI.

Table 3.7-4. Launch Vehicle Emissions Compared to Region of Influence Baseline Emissions

Launch Vehicle	CO	NO_x	PM_{10}	$PM_{2.5}$[b]	SO_2	VOCs
Atlas V 551/552[a]	0.01	1.1	15	15	0	0
Atlas V H[a]	0	1.2	0	0	0	0
Total ROI	**888,285**	**113,097**	**175,491**	**56,159**	**41,876**	**415,636**
Percentage of ROI[c]	**0.00%**	**0.00%**	**0.01%**	**0.03%**	**0.00%**	**0.00%**

Notes:

(a) Source: (NASA 2011)

(b) $PM_{2.5}$ assumed equal to PM_{10} emissions.

(c) Although the Atlas 541 will be the Mars 2020 ELV, to provide a conservative analysis, the highest of Atlas V 551/552 and Atlas H emissions were used for comparison.

Key: CO = carbon monoxide; ELV = expendable launch vehicle; NO_x = nitrogen oxides; PM_{10} and $PM_{2.5}$ = particulate matter with a diameter of less than or equal to 10 micrometers and 2.5 micrometers, respectively; ROI = region of influence; SO_2 = sulfur dioxide; VOC = volatile organic compound.

In the unlikely event of a launch vehicle accident, the MMRTG on the Atlas V could release radioactive material leading to possible dispersal in the air. Based on recent modeling, the ROI for potential radioactive impacts is broader than analyzed in the 2014 FEIS. But as noted in Section 3.5 (Health and Safety), the probability of a launch incident remains very low, and the probability of an incident leading to release of radioactive materials would be about a factor of about 1.9 lower still. In the unlikely event of such an accident, data indicate that the amount of radioactive contamination would theoretically still be below the level considered likely harmful to human health (see Section 3.5). In addition, based on the analysis in Section 4.1.3.2 of the 2014 FEIS, emissions from an accident during an Atlas V launch would not be expected to produce adverse short- or long-term air quality impacts in the ROI.

Climate Change

On June 21, 2019, the CEQ submitted its “Draft NEPA Guidance on Consideration of Greenhouse Gas (GHG) Emissions” to the Federal Register for publication and public comment (EPA 2019b). Although this guidance has not been finalized, the main principles of GHG evaluation and potential impacts on climate change are likely to remain applicable. The CEQ’s draft guidance suggests that agencies should use estimated GHG emissions as a proxy for assessing potential effects on climate change and that emissions should be quantified when practicable.

As discussed in Section 4.1.2.14 of the 2014 FEIS, GHGs mainly in the form of carbon dioxide and, to a lesser extent, black carbon “soot” would be emitted during an Atlas V launch. The 2014 FEIS analysis estimated that a Falcon Heavy launch would produce up to 976 metric tons of carbon dioxide. Due to its higher fuel usage, an Atlas V launch would emit about twice the amount of carbon dioxide as a Falcon Heavy launch. This level of emissions would amount to about 0.06 percent of the ROI GHG baseline and 0.00003 percent of the net GHGs emitted by the United States in 2017 of approximately 6,742 million metric tons of CO_2e (EPA 2018). This inconsequential amount of GHGs produced by a proposed Atlas V launch would not cause substantial or long-term environmental impacts on climate change.

3.8 SOILS AND GEOLOGY

3.8.1 Affected Environment

This section corresponds to Section 3.1.4 of the 2014 FEIS and discusses soils, geology, and seismology in the ROI. The subsection below compares the state of the resource in the 2014 FEIS and any changes that have occurred since then.

Changes to ROI Since 2014 FEIS

The 2014 FEIS focused on the soils, geology, and seismology of both CCAFS and KSC. The previous analysis included the CCAFS ROI, which was subsequently selected as the launch site for this SEIS. The existing conditions at CCAFS regarding soils, geology, and seismology remain unchanged since 2014 and are largely identical to the description in Section 3.1.4 of the 2014 FEIS (NASA 2014).

Existing conditions associated with the expanded ROI in 2019 include all or portions of the following counties: Brevard, Flagler, Indian River, Lake, Orange, Osceola, Polk, Seminole, and Volusia.

3.8.1.1 Soils

The entire expanded ROI falls within the Southern Coastal Plain ecoregion. Portions of the nine-county area fall within the southwestern and eastern Florida Flatwoods subregion, and the rest falls within the central Florida Ridges and Uplands subregion. Across the ROI, soil associations vary from well-drained and deep sandy ridges in upland areas and along portions of the Atlantic Coastal Plain to more level and poorly drained associations found along lowlands and areas along the St. Johns River. The inland areas are characterized by flatwoods, consisting of poorly drained, nearly level sandy soils at the upper horizons often underlain by loamy material. In addition, sloping broad ridges, lowlands, and urban environments occur throughout the study area. Within swamp and marsh areas throughout the ROI, soil associations consist of nearly level and very poorly drained organic soils. These associations consist of a varied pattern of sandy and loamy soils.

As stated in the 2014 FEIS, the CCAFS soil pattern is complex and of varying ages, leading to less-weathered soils in areas such as on Cape Canaveral. Well-drained soil series on CCAFS retain marine shell fragments in the upper layers, which in turn influence soil nutrient and acidity (pH) levels (NASA 2014). As within many areas of the ROI, soils at CCAFS are highly permeable and allow water to quickly percolate into the ground. Within both the larger ROI and CCAFS, topography and slope have a major effect on soil formation and an increasing potential for erosion and soil transport (NASA 2014).

When reviewing soils in a given region, the presence of prime farmland areas is considered due to the need to conserve agriculturally important land resources. Prime farmland has the characteristics to produce economically sustained high yields of crops when managed according to acceptable farming methods. Unique farmland is land other than prime farmland that is used for the production of specific high value crops (e.g., citrus, tree nuts, olives, cranberries). No prime or unique farmland is present at CCAFS (NASA 2014). Within the nine-county ROI, no prime farmland is identified, but there are 5,408 km^2 (1,336,446 acres or 2,088 mi^2) of farmland of unique importance in the study area (Table 3.8-1) (Natural Resources Conservation Service 2019).

Table 3.8-1. Farmland Soils by County with the Region of Influence

Description	Brevard	Flagler	Indian River	Lake	Orange	Osceola	Polk	Seminole	Volusia
Farmland of Unique Importance	873 km^2 (337 mi^2)	194 km^2 (75 mi^2)	743 km^2 (287 mi^2)	875 km^2 (338 mi^2)	347 km^2 (134 mi^2)	1,406 km^2 (543 mi^2)	943 km^2 (364 mi^2)	23 km^2 (9 mi^2)	3 km^2 (1 mi^2)
Not Prime Farmland	1,777 km^2 (686 mi^2)	1,080 km^2 (417 mi^2)	583 km^2 (225 mi^2)	2,108 km^2 (814 mi^2)	2,041 km^2 (788 mi^2)	2,103 km^2 (812 mi^2)	3,833 km^2 (1,480 mi^2)	777 km^2 (300 mi^2)	2,922 km^2 (1,128 mi^2)

Source: (Natural Resources Conservation Service 2019)
Note: 1 km^2 is about 247 acres; 1 mi^2 is about 640 acres.
Key: km^2 = square kilometers; mi^2 =square miles.

3.8.1.2 Geology

The basement geologic feature under the study area is the Florida Platform composed at its upper layers of carbonates such as dolomite and limestone. The overlying and surficial geology of the ROI consists of Tertiary deposits overlain by Holocene epoch sediments along the Atlantic coast with Pleistocene and Holocene dune and undifferentiated sediments found further inland to the west (Hine 2009). The western portion of the study area is primarily composed of Pliocene period formations interspersed with Holocene period deposits. The geology, topography, and soils underlying CCAFS remain as described in the 2014 FEIS. Generally, the surficial sands immediately underlying the surface are marine deposits with the Caloosahatchee Marl formation underlying these surficial sands (NASA 2014).

The topography of the expanded study area is characterized by a relatively elevated central region of rolling hills, with lakes, rivers, and springs. The landscape to the east gradually descends eastward to a lower elevated coastline, punctuated by dunes and broad ridges and barrier islands. The CCAFS topography consists of a series of relic dune ridges with a gentle slope to lower elevations toward the marshlands along the Banana River (NASA 2014).

3.8.1.3 Seismology

Most seismic activity is associated with the margins of the Earth's tectonic plates and the nine-county ROI within Florida is distant from any of these tectonic boundaries. The closest plate transform boundary is between the North American and Caribbean tectonic plates, almost 800 miles to the south (FDEP 2019c). Although earthquakes can occur in Florida, no seismic activity of note has been recorded in close proximity to Florida since 1997 (USGS 2019b).

As discussed in the 2014 FEIS (NASA 2014), seismological investigations of the Cape Canaveral area include refraction surveys and well logs. Previous investigations showed that the Cape Canaveral underground structure is normal and free of voids or anomalies. The Florida Platform exhibits high seismologic stability with very few confirmed earthquakes.

3.8.2 Environmental Consequences

3.8.2.1 No Action Alternative

The No Action Alternative would be the same as that described in Section 2.4 of the 2014 FEIS (NASA 2014). Under the No Action Alternative, NASA would discontinue preparations for the Mars 2020 mission, and so there would be no impacts to geology and soils within the CCAFS or the larger nine-county ROI.

3.8.2.2 Proposed Action

Estimated spatial dispersion of radiological contamination levels within the nine-county area would depend on specifics of the accident, launch phase, weather, and wind conditions at the time of the event. As described in Section 3.5 (Health and Safety), using the screening level of 0.2 $\mu Ci/m^2$, an area of radiological deposition could occur within an area encompassing up to 79 km^2 (31 mi^2), depending on the stage and type of the launch accident. Should such an unlikely event occur, that area would be subject to further evaluation for potential radiological impacts. Land areas exceeding recommended exposure levels would potentially need further action, such as monitoring or cleanup (see Section 3.5).

Although the ROI for this SEIS is larger than that of the 2014 FEIS, the scope of potential impacts from a launch-related accident resulting in a radiological release under Proposed Action are essentially the same.

The environmental impacts of a radiological release due to accidents include the potential for plutonium dioxide to be released to the environment, resulting in potential land area effects. The methodology of determining radioactive material release consequences to geology and soils would remain the same as that described in the 2014 FEIS. As discussed in Section 4.1.4.5 of the 2014 FEIS and Section 3.5 (Health and Safety) of this SEIS, launch area accidents (Phases 0 and 1) would initially release material into the ROI. The extent of potential impacts is based on several factors, including the location of the accident, dispersion factors associated with atmospheric conditions, and soil types. In the 2014 FEIS analysis, the extent of land area that would need further evaluation due to a release of plutonium dioxide under an early launch accident scenario was estimated to be up to 7.4 km^2 (2.9 mi^2) (NASA 2014). According to the 2019 NRA Update, the land area that would need further evaluation due to a release of plutonium dioxide under the same scenario is an average of 79 km^2 (31 mi^2), which could include less than 0.014 km^2 (3.5 acres) of cropland (see Section 3.5, Health and Safety); this may include areas of unique farmland depending on the accident and dispersion scenario. With any radiological release, the greater the distance from the release point, the lower the concentrations of radioactive material.

As discussed in Appendix B of the 2014 FEIS, plutonium dioxide is very insoluble. As a result of this insolubility, movement through soils occurs primarily through physical processes such as rainfall percolation causing particles to leach into the soil, animal burrowing activity, and plowing or other disturbance of the soil by humans. Migration of plutonium dioxide into the soil column is of concern, primarily because of the potential for plutonium dioxide to reach groundwater sources. But once deposited on soil, plutonium dioxide appears to be extremely stable and likely to remain in the upper soil horizon for decades (NASA 2014). In the event of a radiological release, exposure pathways connected to soils would involve external exposure from settled particles of plutonium dioxide or by ingestion of soils or contaminated vegetation.

Chapter 4 of the 2014 FEIS details the remediation costs of a radiological release. Such costs would involve a variety of potential actions, including land acquisition, site restoration, and cropland decontamination. The costs of remediation are difficult to quantify and depend on different factors, including the scope of contamination and media/land cover type (e.g., soil type, water, substrate, land cover type). Such costs would be determined as part of the evaluation and remediation process discussed in the 2014 FEIS and Sections 3.5 (Health and Safety) and 3.6 (Land Use) of this SEIS.

3.9 WATER RESOURCES

3.9.1 Affected Environment

This section corresponds to Section 3.1.5 of the 2014 FEIS and addresses surface water classification, surface water quality, groundwater sources, and coastal zone management. Surface water resources include lakes, rivers, estuaries, and streams and are important for many reasons, including economic, ecological, recreational, and human health factors. Wild and Scenic Rivers are discussed in this section. The *Surface Water Quality* subsection discusses the existing conditions of surface water resources and describes impaired water resources in the region. Groundwater includes the subsurface hydrologic resources of the physical environment; its properties are often described in terms of depth to aquifer or water table, water quality, and surrounding geologic composition. The *Coastal Zone Management* subsection deals with the regulations to preserve, protect, develop, restore, and enhance the resources of the nation's coastal zone.

Changes to ROI Since 2014 FEIS

Surface Water Classification

The 2014 FEIS focused on the surface waters of both CCAFS and KSC. The surface waters and associated factors affecting surface waters within CCAFS have largely remained unchanged since 2014 and remain similar to that described in Section 3.1.5.1 of the 2014 FEIS.

Surface waters within the 2019 ROI (Brevard, Indian River, Orange, Osceola, Seminole, Volusia, Flagler, Lake, and Polk Counties) include a large number of rivers, streams, lakes, and other surface waterbodies. Examples of rivers in the ROI include the St. Johns, Palatlakaha, Peace, and Kissimmee Rivers. Example streams include Middle Haw, Little Haw, Haynes, Taylor Wolf, and Reedy Creeks. Lakes include Lake George, Lake Kissimmee, Lake Apopka, Lake Harris, Crescent Lake, and Lake Jesup. Approximately 50 waterbodies within the ROI are considered Outstanding Florida Waters (FDEP 2019b).

Several waterways within the ROI have been designated as Wild and Scenic Rivers or are rivers that are listed on the Nationwide Rivers Inventory. Table 3.9-1 lists the designation of these rivers and the counties in which they are located. Additional information on these rivers is available from the National Wild and Scenic Rivers System (NWSRC 2019) and the National Park Service (NPS 2017).

Table 3.9-1. National Wild and Scenic Rivers

River	Designation	County
Arbuckle Creek	Nationwide Rivers Inventory	Polk
Black Water Creek	Wild and Scenic River	Lake
Econlockhatchee River	Nationwide Rivers Inventory	Orange, Seminole
Peace River	Nationwide Rivers Inventory	Polk
Rock Springs Run	Wild and Scenic River	Orange
St. Johns River	Nationwide Rivers Inventory	Seminole, Volusia, Orange, Brevard
Tomoka River	Nationwide Rivers Inventory	Volusia
Wekiva River	Wild and Scenic River	Seminole, Lake, Orange
Withlacoochee River	Nationwide Rivers Inventory	Polk, Lake

Sources: (NWSRC 2019, NPS 2017)

Surface Water Quality

The 2014 FEIS focused on the surface water quality within CCAFS and KSC. The surface water quality within CCAFS has largely remained unchanged since 2014 and remains similar to that described in Section 3.1.5.2 of the 2014 FEIS.

Over 200 impaired waterways occur in the ROI (FDEP 2018). Impairments include nutrients, bacteria, and dissolved oxygen. Additional information on impaired waterways is available from the FDEP (FDEP 2019a).

Groundwater Sources

The 2014 FEIS focused on the groundwater resources within CCAFS and KSC. These groundwater resources correspond to the groundwater resources within the larger 2019 ROI and have largely remained unchanged since 2014. Groundwater resources remain similar to that described in Section 3.1.5.3 of the 2014 FEIS.

Coastal Zone Management

The 2014 FEIS focused on the coastal zone management requirements for both the USAF and NASA. These requirements remain unchanged since 2014 and are covered in Section 3.1.5.4 of the 2014 FEIS.

3.9.2 Environmental Consequences

3.9.2.1 No Action Alternative

Under the No Action Alternative, NASA would discontinue preparations for the Mars 2020 mission. The spacecraft would not be launched, so there would be no environmental impacts associated with the No Action Alternative.

3.9.2.2 Proposed Action

Estimated spatial dispersion of radiological contamination levels within the nine-county area would depend on specifics of the accident, launch phase, weather, and wind conditions at the time of the event. As described in Section 3.5 (Health and Safety), using the screening level of 0.2 $\mu Ci/m^2$, an area of radiological deposition could occur within an area encompassing an average of 79 km^2 (31 mi^2), depending on the stage and type of the launch accident. Should such an unlikely event occur, that area would be subject to further evaluation for potential radiological impacts. Land areas exceeding recommended exposure levels would potentially need further action, such as monitoring or cleanup (see Section 3.5).

While revised 2019 modeling results indicate that the ROI for radiological impacts may be broader than what was predicted by the 2014 FEIS, a launch accident that results in a loss of containment of the radioactive power source is unlikely, and the environmental impacts (if such an accident were to occur) would not be substantially different from the water resource impacts described in past EISs (NASA 2014, NASA 1989, NASA 1990). The significance of the environmental impacts of the Proposed Action (i.e., launching the Mars 2020 spacecraft equipped with an MMRTG), is not substantively different than what was evaluated in the 2014 FEIS. A summary of impacts by water resources subcategory is included below.

Surface Water Classification

As described in Appendix B of the 2014 FEIS, radiation doses can result from the bioaccumulation of plutonium dioxide deposited on surface waters. The availability of plutonium dioxide is dependent on dilution and partitioning between the water and underlying sediments. Larger particles would sink to the sediment layer, while smaller particles would float within the water column and the smallest particles would likely form a thin layer on top of the water surface. Aquatic species that feed within and occupy the water column have the potential to encounter plutonium dioxide that could be released during a launch accident (see Section 3.11, Biological and Natural Resources). Some plutonium dioxide would partition into the sediments, which could get re-suspended into the water column from natural processes such as tides or currents, as well as foraging activities of bottom-feeding marine species. Recreational activities, including fishing, boating, and swimming may disturb sediments and re-suspend plutonium dioxide particles into the water column. But resuspension would be temporary, as particles would settle to the bottom once the disturbance ceases.

During the development of the 2014 FEIS, a conservative screening level of 0.2 $\mu Ci/m^2$ was used to determine land areas that would potentially require further evaluation and detailed characterization for potential cleanup actions. Overall, plutonium dioxide concentrations in aquatic and marine environments are expected to be less than those in terrestrial environments, primarily due to insolubility in water and potentially high rates of dilution. In the unlikely event of a loss of containment of the radioactive power source, it is possible that further evaluation could determine that surface waters, including Wild and Scenic Rivers and Outstanding Florida Waters, could have sufficient levels of plutonium dioxide to require additional evaluation and, if necessary, cleanup. Those areas may require closure during the initial evaluation of impacts and, if necessary, during cleanup efforts. Closure could be limited to restricting certain recreational uses of the waters. For example, sufficient levels of contamination in waters that are conditionally approved for shellfish harvesting could result in closure of those areas for harvesting until contamination levels were reduced. The duration, type, and extent of closures would be dependent upon the level and extent of impact, as determined during the evaluation process.

Inland Surface Water Resources

Impacts to inland surface water quality would be highly variable, depending on the mobility and availability of plutonium dioxide in the environment (see Section 3.10, Offshore Environment, for discussion of impacts to the ocean environment). The mobility and availability of plutonium dioxide is directly controlled by physical and chemical parameters, including particle size, potential for suspension and resuspension, solubility, and oxidation state of any dissolved plutonium dioxide (NASA 1989). Smaller particles that float on or within the water column or are re-suspended have the potential to indirectly degrade water quality for use as potable drinking via migration through surface waters and the soil profile. Although unlikely, should a launch accident with radiological release occur, some surface waters may be exposed to contamination. The specific areas requiring further evaluation would depend on the type of accident and the dispersion factors present at the time of the accident. These areas would require additional characterization to determine if additional monitoring of surface water quality is required, if additional water treatment is needed, or if alternative water supplies would be developed.

Groundwater Sources

The potential for impacts to groundwater has been discussed in previous EISs (NASA 2014, NASA 1989, NASA 1990). In the central region of Florida, groundwater is recharged through the soil profile and surface waters. Surface water and soil contamination within aquifer recharge areas of the surficial aquifer could result in contamination of potable water sources. But the potential of groundwater contamination is limited by the insoluble nature of plutonium dioxide and its limited potential to move through the soil column and into groundwater resources (see Section 3.8, Soils and Geology) (NASA 1989, NASA 1990, NASA 2014). In the unlikely event that an accident resulting in radiological release occurs, surface waters, soils, and groundwater sources within a 79 km^2 (31 mi^2) area around the accident would require additional characterization to determine the scope of impact, if water quality monitoring is required, if additional water treatment is needed, or if alternative water supplies would need to be developed.

3.10 OFFSHORE ENVIRONMENT

3.10.1 Affected Environment

The offshore environment adjacent to CCAFS consists of the Atlantic Ocean, including the water column and underlying sediments. The ROI for this SEIS extends from the coastline of CCAFS out to 100 km (62 mi). Existing conditions of the offshore environment have not changed over those presented and analyzed in the 2014 FEIS. The only difference considered in this SEIS is the increased area of the Atlantic Ocean potentially impacted by the Proposed Action. A description of the biological resources supported by the offshore environment is included in Section 3.11 (Biological and Natural Resources).

3.10.2 Environmental Consequences

3.10.2.1 No Action Alternative

The No Action Alternative addressed in this SEIS is the same as that described in Section 2.4 of the 2014 FEIS. NASA would discontinue preparations for any Mars 2020 mission, and the spacecraft would not be launched, so no impacts to the offshore environment would occur under the No Action Alternative.

3.10.2.2 Proposed Action

Environmental consequences to the offshore environment would not change over those presented in the 2014 FEIS. This SEIS considers the increased area included in the ROI as it relates to a launch accident that would result in a release of nuclear materials. Section 4.1.2.6. of the 2014 FEIS describes impacts to the offshore environment during a normal launch, which would not change under this SEIS. Impacts to biological and natural resources supported by the offshore environment from a launch vehicle-related accident with a radiological release are discussed in Section 3.11.2 (Biological and Natural Resources, Environmental Consequences).

3.11 BIOLOGICAL AND NATURAL RESOURCES

3.11.1 Affected Environment

This section corresponds to Section 3.1.6 of the 2014 FEIS. Biological resources include living, native, or naturalized plant and animal species and their habitats within an area potentially affected by the proposed activity. Within this SEIS, biological resources are divided into vegetation, wetlands, and terrestrial wildlife; aquatic resources (including marine biological resources); threatened or endangered species; and sensitive habitats. Sensitive habitats include wetlands, critical habitats for threatened and endangered species as defined by the Endangered Species Act (ESA), Wildlife Management Areas, essential fish habitat (EFH), National Estuarine Research Areas, aquatic preserves, and sensitive ecological areas as designated by state or Federal rulings.

Changes to ROI Since 2014 FEIS

Vegetation, Wetland, and Terrestrial Wildlife Resources

The ROI for biological resources for the 2014 FEIS included CCAFS, the adjacent Atlantic Ocean, and three major inland water bodies, including the Banana and Indian Rivers and Mosquito Lagoon. Refer to Section 3.1.6.1 of the 2014 FEIS for a description of vegetation, wetland, and wildlife resources at CCAFS.

The 2019 ROI for terrestrial biological resources includes the nine-county area surrounding the launch site (Figure 1.1-1). The ROI lies within the Southern Coastal Plain ecoregion of Florida (EPA 2019c). Historical land cover consisted of flat plains with wet soils, marshland, and swamps, but due to urban and agricultural development and changes in hydrology, most of the original vegetation communities have been altered (USGS 2019a). Current land cover generally consists of the following vegetation communities: longleaf-slash pine forest, savanna-grasslands, oak-gum-cypress forest, coastal/estuarine, and swamps, marshes, and lakes associated with inland water bodies. Refer to the Florida Natural Areas Inventory for more information on land cover classes: https://myfwc.com/research/gis/applications/articles/fl-land-cover-classification/.

There are approximately 2,234,205 acres of wetlands within the 2019 ROI, classified into eight categories, according to the National Wetland Inventory classification system (Cowardin et al. 1979). These are shown in Figure 3.11-1, and information about these wetland categories can be found in Section 3.9 (Water Resources).

Common types of wetland and open water areas within the 2019 ROI include mangrove swamp, tidal salt marshes, freshwater marshes, riparian river/stream systems, brackish water impoundments, borrow pits, and drainage canal systems (USAF 2008, University of Florida 2010).

The Southern Coastal Plain ecoregion supports a wide diversity of terrestrial and aquatic plants, animals, and habitats. Wildlife within Florida includes more than 700 terrestrial animals, 200 freshwater fish, and more than 500 marine fish and mammals (FWC 2019).

Eastern Florida is located within the Atlantic Flyway, used by over 500 species of migratory birds (Audubon 2011). Migratory bird species are protected under the Migratory Bird Treaty Act and EO 13186, *Responsibilities of Federal Agencies to Protect Migratory Birds*. According the USFWS *Birds of Conservation Concern* (BCC) report, the 2019 ROI falls within Bird Conservation Region 31 (Peninsular Florida), for which 49 BCC species are listed (USFWS 2008). A full list of protected migratory bird species can be found in the USFWS BCC report: https://www.fws.gov/migratorybirds/pdf/grants/BirdsofConservationConcern2008.pdf.

Bald eagles (*Haliaeetus leucocephalus*) are protected under the Bald and Gold Eagle Protection Act. Florida has one of the densest concentrations of nesting bald eagles in the lower 48 states, with an estimated 1,500 nesting pairs. Concentrations of nesting territories are clustered around several significant lake, river, and coastal systems throughout the state. Eagle nesting locations and survey data are managed by the Florida Fish and Wildlife Conservation Commission (FWC). According to the FWC Bald Eagle Nest Locator, there are various nesting sites located within the 2019 ROI (FWC 2017).

Aquatic Resources

Aquatic resources at CCAFS have not substantively changed since the 2014 FEIS. Section 3.1.6.2 of the 2014 FEIS provides a description of the aquatic resources at CCAFS. This section provides updated information on aquatic resources under the expanded ROI for this SEIS.

Aquatic resources within the 2019 ROI include approximately 5,786,564 km^2 (2,234,205 mi^2) of freshwater and estuarine wetlands, 251 km^2 (97 mi^2) of NOAA-designated EFH, 5,289 km^2 (2,042 mi^2) of National Estuarine Research Areas, and 290 km^2 (112 mi^2) of aquatic preserves protected by the Florida Aquatic Preserve Act. These areas serve as important habitats for marine mammals; shorebirds; amphibians; sea turtles and other reptiles; fresh and salt water fish species; and designated manatee refuges and sanctuaries. Many of these areas are also considered as sensitive habitats, as discussed in the *Sensitive Habitats* subsection further below.

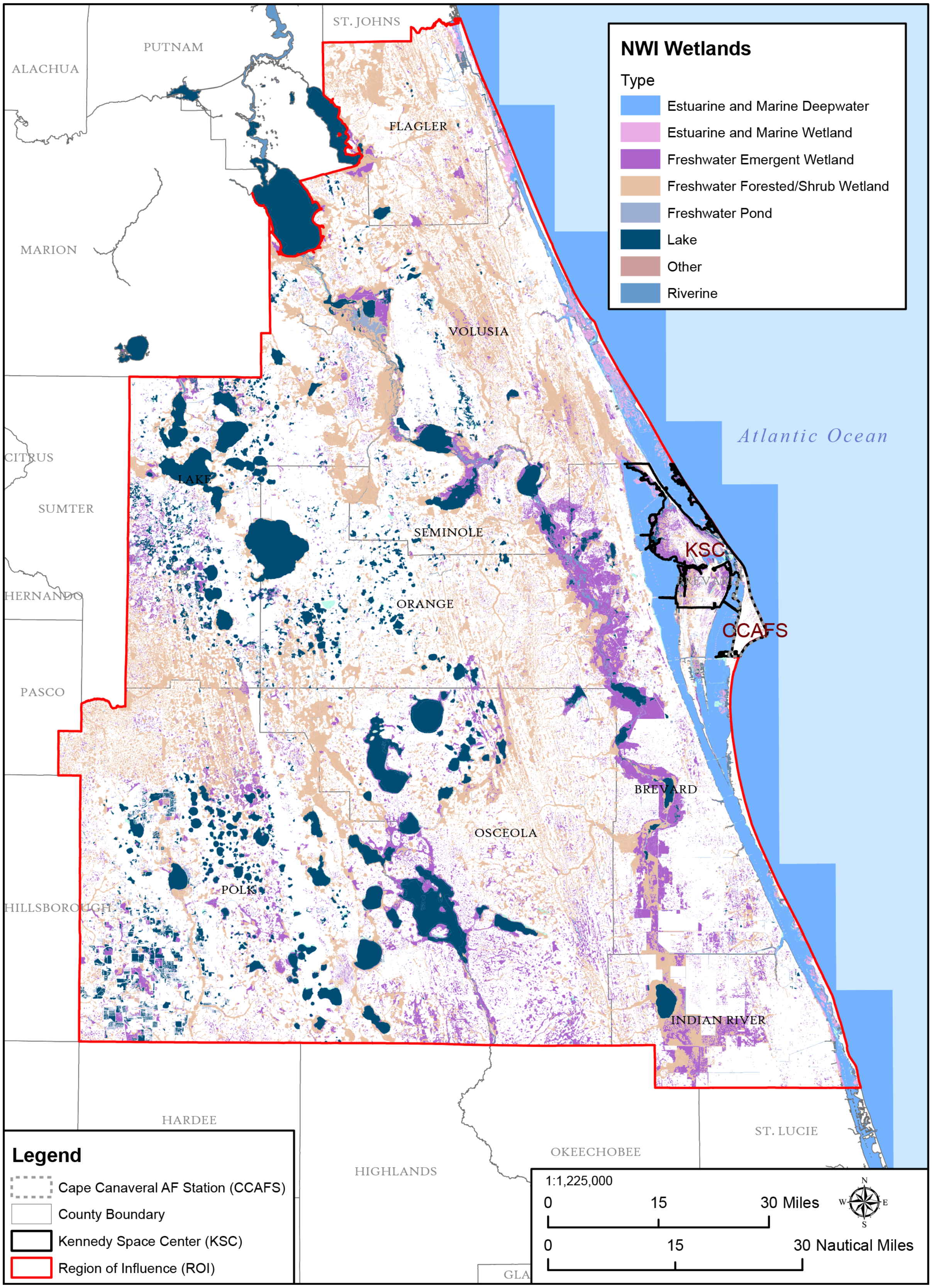


Figure 3.11-1. Wetland Areas Within the 2019 SEIS Region of Influence

Marine species that occur in the Atlantic Ocean, including marine mammals, saltwater fish species, sea turtles, and marine invertebrates have not changed since the publication of the 2014 FEIS. All marine mammals that occur in the ROI are protected by the Marine Mammal Protection Act. Threatened and endangered marine species are discussed in the next subsection. EFH as defined under the Magnuson-Stevens Fishery Conservation and Management Act of 1976 also occurs in the marine portion of the ROI and is described in the *Sensitive Habitats* subsection.

Threatened and Endangered Species

The numbers of threatened and endangered species that occur on or around CCAFS have changed over what was described in Section 3.1.6.3 of the 2014 FEIS. Queries on the USFWS's Information for Planning and Consultation (IPaC) website (available at https://ecos.fws.gov/ipac/) were performed for the entire state of Florida and for each county in the 2019 ROI. Results from the statewide IPaC query determined that the number of Federally endangered or threatened species listed by the USFWS in the state of Florida increased from 112 species in 2014 to 136 species in 2019 (USFWS 2019k). Additionally, the number of candidate species recognized by USFWS decreased from 22 animal and plant species to 1 animal species (USFWS 2019k). The FWC maintains the list of Florida's state-listed threatened and endangered species. The number of state-listed endangered, threatened, or species of special concern decreased from 173 animal and plant species as presented in the 2014 FEIS to 131 species (FWC 2018).

Table 3.11-1 presents the total number of animal and plant species under Federal and state listing status for each county included in the ROI for this SEIS.

In the nine-county ROI, there are a total of 52 ESA-listed species under USFWS jurisdiction. Table 3.11-2 breaks out the number of Federally listed species occurring or potentially occurring in each county by taxa. (Note: some species occur in multiple counties.) The table also cites the results of IPaC queries performed for each county in the ROI. The search results cited in this table contain additional information on ESA-listed species in each county that are managed by USFWS.

Table 3.11-1. Number of Federally and State-Listed Species Occurring or Potentially Occurring Within the 2019 SEIS Region of Influence

Florida County	Federal Endangered Species	Federal Threatened Species	Proposed Threatened Species	Federal Candidate Species	State Endangered Species	State Threatened Species
Brevard	6	11	1	1	19	18
Flagler	3	7	1	1	6	6
Indian River	9	13[(a),(b)]	0	0	8	11
Lake	7	9	1	1	26	14
Orange	8	9	1	1	26	16
Osceola	11	14[(a),(b)]	0	0	22	16
Polk	22	13[(a),(b)]	0	0	39	17
Seminole	2	5	1	1	10	11
Volusia	6	10	1	1	27	21

Sources: (USFWS 2019a, USFWS 2019b, USFWS 2019c, USFWS 2019d, USFWS 2019e, USFWS 2019f, USFWS 2019g, USFWS 2019h, USFWS 2019i) and (FNAI 2019a, FNAI 2019b, FNAI 2019c, FNAI 2019d, FNAI 2019e, FNAI 2019f, FNAI 2019g, FNAI 2019h, FNAI 2019i)

Notes:

(a) This number includes species that are Federally listed as Similarity of Appearance, Threatened (SAT).

(b) This number includes a species that is listed as Experimental population, Non-essential (EXPN).

Key: SEIS = Supplemental Environmental Impact Statement.

Table 3.11-2. Taxa of Federally Listed and Candidate Species Under USFWS Jurisdiction Occurring or Potentially Occurring Within the 2019 SEIS Region of Influence

Florida County	Mammals	Birds	Reptiles	Flowering Plants	Insects	Lichens	Total Number of Species	Source
Brevard	2	8	7	2	0	0	19	(USFWS 2019a)
Flagler	1	5	6	0	0	0	12	(USFWS 2019b)
Indian River	4	9	6	2	1	0	22	(USFWS 2019c)
Lake	1	4	3	10	0	0	18	(USFWS 2019d)
Orange	0	6	3	10	0	0	19	(USFWS 2019e)
Osceola	3	8	4	10	0	0	25	(USFWS 2019f)
Polk	3	8	4	19	0	1	35	(USFWS 2019g)
Seminole	1	4	3	1	0	0	9	(USFWS 2019h)
Volusia	2	7	7	2	0	0	18	(USFWS 2019i)
Total[(a)]	**5**[(a)]	**11**[(a)]	**10**[(a)]	**24**[(a)]	**1**	**1**	**52**	(USFWS 2019j)

Note:

(a) This number reflects the total number of a species in a group from each taxa for the nine-county region of influence, since some species are found in multiple counties.

Key: SEIS = Supplemental Environmental Impact Statement; USFWS = U.S. Fish and Wildlife Service.

NOAA Fisheries (also known as the National Marine Fisheries Service [NMFS]) has listed 24 species as endangered or threatened within the Atlantic Ocean portion of the ROI, which extends from the coastline of CCAFS and the surrounding four coastal counties (Flagler, Volusia, Brevard, and Indian River) out to 100 km (62 mi) (NOAA Fisheries 2019a). These include five marine mammal species, five sea turtle species, six fish species, seven invertebrate species, and one seagrass species. Information on each of these species can be obtained from the NOAA Fisheries Species Directory for ESA Threatened and Endangered Species website at: https://www.fisheries.noaa.gov/species-directory/threatened-endangered.

Sensitive Habitats

Section 3.1.6.4 of the 2014 FEIS describes sensitive habitats on CCAFS. Areas identified include wetlands, critical habitats for threatened and endangered species as defined by the ESA, and the nearby Canaveral National Seashore and Merritt Island National Wildlife Refuge. This section provides updated information on sensitive habitats that occur within the 2019 ROI.

USFWS has designated critical habitat for five ESA-listed species within the nine-county ROI, as presented in Figure 3.11-2. Additionally, NOAA Fisheries has designated four critical habitat areas for two ESA-listed species that overlap with the Atlantic Ocean offshore of Florida's east coast (NOAA Fisheries 2019a). These areas are displayed in Figure 3.11-3.

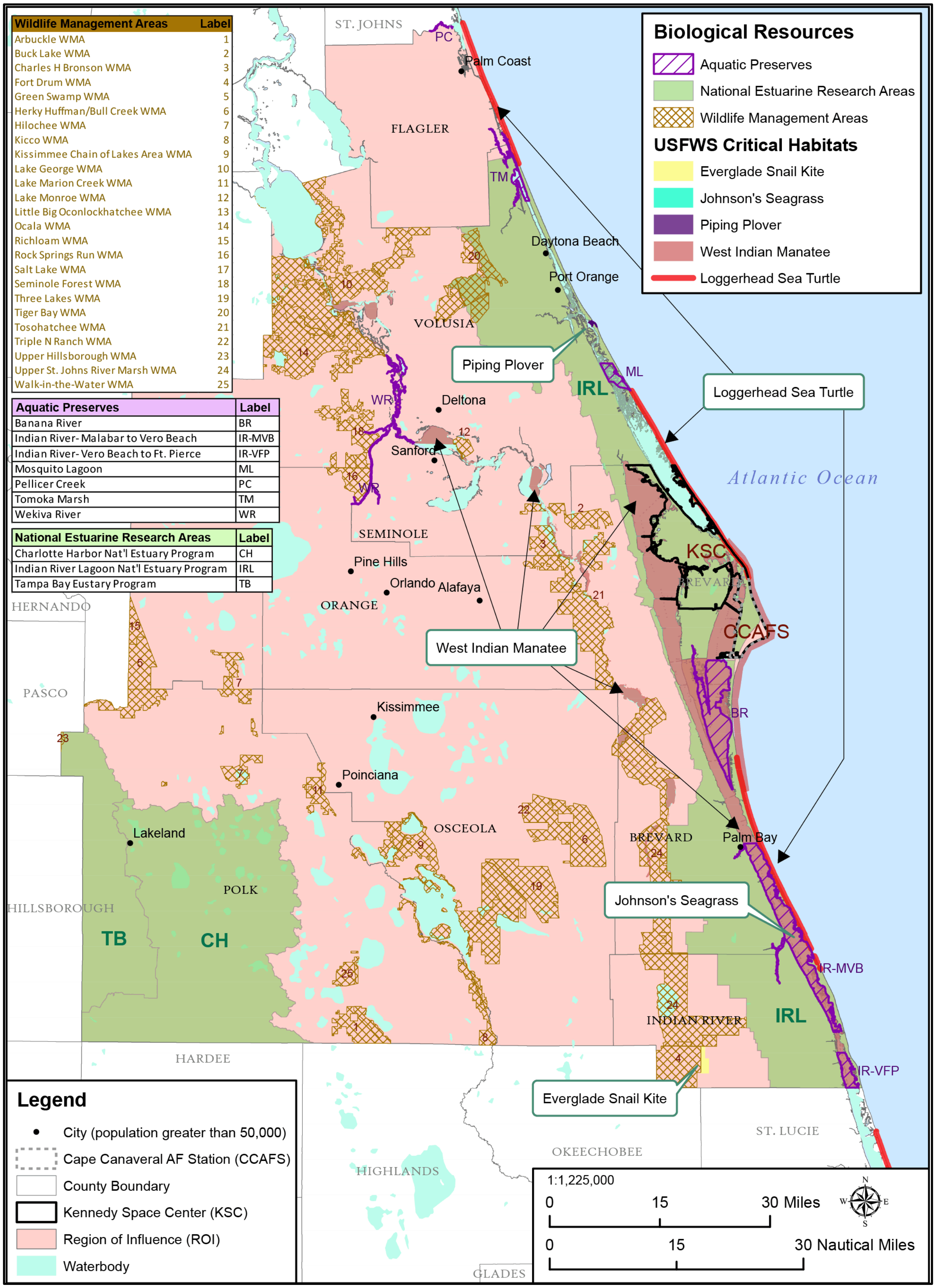


Figure 3.11-2. Terrestrial Sensitive Habitats Within the 2019 SEIS Region of Influence

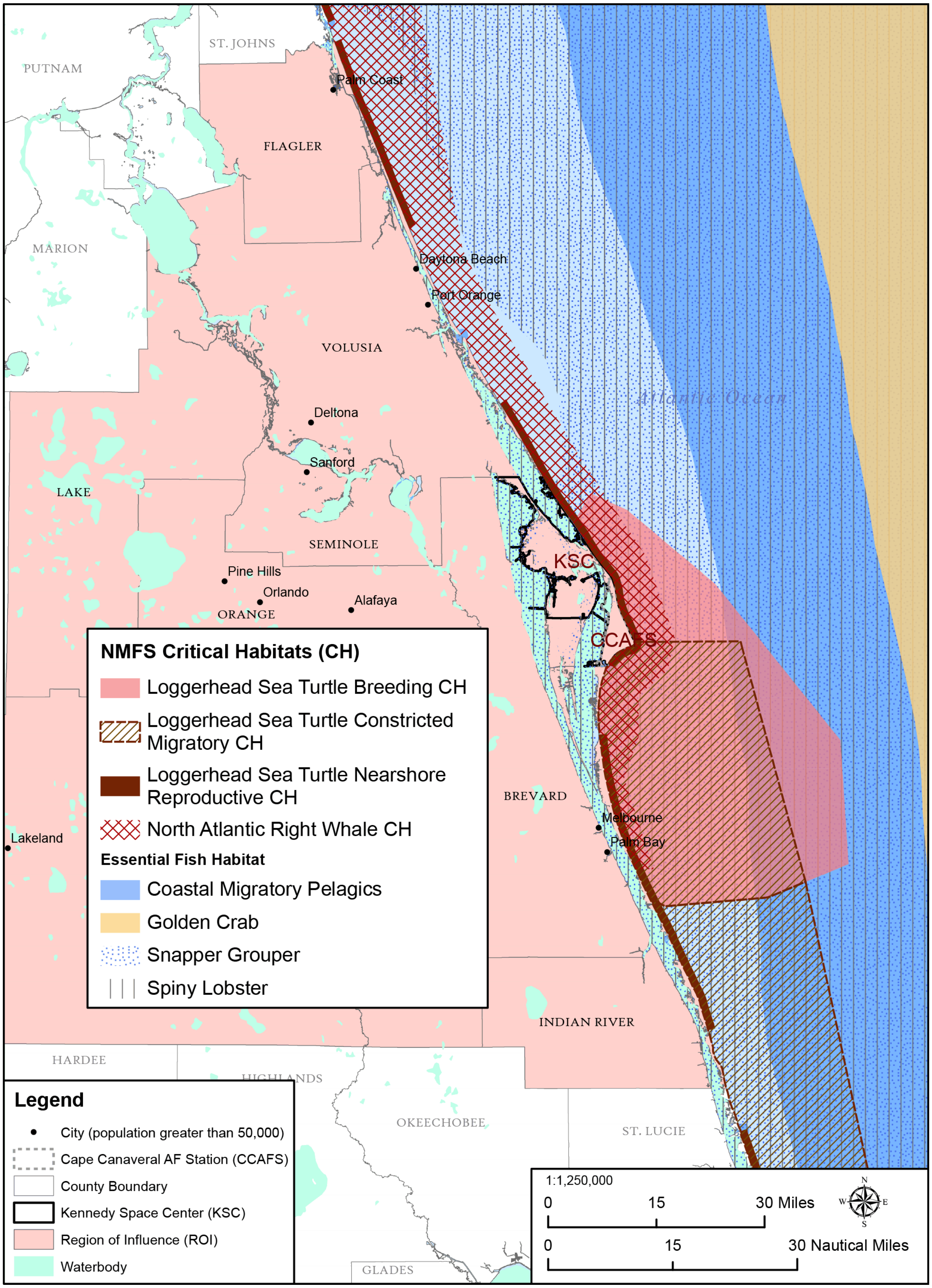


Figure 3.11-3. Marine Sensitive Habitats Within the 2019 SEIS Region of Influence

There are 31 Wildlife Management Areas, three National Estuarine Research Areas, and seven aquatic preserves within the nine-county ROI for this SEIS. These are shown in Figure 3.11-2.

In addition to the habitats listed above, sensitive ecological areas as designated by the state were also considered. According to the FWC *State Wildlife Action Plan*, there are 45 habitat categories listed as ecologically important within the state, but 18 of these habitats have been identified as being under the greatest overall threat (FWC 2012). (Refer to Chapter 6, Habitats, of the *State Wildlife Action Plan* for a complete list and description of these areas: https://myfwc.com/media/5739/chapter6_habitats.pdf.)

EFH at CCAFS has not substantially changed since the 2014 FEIS. Section 3.1.6.2 of the 2014 FEIS that discusses aquatic resources includes a description of EFH in and around CCAFS. Additional EFH areas for the nine-county ROI and expanded areas in the Atlantic Ocean considered in this SEIS are displayed in Figure 3.11-3, which includes designations for corals, coastal migratory pelagics, spiny lobster, snapper/grouper complex, and highly migratory species. Habitats in these areas consist of estuarine and marine emergent wetlands; submerged aquatic vegetation; sandy shoals of capes and offshore bars; high salinity bays, estuaries, and seagrass habitat; shallow subtidal bottom; ocean high-salinity surf zones; nearshore shelf and oceanic waters; and areas containing floating *Sargassum* (SAFMC 2019).

3.11.2 Environmental Consequences

3.11.2.1 No Action Alternative

The No Action Alternative addressed in this SEIS is the same as that described in Section 2.4 of the 2014 FEIS. NASA would discontinue preparations for any Mars 2020 mission, and the spacecraft would not be launched, so no impacts to biological and natural resources would occur under the No Action Alternative.

3.11.2.2 Proposed Action

Within the expanded ROI of this SEIS, potential impacts to biological and natural resources from normal launches and launch accidents resulting in no nuclear material releases would not be substantially different from those presented and analyzed in Section 4.1.2.7 of the 2014 FEIS. This section describes potential impacts from the release of radioactive material associated with a launch-related accident for these resources: vegetation, wetlands, and terrestrial wildlife; aquatic resources (including marine biological resources); threatened or endangered species; and sensitive habitats.

Estimated spatial dispersion of radiological contamination levels within the nine-county area would depend on specifics of the accident, launch phase, weather, and wind conditions at the time of the event. However, as discussed in Section 3.5 (Health and Safety), the land area potentially measuring more than 0.2 $\mu Ci/m^2$ of radioactivity from a launch vehicle accident resulting in a release affecting U.S. land areas would be between 7.4 km^2 (2.9 mi^2) during Phase 0 and 79 km^2 (31 mi^2) from a launch vehicle accident with release in Phase 1 (early launch). Land areas exceeding recommended exposure levels would potentially need further action, such as monitoring or cleanup (see Section 3.5).

The potential for launch accidents that would result in the loss of containment of the radioactive power source and subsequent release of plutonium dioxide was re-evaluated in the 2019 NRA Update. Changes in the launch-related probabilities (presented in Table 2.4-1) show that the overall probability of a launch-related accident is less likely than what was analyzed in the 2014 FEIS (2.5 percent in 2014 and 1.25 percent in 2019). However, the overall probability of an early launch area accident with a release of plutonium dioxide increased by about a factor of 10 (e.g., increasing from about 1 in 11,000 to about 1 in 1,100). The accidental release of plutonium dioxide from the spacecraft's radioactive power source could result in radiation exposure to biological and natural resources in the ROI, resulting in various radioactive impacts. Appendix B of the 2014 FEIS describes the factors that influence the movement and transport of plutonium dioxide through the environment in the event of a release during a launch accident as well as typical exposure impacts associated with various biota and media.

Overall, NASA finds that, while the area of potential impact is estimated to be larger than that identified in the 2014 FEIS, the potential for adverse impact to vegetation, wetlands, and terrestrial wildlife from a launch-related accident resulting in radiological material release remains essentially the same as discussed in the 2014 FEIS. This conclusion is based on the following factors: 1) the overall probability of an early launch accident with a release of plutonium is small, and 2) there is no indication that exposure levels resulting from an accident with release would result in substantive adverse impacts to vegetation, wetlands, and terrestrial wildlife; aquatic resources (including marine biological resources); threatened or endangered species; and sensitive habitats. Mitigations and monitoring requirements described in the 2014 FEIS and the 2015 ROD remain applicable and would be expected to further reduce the potential for, and scope of, any identified impacts.

Vegetation, Wetlands, and Terrestrial Wildlife Impacts

As described in Appendix B of the 2014 FEIS, plutonium dioxide is insoluble and poorly transported in terrestrial environments. It is primarily removed from biological pathways by processes such as stabilization in the soil, leaving very small amounts potentially available for accumulation into vegetation and subsequent bioaccumulation from consumption by wildlife. Additionally, dispersal of the plutonium dioxide particles via atmospheric conditions is not likely to result in distributions that would allow for concentrated exposure away from the launch area. Studies on radiological impacts to flora and fauna populations surrounding facilities that process, store, or conduct testing on large amounts of radioactive materials, including plutonium-239, uranium-238, and barium-140, have shown that concentrations of these radionuclides in surrounding soils were not sufficient to result in negative impacts to plant or animal populations (DOE 2013, DOE 2018). These studies used the RESRAD-BIOTA code (http://resrad.evs.anl.gov/codes/resrad-biota/) developed by the DOE, EPA, and Nuclear Regulatory Commission as a standardized screening and analysis methodology that consists of a graded approach for evaluating radiation doses to aquatic and terrestrial biota (Yu et al. 2002, DOE 2019, DOE 2002b).

There are three tiers of analysis in the graded approach. The first step (Level 1) is a general screening level that provides generic limiting concentrations of radionuclides in environmental media called Biota Concentration Guides (BCGs), which represents the environmental concentration of a given radionuclide in soil or water that would result in a minimum dose rate for terrestrial plants and animals. If the minimum dose rate is not exceeded during the Level 1 screening process, then negative impacts to plant or animals are not expected. If the minimum dose rate is exceeded in the initial screening process, then more realistic dose calculations are conducted using more site- and organism-specific input data (Level 2 and Level 3 screening). Failure at the Level 1 screening does not necessarily mean harm to plants or animals would occur, but it is an indication that more realistic model inputs are needed to assess the actual dose rate. The BCGs around the DOE facilities investigated in the previously mentioned studies were not exceeded at the Level 1 screening, which led to the conclusion that surrounding plants and animals were not negatively impacted by long-term continuous releases of small amounts of radioactive material.

The amount of nuclear material potentially released during a launch accident would be an isolated event or single exposure to plants and animals in the expanded ROI. Based on the findings from DOE studies that analyzed impacts to terrestrial plants and animals from long-term exposure (DOE 2013, DOE 2018), concentrations of nuclear material in the ROI from a launch accident would be miniscule, and associated impacts would be similarly negligible. A larger area of vegetation, wetlands, and occupying terrestrial wildlife may be exposed to radiological impacts from a launch accident, but the resulting effects would be discountable. Refer to Section 3.8.2 (Geology and Soils, Environmental Consequences) and Section 3.9.2 (Water Resources, Environmental Consequences) for descriptions of impacts to soils and wetlands from the Proposed Action, respectively.

Aquatic Resources Impacts

As indicated in Appendix B of the 2014 FEIS, radiation doses can result from the bioaccumulation of plutonium deposited on surface waters. The availability of plutonium is dependent on dilution and partitioning between the water and underlying sediments. Larger particles would sink to the floor, while smaller particles would float within the water column, and the smallest particles would likely form a thin layer on top of the water surface. Aquatic species that feed within and occupy the water column have the potential to encounter trace amounts of plutonium dioxide that could be released during a launch accident. Some plutonium dioxide would partition into the sediments, which could get re-suspended into the water column from natural processes such as tides or currents, as well as foraging activities of bottom-feeding marine species. Recreational activities, including fishing, boating, and swimming may disturb sediments and re-suspend plutonium dioxide particles into the water column. But resuspension would be temporary as particles would settle to the bottom once the disturbance ceased.

Overall, plutonium dioxide concentrations in aquatic and marine environments are expected to be less than those in terrestrial environments as described above, primarily due to the high rates of dilution and wave action that would disperse the material and transport it across large geographic areas. Additionally, aquatic and marine species may encounter and feed within areas where plutonium dioxide has been released during an accident, but concentrations would not be sufficient to result in a discernible direct impact or indirect bioaccumulation effect.

While a larger area with aquatic resources may be exposed to radiological impacts from a launch accident, the resulting effects are insignificant. Furthermore, updated analysis indicates that, while the overall probability of a launch-related accident under the Proposed Action has decreased from that stated in the 2014 FEIS, should an accident occur, the probability of a release of nuclear material has increased slightly (a 0.06-percent probability increase; see Section 3.5, Health and Safety, for more details). Therefore, impacts to aquatic resources would not substantially differ compared to those discussed in the 2014 FEIS.

Threatened and Endangered Species Impacts

Threatened and endangered species in the ROI would be exposed to the same impacts as those described for terrestrial wildlife and aquatic resources in the preceding subsections, which would not substantially differ from those described in the 2014 FEIS. In the 2014 FEIS, NASA relied on and referenced USAF and KSC ESA Section 7 consultations that were already in place. NASA sought comment from the USFWS as it prepared the 2014 FEIS. USFWS reviewed both the 2014 Draft EIS and 2014 FEIS and indicated no objections to the Proposed Action. Impacts from nominal launch activities at SLC-41 have previously been addressed under USAF consultations with the USFWS. Most recently, the 45th Space Wing at CCAFS completed an informal consultation with the USFWS office in April 2019 (FWS Log No. 2019-1-0544) for launching the Vulcan Centaur launch vehicles from SLC-41 at CCAFS. Under that consultation, the USFWS concurred with the USAF determination that the launch activity at SLC-41 may affect, but is not likely to adversely affect resources protected under the ESA.

Based on NASA's review of past environmental documentation, previous consultations with the USFWS and NMFS, and direct observations of current and past launch operations, NASA has determined that implementation of the Proposed Action (a nominal launch event) as described in the 2014 FEIS, as supplemented in this SEIS, may affect, but is not likely to adversely affect resources protected under the ESA. The probability of a launch accident is highly unlikely, and the probability of a launch accident that involves a release of radiological material into the environment that results in an adverse effect to threatened or endangered species is even lower. As noted above, the USFWS has recently concurred on the effect to listed species from similar USAF launch operations from the same location. In the unlikely event of an off-nominal launch event 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 402.05.

Sensitive Habitats Impacts

Impacts to sensitive habitats from a launch accident that resulted in a release of plutonium dioxide would be similar to those presented in the previous subsections.

Radioactive material may be deposited onto larger areas of sensitive terrestrial habitats such as wetlands, USFWS-designated critical habitat, wildlife management areas, National Estuarine Research Areas, and sensitive ecological areas designated by the state. Refer to Section 3.9.2 (Water Resources, Environmental Consequences) for impacts to wetlands, Section 3.8.2 (Soils and Geology, Environmental Consequences) for impacts to soils, and Section 3.6.2 (Land Use, Environmental Consequences) for impacts to wildlife management areas, sensitive ecological areas, and refuges. Overall, concentrations of radionuclides potentially deposited on sensitive terrestrial habitats from a launch accident are not expected to exceed concentration levels that would result in a negative impact to biota supported by these habitat areas. Refer to the *Vegetation, Wetland, and Terrestrial Wildlife Impacts* section above. Therefore, the Proposed Action may affect, but would not adversely modify USFWS-designated critical habitat discussed in Section 3.11.1 (Biological and Natural Resources, Affected Environment).

Sensitive aquatic habitats include aquatic preserves, EFH, and NMFS-designated critical habitat in the Atlantic Ocean. In the unlikely event of a launch accident that results in a release of radiological material, larger particles of plutonium dioxide would sink to the floor while smaller particles would float either on top of the water surface or within the water column. For larger particles that would sink to the sediments, binding of plutonium dioxide typically only occurs in the first few centimeters, especially for sediments consisting of clay, organics, and other anionic constituents (see Appendix B of the 2014 FEIS). Given the larger ROI considered in this analysis, concentrations of plutonium dioxide would not be significant and would not result in a discernible radiological effect on sensitive aquatic habitats. Therefore, the Proposed Action may affect, but would not adversely modify NMFS-designated critical habitat discussed in Section 3.11.1 (Biological and Natural Resources, Affected Environment). The USAF completed a programmatic consultation with NMFS on EFH regarding Atlas V and Delta IV launches from CCAFS (USAF 2000). The Proposed Action would be covered by this consultation for EFH considerations.

In summary, impacts to sensitive habitats would not substantially differ compared to those discussed in the 2014 FEIS.

3.12 SOCIOECONOMICS AND CHILDREN'S ENVIRONMENTAL HEALTH AND SAFETY

3.12.1 Affected Environment

This section corresponds to Section 3.1.7 of the 2014 FEIS. Similar to the 2014 FEIS, this section considers the nine surrounding counties of CCAFS, which include Brevard, Flagler, Indian, Lake, Orange, Osceola, Polk, Seminole, and Volusia Counties. The socioeconomics resources in this region include the population, economy, transportation system, public and emergency services, and recreational opportunities. Under EO 13045, *Protection of Children from Environmental Health Risks and Safety*

Risks, dated April 23, 1997, Federal agencies are encouraged to consider potential impacts of proposed actions on the safety or environmental health of children.

Changes to ROI Since 2014 FEIS

Population

The 2014 FEIS focused on the population of the surrounding counties of CCAFS and KSC, which include Brevard, Flagler, Indian, Lake, Orange, Osceola, Polk, Seminole, and Volusia Counties. Similar to the 2014 FEIS, this SEIS considers the same nine counties. Following the same methodology as the 2014 FEIS, this SEIS uses the most recent population estimates from the American Community Survey (ACS) One-Year Estimates for 2017. Updated estimates for the 2020 populations living in the nine counties were obtained as linear projections of resident populations for the years 2010 and 2017.

Table 3.12-1 presents the most recent ACS one-year population estimates for the nine-county region and projected populations for 2020. As shown in Table 3.12-1, the 2017 population estimates for several counties have already exceeded the projected 2020 population estimates that were presented in the 2014 FEIS.

Table 3.12-1. Population of the Nine-County Region

Geographic Area	Census Population 2010	Projected Population 2012 (2014 FEIS)	Projected Population 2020[(a)] (2014 FEIS)	Projected Population 2017 (2019 SEIS)	Projected Population 2020[(a)] (2019 SEIS)
Florida	18,801,310	19,317,568	21,528,304	20,984,400	21,995,966
County					
Brevard	543,376	547,307	563,317	589,162	609,947
Flagler	95,696	98,359	109,773	110,510	117,541
Indian River	138,028	140,567	151,199	154,383	161,973
Lake	297,052	303,186	329,015	346,017	369,400
Orange	1,145,956	1,202,234	1,456,375	1,348,975	1,446,646
Osceola	268,685	287,416	376,341	352,180	395,486
Polk	602,095	616,158	675,772	686,483	726,178
Seminole	422,718	430,838	464,908	462,659	480,912
Volusia	494,593	496,950	506,491	538,692	558,775
Nine-County Region	4,008,119	4,123,015	4,633,191	4,589,061	4,866,858

Source: (USCB 2017a)

Note:

(a) Projected population values do not represent absolute limits to growth. For any geographic area, the future population may be above or below the projected value; numbers and percentages may be subject to rounding errors.

Key: FEIS = Final Environmental Impact Statement; SEIS = Supplemental Environmental Impact Statement.

The nearest community to CCAFS is the city of Cape Canaveral with a population of approximately 10,449. Other nearby communities to CCAFS include Titusville to the northwest and the unincorporated area of Merritt Island to the west, with populations of approximately 46,497 (USCB 2018) and 36,380 (USCB 2017c), respectively. To the south of CCAFS are Cocoa Beach with a population of 11,737, Palm Bay with a population of 114,194, and Melbourne City with a population of 82,826 (USCB 2018). Cocoa Beach experienced the least amount of growth since 2010 census (approximately 4.51 percent), while Palm Bay experienced the largest population growth since 2010 (over 10 percent) (USCB 2017c, USCB 2018).

Table 3.12-2 presents the minority population in 2010 and the projected total populations for 2017 and 2020 for each of the nine counties. The projected percent minority population presented in the 2014 FEIS for Florida was 23.7 percent, and the updated projected percent minority population for this SEIS is 24.9 percent. The minority population projected in the 2014 FEIS for the nine-county region was 24.1 percent, compared to 26 percent shown in Table 3.12-2 for this SEIS.

Table 3.12-3 presents poverty estimates as presented in the 2014 FEIS along with poverty estimates for this SEIS from the most recent ACS population estimates for the nine-county region, the state, and the nation. As shown in Table 3.12-3, 13.5 percent of the population living within the nine-county region reported incomes below the poverty threshold, which is lower than those reported in Florida (14.0 percent) but nearly the same as the United States (13.4 percent) (USCB 2017b).

Table 3.12-2. Minority Population of the Nine-County Region

Geographic Area	Minority Population 2010	Percent Minority 2010	Projected Minority Population 2017[(a)]	Projected Percent Minority 2017	Projected Minority Population 2020[(a)]	Projected Percent Minority 2020
Florida	4,692,148	25.0%	5,216,085	24.9%	5,467,530	24.9%
County						
Brevard	92,449	17.0%	105,022	17.8%	108,727	17.8%
Flagler	16,986	17.7%	19,381	17.5%	20,614	17.5%
Indian River	21,682	15.7%	20,191	13.1%	21,184	13.1%
Lake	53,428	18.0%	66,688	19.3%	71,195	19.3%
Orange	417,161	36.4%	517,507	38.4%	554,977	38.4%
Osceola	78,044	29.0%	100,779	28.6%	113,171	28.6%
Polk	149,241	24.8%	154,079	22.4%	162,988	22.4%
Seminole	92,054	21.8%	105,262	22.8%	109,415	22.8%
Volusia	86,337	17.5%	101,562	18.9%	105,348	18.9%
Nine-County Region	1,007,382	25.1%	1,190,471	26.0%	1,267,619	26.0%

Source: (USCB 2017a)

Note:

(a) Projected population values do not represent absolute limits to growth. For any geographic area, the future population may be above or below the projected value; numbers and percentages may be subject to rounding errors.

Table 3.12-3. Low-Income Population of the Nine-County Region

Geographic Area	Census Population 2010 (2014 FEIS)	ACS One-Year Population 2017 (2019 SEIS)
Florida	14.7%	14.0%
United States	14.3%	13.4%
County		
Brevard	13.7%	12.3%
Flagler	13.3%	14.2%
Indian River	13.4%	8.7%
Lake	11.4%	13.0%
Orange	14.9%	15.4%
Osceola	13.9%	14.1%
Polk	16.4%	16.0%
Seminole	10.0%	11.5%
Volusia	15.0%	15.1%
Nine-County Region	13.7%	13.5%

Source: (USCB 2017b)

Key: ACS = American Community Survey; FEIS = Final Environmental Impact Statement; SEIS = Supplemental Environmental Impact Statement.

Economy

The most recent estimates of total full-time and part-time employment (number of jobs) throughout the nine-county region totaled 2,560,532 (BEA 2018). The 2014 FEIS reported that in 2012, 1,858,000 people throughout the nine-county region had jobs with an estimated unemployment rate of 8.8 percent. The 2018 annual average, the most recent labor force data by county provided by the Bureau of Labor Statistics (BLS), reported a total of approximately 2.2 million people employed throughout the nine-county region with an unemployment rate of 3.5 percent (BLS 2018).

The region's economic base continues to be tourism and manufacturing. Approximately 1.693 million tourists visited the KSC Visitor Complex, of which 1.4 million (82.6 percent) were from out of state and spent $110.1 million during fiscal year 2017 (NASA 2017). Port Canaveral also continues to contribute to the central Florida economy, supporting over 21,000 direct, induced, and indirect jobs related to cargo, cruise, marinas, and real estate; over $1.1 billion in income; $2.156 billion in business revenue; and almost $100 million in state and local taxes (Canaveral Port Authority 2017).

Industrial sections in the region that provide significant employment in 2017 include retail trade; health care and social assistance; accommodation and food services; administrative and support; waste management; and government and government enterprises (BEA 2018).

The 45th Space Wing at Patrick AFB, located approximately 32 km (20 mi) south of CCAFS, is responsible for mission support to "assure success of the wing's launch, range and expeditionary operations and provides comprehensive support to the wing's mission partners" (Patrick AFB 2017). The wing has 15,537 personnel, which includes 3,951 active-duty and reservists/Air National Guard, 5,931 civilian and contractor employees, and 6,195 family members (Patrick AFB 2017).

NASA and KSC continue to be an important economic driver to the state of Florida and to Brevard County. During fiscal year 2017, total spaceport operations in Florida supported 23,753 jobs, generated $1.6 billion in income and added $2.2 billion to Florida's gross domestic product for an overall total economic impact of $3.9 billion in the state, of which $3 billion (approximately 77 percent) was in Brevard County (NASA 2017). For every dollar of direct output spent at KSC, an additional $0.92 of statewide output was generated (NASA 2017).

Transportation Systems

As part of Florida's transportation system, the nine-county region's transportation system includes roadway, air, rail, sea, spaceports, bus transit, and bicycle and pedestrian facilities (FDOT 2019). County general highway maps are available on the Florida Department of Transportation's website located at https://www.fdot.gov/geospatial/countymap.shtm.

Public and Emergency Systems

Public and emergency systems discussed in the 2014 FEIS are still applicable. Fire protection and emergency management and emergency medical services at CCAFS are provided by Centerra Group, LLC. The existing five-year contract was awarded to Centerra in 2016 and will run through 2021 (Homeland Security Today 2016). Centerra operates three fire stations that provide fire and emergency services for the entire 15,000-acre restricted-access site.

Advanced notifications to the public of potential closed areas and airspace during launch activities are provided via "Notice to Mariners" and "Notice to Aviators" issued by the USAF, along with marine radio broadcast warnings issued by the U.S. Coast Guard, and warning signs posted in various Port Canaveral areas. There is also a website and toll-free number with launch hazard area information maintained by Patrick AFB.

The City of Cocoa provides water to CCAFS (City of Cocoa 2015). The water distribution system at CCAFS is sized to accommodate the short-term, high-volume flows during launches.

Recreation

The nine-county region has an abundance of public recreational opportunities with beaches, waterways, lakes, open land, and parks. Within the confines of CCAFS, access to recreational areas and facilities is limited to CCAFS personnel. For the public, tours of several facilities located on CCAFS, including stops at the Cape Canaveral Lighthouse, Air Force Space and Missile History Center, and two historic launch complexes, as well as Exploration Tower at Port Canaveral, are offered on Fridays and Saturdays with advanced reservations and limited to people of age 12 and older (Florida Space Coast Office of Tourism 2019).

Due to the many recreational opportunities available to the public outside the installation boundaries, public demand for outdoor recreational use at CCAFS is low. "Restricted Areas" exist within CCAFS for badged personnel and their guests. Recreational activities at CCAFS available for authorized personnel include jogging paths, volleyball, racquetball, and basketball courts. There is also a pavilion located on CCAFS with areas for barbecues, horseshoes, and a softball field (Patrick AFB 2015).

Protection of Children from Environmental Health Risks and Safety Risks

The nearest location to the proposed launch area with a moderate concentration of children identified in the 2014 FEIS was the KSC Child Development Center. The center, which offers curriculum for infants as young as six weeks old to pre-school students aged five years old (KSCCDC 2018) is located approximately 10.78 km (6.7 mi) from the launch site and continues to be the closest school/day care to the launch site. Other areas nearby the launch site at CCAFS that may be likely to have a high concentration of children include a public beach access located 9.3 km (5.8 mi) to the north northwest; Kars Park in Merritt Island located 17.9 km (11.1 mi) to the south southwest; Comprehensive Health Services medical facility in Cape Canaveral located 20 km (12.4 mi) to the south; Parrish Medical Center in Titusville located 15 miles to the west; and Manatee Hammock Park in Titusville located 21.2 km (13.2 mi) to the west-southwest.

3.12.2 Environmental Consequences

3.12.2.1 No Action Alternative

The No Action Alternative addressed in this SEIS would be the same as described in the 2014 FEIS. NASA would discontinue preparations for the Mars 2020 mission, and the spacecraft would not be launched. Thus, potential impacts to socioeconomics and children’s environmental health and safety under the No Action Alternative would be the same as what was evaluated in the 2014 FEIS, and there would be no environmental impacts associated with the No Action Alternative, including any environmental impacts associated with potential launch-related accidents or radiological risks associated with potential launch accidents.

3.12.2.2 Proposed Action

Updated analysis indicates that while the overall probability of a launch-related accident under the Proposed Action has decreased as compared to the 2014 FEIS, should an accident occur, the probability of a release of nuclear material has increased slightly (a 0.06-percent probability increase). See Section 3.5 (Health and Safety) for more detail. Additionally, a potential release would potentially affect a larger land area. However, estimated spatial dispersion of radiological contamination levels within the nine-county area would depend on specifics of the accident, launch phase, weather, and wind conditions at the time of the event. As described in Section 3.5 (Health and Safety), using the screening level of 0.2 $\mu Ci/m^2$, an area of radiological deposition could occur within an area encompassing an estimated 79 km^2 (31 mi^2), depending on the stage and type of the launch accident. Should such an unlikely event occur, that area would be subject to further evaluation for potential radiological impacts. Land areas exceeding recommended exposure levels would potentially need further action, such as monitoring or cleanup (see Section 3.5).

In the event of an accident resulting in a plutonium dioxide release, there would be potential for adverse impacts to socioeconomic factors and children's environmental health and safety. There would be potential for direct and indirect costs following an accident that may be incurred as a result of a radiological release on the environment (see Section 2.4.3.1.1, Accident Probabilities and Consequences). The costs from radiological releases could affect real estate values, tourism, croplands, and recreational activities, which would in turn result in adverse impacts to socioeconomic factors, including demography, employment, and income. The potential socioeconomic impacts and costs of an accident are difficult to quantity and could vary widely, depending on many situational factors associated with dispersion and concentrations.

Some areas have high value for a particular use, due to their intrinsic or societal value, and so are specifically sensitive to degradation. Examples include nearby theme/amusement parks, state and national parks, monuments, seashores, and wildlife areas. An impact that disrupts access to these areas or their environmental qualities for longer periods could have lasting effects. If use is prevented for extended times, it can change the choices people make when selecting areas to use for vacationing and recreation, for example. These areas have distinctive qualities and contribute greatly to the regional economy. Loss or degradation of a special use area would cause impacts that vary from a minor to high impact on the particular area affected due to high land resource value. Remediation or redevelopment could lessen the long-term impact on these special areas.

While economic impacts are difficult to quantify due to many unknown factors, it is assumed that because the 2019 ROI is larger area than in 2014, it would be anticipated that any direct or indirect costs incurred resulting from an accident resulting in radiological release would be higher than previously anticipated. As described in Section 2.6.2.3.2 of the 2014 FEIS, the DOE retains title and responsibility for the MMRTG, and thus the Price-Anderson Act of 1957 as amended (42 U.S.C. 2210) would be applicable and affected persons within or outside the United States would be eligible for compensation for damages to or loss of property arising from the nuclear incident under the Act's provisions.

Potential health impacts to the public could result if, in the event of a launch accident, plutonium dioxide from the MMRTG is released. Section 3.5.2.2.6 (Mission Risks) describes mission risks to the global population and to individuals. As stated in that section, the total probability of a health effect within the regional population estimated for this SEIS is about 1 in 3,000 (66 percent of the total risk of the entire launch event) compared to about 1 in 61,000 (57 percent of the total risk of the entire launch event) computed for the 2014 FEIS. Not everyone within the 100 km (62 mi) or nine-county area would be impacted since exposure would depend upon several factors (e.g., weather, location of the accident, locations of persons within the area). The risk of contracting a fatal cancer for an individual within the affected population from receipt of the maximum individual dose is considered very small (less than 1 in several million) for the Mars 2020 mission (see Section 3.5.2.2.5, Radiological Consequences). The analysis also estimates that for less than 0.10 percent of the time, a launch could result in an accident with the release of plutonium dioxide but typically not in a quantity large enough to result in discernible radiological consequences. Since children are more vulnerable to environmental risks than adults, exposure to plutonium dioxide from the MMRTG could have greater adverse health consequences to a child than to an adult. To minimize the risks to the public of all ages, range safety considerations along with radiological contingency response planning have been developed and would be implemented. Section 4.1.5 of the 2014 FEIS describes the radiological contingency response planning that would be implemented prior to launch of the Mars 2020 mission. As part of the response planning and standard operating procedures, local emergency centers would provide advanced notification to citizens on how to respond in an emergency situation.

3.13 ENVIRONMENTAL JUSTICE

3.13.1 Affected Environment

This section corresponds to Appendix C of the 2014 FEIS and covers environmental justice baseline information and impact analysis.

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

The CEQ has oversight responsibility for documentation prepared in compliance with NEPA as amended (42 U.S.C. 4321 et seq.). In December 1997, the CEQ released its guidance on environmental justice (CEQ 1997). The CEQ's guidance was adopted as the basis for the information provided in the 2014 FEIS and this SEIS.

This section provides data necessary to assess the potential for disproportionately high and adverse human health or environmental effects on minority and low-income populations that may be associated with implementation of the Mars 2020 mission. The areas examined in this section include the counties for which any part of the county is within 100 km (62 mi) of CCAFS: Brevard, Flagler, Indian River, Lake, Orange, Osceola, Polk, Seminole, and Volusia Counties (see Figure 1.1-1).

Definitions

Minority. During the 2010 census, the U.S. Census Bureau (USCB) collected population data in compliance with guidance adopted by the Office of Management and Budget (62 FR 58782). The following definitions of minority individuals and populations are used in this analysis of environmental justice.

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

Minority Population. The minority population is the total number of minority individuals residing within a potentially affected area. Persons self-designated as Hispanic or Latino are included in the Hispanic or Latino population regardless of race. For example, Asians self-designated as Hispanic or Latino are included in both the Hispanic or Latino population and in the Asian population. To characterize minority populations in the 2014 FEIS, data from 2010 and 2012 were extracted from the American Fact Finder portion of the 2010 census website containing Census 2010 demographic data. Data used for the projection of population groups in Florida for 2020 were projected from the 2010 and 2012 (projected) census data for the nine surrounding counties. For this SEIS, the same methodology was used, but data used for the projection of population groups in Florida for 2020 were projected from the 2010 and the most recent American Fact Finder demographic data, 2017 (projected) census, for the nine surrounding counties.

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

Low-Income Individuals. Persons whose self-reported income is less than the poverty threshold for a given year are considered to be low-income individuals.

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

Data used to characterize low-income populations in 2017 were extracted from the American Fact Finder portion of the ACS one-year estimate (USCB 2017b).

Disproportionately High and Adverse Human Health Effects. Disproportionately high and adverse health effects are those that are significant (40 CFR 1508.27) or above generally accepted norms, and for which the risk of adverse impacts to minority populations or low-income populations appreciably exceeds the risk to the general population.

Disproportionately High and Adverse Environmental Effects. Disproportionately high and adverse environmental effects are those that are significant (40 CFR 1508.27), and that would adversely impact minority populations or low-income populations appreciably more than the general population.

Changes to ROI Since 2014 FEIS

Similar to the 2014 FEIS, the analysis of environmental justice impacts uses county level data.

The census estimates for population groups living in the nine counties of interest closest to CCAFS for 2010 and 2017 are shown in Table 3.13-1. Estimates for the 2020 populations living in the nine counties were obtained as linear projections of resident populations for 2010 and 2017. Table 3.13-1 also shows estimates from the 2014 FEIS, which used the same methodology, but for 2010 and 2012.

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

Approximately 4,008,199 people lived in the nine counties in 2010 (Table 3.13-1). As presented in the 2014 FEIS, between 2010 and 2012, the minority population declined and was approximately 24 percent of the total population in 2012. Based on 2010 and 2012 projections, by 2020, the total population was estimated to reach over 4.63 million, of which approximately 24.1 percent would be minority population. Updated projections for 2020, based on 2010 and 2017 population estimates, indicate that the population throughout the nine-county region will reach over 4.86 million, of which 26 percent would be minority population. The largest minority groups within the nine-county region continues to be persons that identified themselves as “Hispanic or Latino” and “Black or African American” (USCB 2017a). Orange County continues to have the greatest proportion of minority population of the nine counties, with approximately 38.4 percent of the total county population (USCB 2017a).

As shown in Table 3.12-3 in Section 3.12 (Socioeconomics and Children’s Environmental Health and Safety), the 13.5 percent of the nine-county region population reported incomes below the poverty threshold compared to 14.0 percent of the total population throughout the state and 13.4 percent in the nation (USCB 2017b). The proportion of the low-income population throughout the nine-county region, the state, and the nation has declined since 2010, in which 13.7 percent of the population living within the nine counties reported incomes below the poverty threshold; Florida reported 14.7 percent, and the United States reported 14.3 percent. Table 3.13-2 through Table 3.13-10 present the composition of the population for each of the nine counties, respectively.

Table 3.13-1. Composition of the Population in the Nine-County Area

Population	2010 (2014 FEIS)	2012 (2014 FEIS)	2020[a] (2014 FEIS)	2017 (2019 SEIS)	2020[b] (2019 SEIS)
Total	**4,008,199**	**4,123,015**	**4,633,191**	**4,589,061**	**4,866,858**
White alone	3,000,817	3,150,914	3,517,600	3,398,590	3,599,239
Black or African American alone	563,524	597,053	682,502	653,587	693,894
American Indian and Alaska Native alone	16,119	10,080	11,225	16,542	17,569
Asian alone	117,240	123,613	142,107	148,969	158,288
Native Hawaiian and Other Pacific Islander alone	3,221	3,574	3,741	4,484	4,776
Some other race alone	194,124	134,859	158,873	214,796	230,220
Two or more races	113,154	102,912	117,142	134,093	142,658
Hispanic or Latino	768,264	840,134	979,685	1,084,781	1,161,699
Percent minority	25.1%	23.6%	24.1%	26.0%	26.0%
Percent low income	13.7%	---	---	13.5%	---

Sources: (USCB 2017a, USCB 2017b, USCB 2017d)

Notes:

(a) Projected based on increase in total population by county between 2010 and 2012.

(b) Projected based on increase in total population by county between 2010 and 2017; numbers and percentages may be subject to rounding errors.

Key: FEIS = Final Environmental Impact Statement; SEIS = Supplemental Environmental Impact Statement.

Table 3.13-2. Composition of the Population in Brevard County

Population	2010 (2014 FEIS)	2012 (2014 FEIS)	2020[(a)] (2014 FEIS)	2017 (2019 SEIS)	2020[(b)] (2019 SEIS)
Total	**543,376**	**547,307**	**563,317**	**589,162**	**609,947**
White alone	450,927	456,906	470,272	484,140	501,220
Black or African American alone	54,799	55,223	56,838	57,969	60,014
American Indian and Alaska Native alone	2,118	1,146	1,180	2,896	2,998
Asian alone	11,349	12,279	12,638	14,471	14,982
Native Hawaiian and Other Pacific Islander alone	514	2,519	2,593	1,146	1,186
Some other race alone	9,299	5,658	5,824	12,445	12,884
Two or more races	14,370	13,576	13,973	16,095	16,663
Hispanic or Latino	43,943	47,891	49,292	61,221	63,381
Percent minority	17.0%	16.5%	16.5%	17.8%	17.8%
Percent low income	13.7%	---	---	12.3%	---

Sources: (USCB 2017a, USCB 2017b, USCB 2017d)

Notes:

(a) Projected based on increase in total population by county between 2010 and 2012.

(b) Projected based on increase in total population by county between 2010 and 2017; numbers and percentages may be subject to rounding errors.

Key: FEIS = Final Environmental Impact Statement; SEIS = Supplemental Environmental Impact Statement.

Table 3.13-3. Composition of the Population in Flagler County

Population	2010 (2014 FEIS)	2012 (2014 FEIS)	2020[(a)] (2014 FEIS)	2017 (2019 SEIS)	2020[(b)] (2019 SEIS)
Total	**95,696**	**98,359**	**109,773**	**110,510**	**117,541**
White alone	78,710	77,874	86,911	91,129	96,927
Black or African American alone	10,884	11,999	13,391	11,965	12,726
American Indian and Alaska Native alone	267	0	0	307	327
Asian Alone	2,046	2,174	2,426	3,064	3,259
Native Hawaiian and Other Pacific Islander alone	59	64	71	0	0
Some other race alone	1,544	4,058	4,529	2,761	2,937
Two or more races	2,186	2,190	2,444	1,284	1,366
Hispanic or Latino	8,251	8,705	9,715	11,546	12,281
Percent minority	17.7%	20.8%	20.8%	17.5%	17.5%
Percent low income	13.3%	---	---	14.2%	---

Sources: (USCB 2017a, USCB 2017b, USCB 2017d)

Notes:

(a) Projected based on increase in total population by county between 2010 and 2012.

(b) Projected based on increase in total population by county between 2010 and 2017; numbers and percentages may be subject to rounding errors.

Key: FEIS = Final Environmental Impact Statement; SEIS = Supplemental Environmental Impact Statement.

Table 3.13-4. Composition of the Population in Indian River County

Population	2010 (2014 FEIS)	2012 (2014 FEIS)	2020[(a)] (2014 FEIS)	2017 (2019 SEIS)	2020[(b)] (2019 SEIS)
Total	**138,028**	**140,567**	**151,199**	**154,383**	**161,973**
White alone	116,346	120,669	129,796	134,192	140,789
Black or African American alone	12,397	12,825	13,795	13,257	13,909
American Indian and Alaska Native alone	408	0	0	179	188
Asian Alone	1,666	1,807	1,944	1,729	1,814
Native Hawaiian and Other Pacific Islander alone	51	0	0	0	0
Some other race alone	4,909	3,080	3,313	985	1,033
Two or more races	2,251	2,186	2,351	4,041	4,240
Hispanic or Latino	15,465	15,970	17,178	19,285	20,233
Percent minority	15.7%	14.2%	14.2%	13.1%	13.1%
Percent low income	13.4%	---	---	8.7%	---

Sources: (USCB 2017a, USCB 2017b, USCB 2017d)

Notes:

(a) Projected based on increase in total population by county between 2010 and 2012.

(b) Projected based on increase in total population by county between 2010 and 2017; numbers and percentages may be subject to rounding errors.

Key: FEIS = Final Environmental Impact Statement; SEIS = Supplemental Environmental Impact Statement.

Table 3.13-5. Composition of the Population in Lake County

Population	2010 (2014 FEIS)	2012 (2014 FEIS)	2020[(a)] (2014 FEIS)	2017 (2019 SEIS)	2020[(b)] (2019 SEIS)
Total	**297,052**	**303,186**	**329,015**	**346,017**	**369,400**
White alone	243,624	254,060	275,704	279,329	298,205
Black or African American alone	29,103	30,197	32,770	38,850	41,475
American Indian and Alaska Native alone	1,472	993	1,078	1,239	1,323
Asian alone	5,173	4,525	4,910	7,868	8,400
Native Hawaiian and Other Pacific Islander alone	215	267	290	357	381
Some other race alone	10,778	5,945	6,451	12,773	13,636
Two or more races	6,687	7,199	7,812	5,601	5,979
Hispanic or Latino	36,009	39,299	42,647	53,353	56,958
Percent minority	18.0%	16.2%	16.2%	19.3%	19.3%
Percent low income	11.4%	---	---	13.0	---

Sources: (USCB 2017a, USCB 2017b, USCB 2017d)

Notes:

(a) Projected based on increase in total population by county between 2010 and 2012.

(b) Projected based on increase in total population by county between 2010 and 2017; numbers and percentages may be subject to rounding errors.

Key: FEIS = Final Environmental Impact Statement; SEIS = Supplemental Environmental Impact Statement.

Table 3.13-6. Composition of the Population in Orange County

Population	2010 (2014 FEIS)	2012 (2014 FEIS)	2020[(a)] (2014 FEIS)	2017 (2019 SEIS)	2020[(b)] (2019 SEIS)
Total	**1,145,956**	**1,202,234**	**1,456,375**	**1,348,975**	**1,446,646**
White alone	728,795	777,502	941,859	831,468	891,669
Black or African American alone	238,241	256,542	310,773	286,324	307,055
American Indian and Alaska Native alone	4,532	1,874	2,270	2,743	2,942
Asian alone	56,581	57,438	69,580	69,335	74,355
Native Hawaiian and Other Pacific Islander alone	1,266	100	121	1,623	1,741
Some other race alone	77,216	72,607	87,955	107,587	115,377
Two or more races	39,325	36,171	43,817	49,895	53,508
Hispanic or Latino	308,244	339,202	410,906	423,707	454,385
Percent minority	36.4%	35.3%	35.3%	38.4%	38.4%
Percent low income	14.9%	---	---	15.4%	---

Sources: (USCB 2017a, USCB 2017b, USCB 2017d)

Notes:

(a) Projected based on increase in total population by county between 2010 and 2012.

(b) Projected based on increase in total population by county between 2010 and 2017; numbers and percentages may be subject to rounding errors.

Key: FEIS = Final Environmental Impact Statement; SEIS = Supplemental Environmental Impact Statement.

Table 3.13-7. Composition of the Population in Osceola County

Population	2010 (2014 FEIS)	2012 (2014 FEIS)	2020[(a)] (2014 FEIS)	2017 (2019 SEIS)	2020[(b)] (2019 SEIS)
Total	**268,685**	**287,416**	**376,341**	**352,180**	**395,486**
White alone	190,641	215,200	281,781	251,401	282,315
Black or African American alone	30,369	34,793	45,558	24,068	27,028
American Indian and Alaska Native alone	1,452	978	1,281	2,422	2,720
Asian alone	7,406	8,402	11,002	8,437	9,474
Native Hawaiian and Other Pacific Islander alone	294	0	0	551	619
Some other race alone	27,623	18,795	24,610	33,261	37,351
Two or more races	10,900	9,248	12,109	14,040	15,766
Hispanic or Latino	122,146	137,250	179,714	189,157	212,417
Percent minority	29.0%	25.1%	25.1%	28.6%	28.6%
Percent low income	13.9%	---	---	14.1%	---

Sources: (USCB 2017a, USCB 2017b, USCB 2017d)

Notes:

(a) Projected based on increase in total population by county between 2010 and 2012.

(b) Projected based on increase in total population by county between 2010 and 2017; numbers and percentages may be subject to rounding errors.

Key: FEIS = Final Environmental Impact Statement; SEIS = Supplemental Environmental Impact Statement.

Table 3.13-8. Composition of the Population in Polk County

Population	2010 (2014 FEIS)	2012 (2014 FEIS)	2020[a] (2014 FEIS)	2017 (2019 SEIS)	2020[b] (2019 SEIS)
Total	**602,095**	**616,158**	**675,772**	**686,483**	**726,178**
White alone	452,854	486,415	533,476	532,404	563,190
Black or African American alone	88,833	93,201	102,218	105,452	111,550
American Indian and Alaska Native alone	2,706	1,878	2,060	2,989	3,162
Asian alone	9,760	10,458	11,470	12,151	12,854
Native Hawaiian and Other Pacific Islander alone	360	213	234	594	628
Some other race alone	32,847	8,954	9,820	15,411	16,302
Two or more races	14,735	15,039	16,494	17,482	18,493
Hispanic or Latino	106,532	114,459	125,533	153,113	161,967
Percent minority	24.8%	21.1%	21.1%	22.4%	22.4%
Percent low income	16.4%	---	---	16.0%	---

Sources: (USCB 2017a, USCB 2017b, USCB 2017d)

Notes:

(a) Projected based on increase in total population by county between 2010 and 2012.

(b) Projected based on increase in total population by county between 2010 and 2017; numbers and percentages may be subject to rounding errors.

Key: FEIS = Final Environmental Impact Statement; SEIS = Supplemental Environmental Impact Statement.

Table 3.13-9. Composition of the Population in Seminole County

Population	2010 (2014 FEIS)	2012 (2014 FEIS)	2020[a] (2014 FEIS)	2017 (2019 SEIS)	2020[b] (2019 SEIS)
Total	**422,718**	**430,838**	**464,908**	**462,659**	**480,912**
White alone	330,664	348,662	376,234	357,397	371,497
Black or African American alone	47,107	48,809	52,669	55,994	58,203
American Indian and Alaska Native alone	1,386	1,422	1,534	1,618	1,682
Asian alone	15,692	18,345	19,796	21,515	22,364
Native Hawaiian and Other Pacific Islander alone	258	58	63	130	135
Some other race alone	15,421	5,099	5,502	11,045	11,481
Two or more races	12,190	8,443	9,111	14,960	15,550
Hispanic or Latino	72,457	78,568	84,781	98,817	102,716
Percent minority	21.8%	19.1%	19.1%	22.8%	22.8%
Percent low income	10.0%	---	---	11.5%	---

Sources: (USCB 2017a, USCB 2017b, USCB 2017d)

Notes:

(a) Projected based on increase in total population by county between 2010 and 2012.

(b) Projected based on increase in total population by county between 2010 and 2017; numbers and percentages may be subject to rounding errors.

Key: FEIS = Final Environmental Impact Statement; SEIS = Supplemental Environmental Impact Statement.

Table 3.13-10. Composition of the Population in Volusia County

Population	2010 (2014 FEIS)	2012 (2014 FEIS)	2020[a] (2014 FEIS)	2017 (2019 SEIS)	2020[b] (2019 SEIS)
Total	**494,593**	**496,950**	**506,491**	**538,692**	**558,775**
White alone	408,256	413,626	421,567	437,130	453,427
Black or African American alone	51,791	53,464	54,490	59,708	61,934
American Indian and Alaska Native alone	1,778	1,789	1,823	2,149	2,229
Asian alone	7,567	8,185	8,342	10,399	10,787
Native Hawaiian and Other Pacific Islander alone	204	363	370	83	86
Some other race alone	14,487	10,663	10,868	18,528	19,219
Two or more races	10,510	8,860	9,030	10,695	11,094
Hispanic or Latino	55,217	58,790	59,919	74,582	77,363
Percent minority	17.5%	16.8%	16.8%	18.9%	18.9%
Percent low income	15.0%	---	---	15.1%	---

Sources: (USCB 2017a, USCB 2017b, USCB 2017d)

Notes:

(a) Projected based on increase in total population by county between 2010 and 2012.

(b) projected based on increase in total population by county between 2010 and 2017; numbers and percentages may be subject to rounding errors.

Key: FEIS = Final Environmental Impact Statement; SEIS = Supplemental Environmental Impact Statement.

3.13.2 Environmental Consequences

3.13.2.1 No Action Alternative

The No Action Alternative addressed in this SEIS would be the same as described in the 2014 FEIS in which NASA would discontinue preparations for the Mars 2020 mission and the spacecraft would not be launched. As such, there would be no environmental impacts associated with the No Action Alternative, including no environmental impacts associated with potential launch-related accidents and no radiological risks associated with potential launch accidents. There would be no disproportionately high and adverse impacts to low income or minority populations within the affected population.

3.13.2.2 Proposed Action

Although less likely than identified in the 2014 FEIS, an early-phase launch accident that has the potential to result in a release of plutonium dioxide from the MMRTG could affect a larger area than that identified in the 2014 FEIS. Estimated spatial dispersion of radiological contamination levels within the nine-county area would depend on specifics of the accident, launch phase, weather, and wind conditions at the time of the event. As described in Section 3.5 (Health and Safety), using the screening level of 0.2 $\mu Ci/m^2$, an area of radiological deposition could occur within an area encompassing an estimated 79 km^2 (31 mi^2), depending on the stage and type of the launch accident. Should such an unlikely event occur, that area would be subject to further evaluation for potential radiological impacts. Land areas exceeding recommended exposure levels would potentially need further action, such as monitoring or cleanup (see Section 3.5).

As presented in Section 3.5 (Health and Safety), the low level of radioactive contamination, which could theoretically be dispersed, would still be below the level that is considered to be harmful to human health. Therefore, the environmental impacts of the Proposed Action (i.e., launching the Mars 2020 spacecraft equipped with an MMRTG) to the public, including minority and low-income groups within the potentially affected population, would not be substantively different than what was evaluated in Appendix C-5 of the 2014 FEIS.

NASA's commitment to ensuring the goals of KSC's Environmental Justice strategy are described in Section 3.1.10.2 of the 2014 FEIS and would continue to be implemented. NASA would continue to communicate with and seek the input of local communities to ensure that members of the community are well informed of potential adverse environmental impacts resulting from NASA activities.

3.14 CULTURAL, ARCHAEOLOGICAL, AND HISTORIC RESOURCES

3.14.1 Affected Environment

This section corresponds to Section 3.1.8 of the 2014 FEIS. Cultural resources listed in the National Register of Historic Places (NRHP) or eligible for listing in the NRHP are "historic properties" as defined by the National Historic Preservation Act (NHPA). The list was established under the NHPA and is administered by the National Park Service on behalf of the Secretary of the Interior. The NRHP includes properties on public and private land. Properties can be determined eligible for listing in the NRHP by the Secretary of the Interior or by a Federal agency official with concurrence from the applicable State Historic Preservation Officer (SHPO). A NRHP-eligible property has the same protections as a property listed in the NRHP and include archaeological and architectural resources.

Historic properties can include prehistoric and historic sites, archeological sites, structures/buildings, districts, historic landscapes, objects, artifacts, cemeteries, traditional cultural properties, sacred sites, monuments and memorials, or any other physical evidence of human activity considered important to a culture or community for scientific, traditional, religious, or any other reasons.

The area of potential effects (APE) for cultural resources is the geographic area or areas within which an undertaking (project, activity, program or practice) may cause changes in the character or use of any historic properties present. The APE is influenced by the scale and nature of the undertaking and may be different for various kinds of effects caused by the undertaking.

For this Proposed Action, NASA and DOE have determined that the APE consists of counties with areas within 100 km (62 mi) of SLC-41 located in the northernmost section of CCAFS, Brevard County, Florida. The APE is the same as the ROI described in Section 1.1 of this SEIS.

Changes to ROI Since 2014 FEIS

The 2014 FEIS focused on the cultural resources of both CCAFS and KSC. The cultural resources within the CCAFS and KSC portions of the 2019 ROI have largely remained unchanged since 2014 and remain similar to that described in Section 3.1.8 of the 2014 FEIS, so this SEIS focuses on the cultural resources in the APE outside the boundaries of CCAFS and KSC.

There are 240 NRHP-listed properties in the six counties that are entirely within the APE (Brevard, Indian River, Orange, Osceola, Seminole, and Volusia), outside the boundaries of CCAFS and KSC. There are no NRHP-listed resources in the three small portions of Polk, Lake, and Flagler Counties that are in the APE. The 240 NRHP-listed properties include buildings (houses, churches, schools, etc.), historic districts (residential and commercial), archaeological sites (prehistoric and historic), structures, and objects (Table 3.14-1). Four of the NRHP-listed properties are also designated as National Historic Landmarks. Two are in Volusia County, and there is one each in Brevard and Indian River Counties.

Table 3.14-1. NRHP-Listed Historic Properties in the Area of Potential Effects Outside CCAFS and KSC

County	Building	Historic District	Archaeological Site	Structure	Object	Total
Brevard	20	4	3	2	--	29
Indian River	22	3	3	--	--	28
Orange	40	12	1	2	--	55
Osceola	7	1	--	--	1	9
Seminole	12	5	--	--	--	17
Volusia	56	22	20	4	--	102
Total	**157**	**47**	**27**	**8**	**1**	**240**

Source: (NPS 2019)

Key: CCAFS = Cape Canaveral Air Force Station; KSC = Kennedy Space Center; NRHP = National Register of Historic Places.

3.14.2 <u>Environmental Consequences</u>

3.14.2.1 No Action Alternative

Under the No Action Alternative, preparations for the Mars 2020 mission would be discontinued and the mission would not be implemented. There would be no change to cultural resources. Therefore, no impacts to cultural resources would occur with implementation of the No Action Alternative.

3.14.2.2 Proposed Action

Estimated spatial dispersion of radiological contamination levels within the nine-county area would depend on specifics of the accident, launch phase, weather, and wind conditions at the time of the event. As described in Section 3.5 (Health and Safety), using the screening level of 0.2 $\mu Ci/m^2$, an area of radiological deposition could occur within an area encompassing an estimated 79 km^2 (31 mi^2), depending on the stage and type of the launch accident. Should such an unlikely event occur, that area would be subject to further evaluation for potential radiological impacts. Land areas exceeding recommended exposure levels would potentially need further action, such as monitoring or cleanup (see Section 3.5).

Potential impacts to cultural resources associated with an early-launch accident involving radiological release would be similar to potential land area effects and land use impacts as described in Section 3.6 (Land Use); this may include loss of utility for certain cultural resources that could potentially exceed recommended exposure levels. Depending on the results of the radiological evaluation, some cultural resources in the APE could be directly affected by temporary loss of use. Those potential impacts, and any others that might be associated with cleanup activities, would be identified and addressed by NASA and DOE under the emergency consultation provision of Section 106 of the NHPA and its implementing regulations (36 CFR 800.12) prior to implementation of any accident restoration activities with the potential to impact cultural resources.

3.15 GLOBAL ENVIRONMENT

3.15.1 Affected Environment

This section corresponds to Section 3.2 of the 2014 FEIS, which provided a general overview of the global environment under EO 12114, *Environmental Effects Abroad of Major Federal Actions*. Basic descriptions of the troposphere and stratosphere, global population distribution and density, distribution of land surface types, and a brief discussion of background radiation and the global atmospheric inventory of plutonium were included. This SEIS identifies any changes to the global environment descriptions since the 2014 FEIS.

Changes to ROI Since 2014 FEIS

Troposphere

Section 3.2.1 of the 2014 FEIS describes the tropospheric global environment. This aspect of the ROI has remained unchanged since 2014, and the discussion presented in the 2014 FEIS remains applicable.

Stratosphere

Section 3.2.2 of the 2014 FEIS describes the stratospheric global environment. This aspect of the ROI has remained unchanged since 2014, and the discussion presented in the 2014 FEIS remains applicable. In addition, measurements show that declining atmospheric concentrations of ODS resulted in about 20 percent less ozone depletion during the Antarctic winter in 2016 compared to 2005, when NASA's Aura satellite first began measuring chlorine and ozone during the Antarctic winter (NASA 2018).

Orbital and Reentry Debris

Section 3.2.3 of the 2014 FEIS provides a discussion of orbital and reentry debris. This discussion has remained unchanged since 2014, and the presentation in the 2014 FEIS remains applicable.

Global Population Distribution

This section presents an update to global population distribution since the 2014 FEIS and provides a description of the Earth's population distributed among equal-sized areas (cells) of the Earth's surface using the same methodology as presented in the 2014 FEIS. As described in the 2014 FEIS, the cells are derived by dividing the Earth from pole to pole into 20 latitude bands of equal area and then segmented further into 36 equal-sized cells for a total of 720 cells. The area of each cell is 708,438 km^2 (273,529 mi^2) (HNUS 1992).

The global distribution of the projected population in 2020 across each of the 20 equal-area latitude bands was based on the previously estimated total population of the Earth of approximately 7.7 billion. But as of 2019, the current world population estimate has already exceeded 7.7 billion and is approximately 7.709 billion. Based on the most recent population growth, the world population is forecasted to reach 7,795,482,309 by 2020 (Worldometers 2019). Table 3.15-1 shows the world population distribution by latitude band as presented in the 2014 FEIS compared to the updated world population distribution by latitude band. To determine the updated band population estimates, the proportion of each latitude band was calculated from the 2014 FEIS and then applied to the most recent estimate of the world population forecast for 2020.

Table 3.15-1. Global Population and Surface Characteristics by Latitude Band

Latitude Band	Latitude Range, degrees	Band Population Estimate for 2020, millions (2014 FEIS)	Band Population Estimate for 2020, millions (2019 SEIS)	Water	Land	Land Rock Fraction	Land Soil Fraction
1	90N-64N	5.5	5.6	0.7332	0.2668	1.0[(a)]	0.0[(a)]
2	64N-53N	201	204	0.4085	0.5915	1.0[(a)]	0.0[(a)]
3	53N-44N	597	606	0.4456	0.5544	0.251[(a)]	0.749[(a)]
4	44N-36N	1,020	1,035	0.5522	0.4478	0.251	0.749
5	36N-30N	1,250	1,268	0.5718	0.4282	0.153	0.847
6	30N-23N	1,490	1,512	0.6064	0.3936	0.088	0.912
7	23N-17N	764	775	0.6710	0.3290	0.076	0.924
8	17N-11N	618	627	0.7514	0.2486	0.058	0.924
9	11N-5N	562	570	0.7592	0.2408	0.077	0.923
10	5N-0	188	191	0.7854	0.2146	0.0844	0.916
11	0-5S	217	220	0.7630	0.2370	0.044	0.956
12	5S-11S	303	307	0.7815	0.2185	0.055	0.945
13	11S-17S	113	115	0.7799	0.2201	0.085	0.915
14	17S-23S	118	120	0.7574	0.2426	0.089	0.911
15	23S-30S	136	138	0.7796	0.2204	0.092	0.980
16	30S-36S	78	79	0.8646	0.1354	0.112	0.888

Table 3.15-1. Global Population and Surface Characteristics by Latitude Band

Latitude Band	Latitude Range, degrees	Band Population Estimate for 2020, millions (2014 FEIS)	Band Population Estimate for 2020, millions (2019 SEIS)	Water	Land	Land Rock Fraction	Land Soil Fraction
17	36S-44S	20	20	0.9538	0.0462	0.296	0.704
18	44S-53S	1.0	1.0	0.9784	0.0216	0.296[a]	0.704[a]
19	53S-64S	0.3	0.3	0.9930	0.0070	1.0[a]	0.0[a]
20	64S-90S	-	-	0.3863	0.6137	1.0[a]	0.0[a]

Sources: (HNUS 1992, Worldometers 2019)

Notes:

Population estimates adapted from Lipinski (2014); numbers may be subject to rounding errors.

(a) assumed values

Key: FEIS = Final Environmental Impact Statement; N = north latitude; S = south latitude; SEIS = Supplemental Environmental Impact Statement.

Florida lies within latitude band 6, one of the latitude bands with the greatest population densities. Due to the launch azimuth angle constraints, launches from CCAFS to other solar system objects would partially circle the Earth between 35° north and 35° south latitudes (bands 6 through 15) before departing for interplanetary space.

Earth Surface Characteristics

The 2014 FEIS focused on the worldwide distribution of water and land surface types as they intersect with global latitude bands. The existing conditions regarding total land fraction for each of the 20 latitude bands and subdivided total land fraction into soil or rock cover and surface water cover have remained unchanged since 2014 and remains identical to that described in Section 3.2.5 of the 2014 FEIS (NASA 2014).

Background Radiation

Section 3.2.6 of the 2014 FEIS provides a discussion of background radiation from both naturally occurring and manmade sources. There have been no substantive changes since 2014, and the presentation in the 2014 FEIS remains applicable.

3.15.2 Environmental Consequences

3.15.2.1 No Action Alternative

The No Action Alternative addressed in this SEIS would be the same as described in the 2014 FEIS. NASA would discontinue preparations for the Mars 2020 mission, and the spacecraft would not be launched. As such, there would be no environmental impacts to the global environment associated with the No Action Alternative, including no environmental impacts associated with potential launch-related accidents and no radiological risks associated with potential launch accidents.

3.15.2.2 Proposed Action

Troposphere

Impacts to the troposphere would be similar to those described under the *Air Quality* subsections in Section 3.7.2 (Air Resources, Environmental Consequences), as well as in Sections 4.1.2.14 and 4.1.4.6 of the 2014 FEIS.

Stratosphere

Section 4.1.2.14 of the 2014 FEIS evaluated the potential for emissions from launch vehicles to impact the global environment. That analysis is applicable to the Proposed Action and focused on the potential for launch vehicle emissions to affect stratospheric ozone levels. Among the launch vehicles evaluated, the Atlas V 551 would emit the largest amount of chlorine into the stratosphere due to its solid rocket booster exhaust. As stated, it was estimated that an Atlas V 551 launch would result in a stratospheric ozone loss of about 0.077 percent (USAF 2000) and the present state of the stratosphere was characterized by annual global ozone losses of about 4 percent, caused by past use of chlorofluorocarbons and other controlled materials (NASA 2011). Since the 2014 FEIS, NASA has selected the Atlas V 541 vehicle, which has undergone evolutionary changes that include the avionics and second stage engine. However, these changes do not substantively affect the air emissions associated with a launch. Therefore, a launch of the Atlas V 541 would not be expected to significantly increase ozone loss over an Atlas V 551, as an Atlas V launch accounts for about 0.08 percent of annual global ozone losses.

Orbital and Reentry Debris

Impacts associated with orbital and reentry debris are the same as described in the Section 4.1.3.2 of the 2014 FEIS.

Global Population Distribution

The updated analysis indicates that the low level of radioactive contamination, which could theoretically be dispersed after certain types of launch accidents, would still be below the level, which is considered to be harmful to human health (see Section 3.5, Health and Safety). Therefore, the environmental impacts of the Proposed Action to the global population distribution are not substantively different than what was evaluated in the 2014 FEIS.

Earth Surface Characteristics

The contributions to radiological risks in the global area are summarized in Table 4-7 of the 2014 FEIS and are not substantively different under this SEIS. Similar to the 2014 FEIS, the launch area and extended ROI (within 100 km [62 mi] of the launch site) risk for this SEIS is about 57 percent of the overall mission risk, while the risk to global areas is 43 percent. Risks within the ROI for the 2019 SEIS are due almost entirely to accidents occurring during Phases 0 and 1. The global risks are due to accidents in all mission phases, with Phase 1 being the primary contributor due to the atmospheric transport of small particles that could become well mixed in the troposphere and travel beyond 100 km (62 mi) from the launch site. As in the 2014 FEIS, suborbital Phase 3 releases could involve reentering modules that could impact the ground in southern Africa. The 2014 FEIS analysis calculated that orbital Phase 4 accidents would impact land surfaces anywhere between 29° north latitude and 29° south latitude, while according to the 2019 NRA Update, orbital Phase 4 accidents would impact land surfaces anywhere between 35° north latitude and 35° south latitude. Releases during Phase 5 could nominally affect the environment anywhere on Earth, but only when the spacecraft impacts land (NASA 2014).

4. CUMULATIVE IMPACTS AND OTHER EFFECTS

4.1 CUMULATIVE IMPACTS

4.1.1 Region of Influence

The ROI for cumulative impacts for this SEIS remains the same as that identified in the 2014 FEIS, Section 4.5, which covered CCAFS/KSC and the global environment.

4.1.2 Past, Present, and Reasonably Foreseeable Actions

Past, present, and reasonably foreseeable actions occurring within the ROI are of the same general nature as those described in Section 4.5 of the 2014 FEIS and include past and future launches, economic growth, and land development.

4.1.3 Cumulative Impact Analysis

Although a larger area may be impacted in the unlikely event of a launch vehicle accident, the cumulative impacts associated with the 2019 NRA Update are not substantively different than that presented in the 2014 FEIS.

4.2 ENVIRONMENTAL EFFECTS THAT CANNOT BE AVOIDED

Environmental effects that cannot be avoided remain the same as those described in the Section 4.6 of the 2014 FEIS.

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

Short-term impacts versus long-term productivity remain the same as those identified the Section 4.8 of the 2014 FEIS.

4.4 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

Irreversible and irretrievable commitment of resources remains largely the same as discussed in the Section 4.9 of the 2014 FEIS. But since the 2014 FEIS, NASA has already 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:** Based on the 2015 ROD to implement Alternative 1, the rover and scientific payload (including instrumentation) have been designed to use the MMRTG. As a result, the solar options under Alternatives 2 and 3 are no longer viable. NASA has committed irrevocable resources in this regard, including proceeding with the MMRTG fueling process.
- **Mars landing site selection:** Based on the 2015 ROD to implement Alternative 1, selection of the landing site on Mars was based on the use of an MMRTG. In November 2018, NASA identified the Jezero Crater as the Mars rover landing site. As a result, this further limits rover design options because under Alternative

2, the rover would not operate during most of the spring and summer (about 50 to 55 percent of the operational lifetime compared to MMRTG), and under Alternative 3, the rover would not operate for part of the summer (about 60 percent of the operational lifetime compared to MMRTG).

- **Selection of launch vehicle:** The 2014 FEIS analyzed the potential impacts associated with use of three different ELVs: the Atlas V, the Delta IV, and Falcon Heavy. Since then, NASA selected the Atlas V as the ELV. As a result, the launch will occur from CCAFS because KSC cannot support the Atlas V ELV.
- **Launch period:** NASA has identified the launch period to begin as early as July 17, 2020, and end in mid-August 2020. If the launch does not occur during this launch period, the alternate launch period of 2022 presented in the 2014 FEIS would apply.

5. MITIGATIONS AND MONITORING REQUIREMENTS

Mitigations and monitoring requirements would be the same as those identified in Section F of the 2015 ROD.

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6. LIST OF PREPARERS

This SEIS for the Mars 2020 mission was prepared by the Science Mission Directorate, NASA. As a cooperating agency, the DOE has contributed expertise in the preparation of this SEIS. The organizations and individuals listed below contributed to the overall effort in the preparation of this document.

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7. AGENCIES, ORGANIZATIONS, AND INDIVIDUALS CONSULTED

7.1 INTRODUCTION

This chapter summarizes the public and agency outreach program NASA has undertaken in support of this 2019 SEIS. This chapter will be updated in the Final SEIS to reflect the results of the public and agency outreach conducted for the Draft SEIS.

7.2 COOPERATING AGENCY

As defined in 40 CFR 1508.5, and further clarified in subsequent CEQ guidance memoranda, a cooperating agency can be any Federal, state, tribal, or local government that has jurisdiction by law or special expertise regarding any environmental impact involved in a proposal or a reasonable alternative.

NASA is the Federal agency that funds the launch of the Mars 2020 mission and is therefore the lead agency for preparation of this SEIS. The DOE is participating as a cooperating agency because they possess both regulatory authority and specialized expertise regarding the environmental context of the use of plutonium. The USAF serves as a cooperating agency due to their jurisdictional authority over the CCAFS launch site and range safety for the Mars 2020 mission, as well as their staff's technical expertise in launch operations and launch vehicle accident response.

7.3 SCOPING PROCESS

The NEPA planning and scoping activities for the 2014 FEIS are described in Section 1.4 of the 2014 FEIS.

Title 40 CFR 1502.9(c)(4) does not require scoping for an SEIS. However, in order to inform the public, NASA did publish a Notice of Intent to conduct this SEIS in the Federal Register on September 26, 2019. No formal scoping process or scoping meetings were conducted for this SEIS.

7.4 WEBSITE

Throughout the duration of the Mars 2020 mission NEPA process, NASA has maintained a website that provides the public with the most up-to-date project information, including electronic copies of the 2014 FEIS and this SEIS, as they are made available. The website may be accessed at: https://www.nasa.gov/agency/nepa/mars2020eis/.

7.5 REVIEW OF DRAFT SEIS

The public was notified of the opportunity to review and comment on this SEIS by an announcement in the Federal Register on October 25, 2019, and local digital and print news media. This Draft SEIS was also available for downloading from the website identified above.

7.6 DRAFT DISTRIBUTION

This SEIS was made available for review and comment by Federal, state, and local agencies and the public. The public review and comment period will extend 45 days from the publication of the EPA's Federal Register NOA published on October 25, 2019. Comments will be considered during the preparation of the Final SEIS.

As announced in the NOA, the Draft SEIS is available for review and download at the NASA web site: https://www.nasa.gov/agency/nepa/mars2020eis/.

NASA mailed copies of the Draft SEIS directly to the agencies, organizations, and individuals who had requested a printed copy or CD of the document. In addition, NASA sent copies of the NOA via mail or email to the stakeholders listed below:

Federal Agencies

Council on Environmental Quality
Advisory Council on Historic Preservation
National Aeronautics and Space Administration
- NASA Headquarters
- NASA Ames Research Center FOIA Customer Service Center
- NASA Goddard Space Flight Center FOIA Customer Service Center
- NASA Johnson Space Center FOIA Customer Service Center
- NASA Langley Research Center FOIA Customer Service Center
- NASA Marshall Space Flight Center FOIA Customer Service Center
- NASA Office of the Inspector General
- NASA Stennis Space Center FOIA Customer Service Center
- NASA Jet Propulsion Laboratory FOIA Customer Service Center
- NASA Public Liaison Office

National Science Foundation
Office of Management and Budget
U.S. Department of Agriculture
U.S. Department of the Air Force
- Patrick Air Force Base

U.S. Department of the Army
U.S. Department of Commerce
- National Oceanic and Atmospheric Administration
- National Marine Fisheries Service (NOAA Fisheries)

U.S. Department of Energy
U.S. Department of Health and Human Services
- Centers for Disease Control and Prevention
- Food and Drug Administration
- National Cancer Institute

U.S. Department of Homeland Security
- Federal Emergency Management Agency, Region 4
- Sustainability and Environmental Programs
- Transportation Security Administration
- U.S. Coast Guard

U.S. Department of the Interior
- Bureau of Safety and Environmental Enforcement
- Fish and Wildlife Service
- National Park Service
- Office of Environmental Policy and Compliance

U.S. Department of State

U.S. Department of Transportation
- Federal Aviation Administration
- Office of Safety, Energy and Environment
- Assistant Secretary for Research and Technology

U.S. Environmental Protection Agency
- NEPA Program Office
- Office of Enforcement and Compliance Assurance
- EPA, Region 4

U.S. House of Representatives
- Col. Paul Cook (ret) (California 8th District)
- Judy Chu (California 27th District)
- Adam Schiff (California 28th District)
- Michael Waltz (Florida 6th District)
- Stephanie Murphy (Florida 7th District)
- Bill Posey (Florida 8th District)
- Darren Soto (Florida 9th District)
- Val Demings (Florida 10th District)
- Daniel Webster (Florida 11th District)
- Ross Spano (Florida 15th District)
- George Steube (Florida 17th District)
- House Committee on Science, Space, and Technology

U.S. Senate
- Senator Diane Feinstein (California)
- Senator Kamala D. Harris (California)
- Senator Marco Rubio (Florida)
- Senator Rick Scott (Florida)
- Senate Committee on Commerce, Science, and Transportation

U.S. Nuclear Regulatory Commission

State Agencies

East Central Florida Regional Planning Council

Florida Division of Emergency Management

Florida Department of Environmental Protection
- Florida State Clearinghouse

State of Florida
- Office of Governor
- Office of Lt. Governor

State of Florida Senate
- Travis Houston (7th District)
- David Simmons (9th District)

- Randolph Bracy (11th District)
- Dennis Baxley (12th District)
- Linda Stewart (13th District)
- Tom Wright (14th District)
- Victor M. Torres Jr. (15th District)
- Debbie Mayfield (17th District)
- Tom Lee (20th District)
- Kelli Stargel (22nd District)
- Ben Albritton (26th District)

State of Florida House of Representatives

- Paul Renner (24th District)
- Thomas Leek (25th District)
- Elizabeth Anne Fetterhoff (26th District)
- David Santiago (27th District)
- David Smith (28th District)
- Scott Plakon (29th District)
- Joy Goff-Marcil (30th District)
- Jennifer Mae Sullivan (31st District)
- Anthony Sabatini (32nd District)
- Brett Thomas Hage (33rd District)
- Josie Tomkow (39th District)
- Colleen Burton (40th District)
- Sam H. Killebrew (41st District)
- Mike La Rosa (42nd District)
- John Cortes (43rd District)
- Kamia L. Brown (45th District)
- Bruce Antone (46th District)
- Anna V. Eskamani (47th District)
- Amy Mercado (48th District)
- Carlos Guillermo Smith (49th District)
- Rene Plasencia (50th District)
- Tyler I. Sirois (51st District)
- Thad Altman (52nd District)
- Randy Fine (53rd District)
- Erin Gall (54th District)

County Agencies

Brevard County

- Board of Commissioners
- Natural Resources Management Office
- Office of Emergency Management
- Planning and Zoning Office

Flagler County Board of Commissioners
Indian River Board of Commissioners
Lake County Board of Commissioners
Orange County Board of Commissioners
Osceola County Board of Commissioners

Polk County Board of Commissioners
Seminole County Board of Commissioners
Volusia County
  County Chair
  County Manager

Local Agencies

Port Canaveral Commissioners, Chairman
Mayor Bob Hoog, City of Cape Canaveral
Mayor Jake Williams, City of Cocoa
Mayor Ben Malik, City of Cocoa Beach
Mayor Jose Alvarez, City of Kissimmee
Mayor Kathy Meehan, City of Melbourne
Mayor Russ Owen, City of New Smyrna Beach
Mayor Buddy Dyer, City of Orlando
Mayor Hal J. Rose, City of West Melbourne
Mayor Nathan Blackwell, City of St. Cloud
Mayor Walt Johnson, City of Titusville
Mayor William Mutz, City of Lakeland
Mayor Milissa Holland, City of Palm Coast
Mayor Michael Holland, City of Eustis
Mayor Val Zundans, City of Vero Beach
Mayor Dominic Persampiere, City of Oviedo

Organizations

Aerospace Industries Association
The American Association for the Advancement of Science
American Astronomical Society
American Institute of Aeronautics and Astronautics
American Society of Mechanical Engineers
Audubon of Florida
  Space Coast Audubon Society
  Pelican Island Audubon Society
Economic Development Commission of Florida's Space Coast
Environmental Defense Fund
Environmental Defense Institute, Inc.
Federation of American Scientists
Florida Coalition for Peace and Justice
Florida Solar Energy Center
Friends of the Earth
Global Network Against Weapons and Nuclear Power in Space
Global Security.org
Greenpeace International
Innovative Health Applications, LLC
International Committee Against Mars Sample Return
Mars Society

National Audubon Society
National Congress of American Indians
National Hispanic Environmental Council
National Space Society
National Fish and Wildlife Foundation
National Wildlife Federation
Natural Resources Defense Council
The Nature Conservancy
Physicians for Social Responsibility
The Planetary Society
Sierra Club National Headquarters
Snake River Alliance
Southwest Network for Environmental and Economic Justice
The Space Foundation
Union of Concerned Scientists

Public Libraries

Orlando Public Library
Lakeland Public Library
Flagler County Public Library Main Branch
Cocoa Beach Public Library
Central Brevard Library and Reference Center
Cape Canaveral Public Library
Titusville Public Library
Melbourne Library
Merritt Island Public Library
Port St. John Public Library
Satellite Beach Public Library
NASA Headquarters Library

Individuals

Sebnem Aynur
Walter Blair
Peter Carson
Sandip Chatterjee
Lois Clark
Kevin Clendaniel
James Dean – Florida Today
Premilla Dixit
Margaret Dutton
Dr. Murray Felsher
Rosemary Galli
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APPENDIX A

HEALTH AND SAFETY SUPPORTING INFORMATION

Table of Contents

Abbreviations and Acronyms

Acronym	Definition
2014 NRA	*Nuclear Risk Assessment for the Mars 2020 Mission Environmental Impact Statement* (2014)
2019 NRA Update	*Nuclear Risk Assessment Update for the Mars 2020 Mission Environmental Impact Statement* (2019)
µCi/m^2	microcuries per square meter
µm	micrometers
°C	degrees Celsius
Ci	curies
DIL	derived intervention level
DOE	U.S. Department of Energy
FSII	full stack intact impact
FTS	flight termination system
GPHS-RTG	General Purpose Heat Source-Radioisotope Thermoelectric Generator
km	kilometers
km^2	square kilometers
MMRTG	Multi-Mission Radioisotope Thermoelectric Generator
rem	roentgen equivalent in man
ROD	Record of Decision
Stage 2/SV	a Stage 2 and space vehicle impact

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ENVIRONMENTAL IMPACTS OF POTENTIAL ACCIDENTS INVOLVING RADIOACTIVE MATERIAL

NASA and the U.S. Department of Energy (DOE) have assessed the potential environmental impacts of launch accidents involving release of plutonium dioxide. The analysis results indicate that the most likely outcome of implementing the Mars 2020 mission is a successful launch of the spacecraft toward Mars. If, however, a launch accident were to occur, the most probable outcome is an accident without a release of the plutonium dioxide.

This section presents a comparison of the environmental impacts of potential accidents involving radioactive materials as presented in the 2014 FEIS, which used the DOE's *Nuclear Risk Assessment for the Mars 2020 Mission Environmental Impact Statement* (SNL 2014) (the "2014 NRA"), versus the updated probabilities and impacts identified in this Supplemental Environmental Impact Statement (SEIS) based on the results of DOE's *Nuclear Risk Assessment 2019 Update for the Mars 2020 Mission Environmental Impact Statement* (SNL 2019) (the "2019 NRA Update").

A.1 Risk Assessment Methodology

The risk assessment methodology used in both the 2014 FEIS and the 2019 SEIS is described in Section 4.1.4.1 of the 2014 FEIS. The 2019 SEIS used only the accident probabilities for the selected Atlas V 541 launch vehicle, whereas the 2014 FEIS relied on a composite approach for accident probabilities derived from the representative Atlas V 551 and Delta IV launch vehicles.

A.2 Launch Accidents and Accident Probabilities

In the 2019 NRA Update, the methodology for calculating accident probabilities is the same as that used for the 2014 FEIS. Importantly, however, two factors result in differences between the probabilities used for the 2014 FEIS and the 2019 SEIS. Since the publication of the ROD for the 2014 FEIS, NASA selected the Atlas V 541 as the mission launch vehicle. Accident probabilities used in the 2019 analysis reflect the selected vehicle. Additionally, it incorporates lessons learned and modeling data updates derived from previous missions, updated analytical models, and computer simulation input parameters. As stated in the 2014 FEIS and in Section 3.3 of the SEIS, NASA continues to evaluate the reliability of the candidate launch vehicles (NASA 2014).

For the purpose of 2014 NRA and 2019 NRA Update, the Mars 2020 mission was divided into six mission phases on the basis of mission elapsed time (the time in seconds relative to launch) reflecting principal launch events (Phase 0 through Phase 5).

The key events in defining the mission phases are: the start of the first stage main engines, which occurs shortly before lift-off; lift-off[1]; the time at which there is no longer a possibility that debris from an accident would impact in the vicinity of the launch area;

[1] The main engine undergoes an automatic health check beginning at first-stage main engine start. If a malfunction is detected before lift-off, the engine would be shut down and the launch would be aborted.

the time at which any debris from an accident would be subject to suborbital reentry heating; and the time orbit is achieved. These events occur at different mission elapsed times for the Atlas V and Delta IV vehicles. The six phases are described as:

- **Phase 0 – Pre-Launch:** from the installation of the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) to just prior to the start of the first stage main engine;
- **Phase 1 – Early Launch:** from the start of the first stage main engines to just prior to the time after which there would be no potential for debris or an intact vehicle configuration to impact land in the launch area, and water impact would occur;
- **Phase 2 – Late Launch:** from the end of Phase 1 to when the launch vehicle reaches an altitude of about 30 kilometers (km) (100,000 feet), an altitude above which reentry heating could occur;
- **Phase 3 – Suborbital Reentry:** from an altitude of about 30 km (100,000 feet) to the first engine cutoff of the second stage and the Command Destruct System is disabled;
- **Phase 4 – Orbit Reentry:** from the first engine cutoff of the second stage to separation of the spacecraft from the second stage; and
- **Phase 5 – Long-term Reentry:** from spacecraft separation to no chance of spacecraft reentry.

Characteristics of accidents and the accident environments in each of these phases is described in the 2014 FEIS.

The composite accident end-state probabilities for the composite launch vehicle and the Atlas V 541 launch vehicle are presented in Table A-1 and Table A-2, respectively.

For the 2014 FEIS, the initiating probabilities and total probabilities of an accident with a release of plutonium dioxide were grouped into categories that allow for a descriptive characterization of the likelihood of each accident. The categories and their associated probability ranges are:

- unlikely: 10^{-2} to 10^{-4} (1 in 100 to 1 in 10,000);
- very unlikely: 10^{-4} to 10^{-6} (1 in 10,000 to 1 in 1 million); and
- extremely unlikely: less than 10^{-6} (less than 1 in 1 million).

Table A-1. 2014 FEIS Accident End-State Probabilities (per Launch Attempt)

Ground Impact Configuration[(a)]	Phase 0	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Total Probability
On-Pad Explosion	3.0×10^{-5}	9.8×10^{-5}	-	-	-	-	1.3×10^{-4}
FSII	-	2.2×10^{-5}	-	-	-	-	2.2×10^{-5}
Stage 2/SV	-	4.8×10^{-5}	-	-	-	-	4.8×10^{-5}
SVII	2.8×10^{-6}	6.3×10^{-7}	-	-	-	-	3.4×10^{-6}
Low Altitude FTS	-	2.9×10^{-3}	-	-	-	-	2.9×10^{-3}

Table A-1. 2014 FEIS Accident End-State Probabilities (per Launch Attempt)

Ground Impact Configuration[(a)]	Phase 0	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Total Probability
High Altitude FTS	-	-	$3.6x10^{-3}$	-	-	-	$3.6x10^{-3}$
Suborbital Reentry	-	-	-	$1.3x10^{-2}$	-	-	$1.3x10^{-2}$
Orbital Reentry	-	-	-	-	$4.7x10^{-3}$	-	$4.7x10^{-3}$
Long-term Reentry	-	-	-	-	-	$1.0x10^{-6}$	$1.0x10^{-6}$
Total	**$3.3 x10^{-5}$**	**$3.1x10^{-3}$**	**$3.6x10^{-3}$**	**$1.3x10^{-2}$**	**$4.7x10^{-3}$**	**$1.0x10^{-6}$**	**$2.5x10^{-2}$**

Source: (SNL 2014)

Note:

(a) The table presents a composite of the accident end-state probabilities for the Atlas V 551 and the Delta IV Heavy, determined by taking the probability-weighted value of the two sets of results, treating the conditional probability of having a given launch vehicle as 0.5.

Key: FSII = full stack intact impact (the entire launch vehicle impacts the ground); Low or High Altitude FTS = flight termination system (the vehicle is destroyed at low or high altitude and debris impacts the ground); Stage 2/SV = stage 2 and space vehicle (the intact stage 2 and the space vehicle impact the ground); SVII = space vehicle intact impact (the entire space vehicle impacts the ground).

Table A-2. 2019 NRA Update Accident End-State Probabilities (per Launch Attempt)

Ground Impact Configuration[(a)]	Phase 0	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Total Probability
On-Pad Explosion	$1.0x 10^{-4}$	$7.9x10^{-5}$	-	-	-	-	$1.8x10^{-4}$
FSII	-	$1.1x10^{-6}$	-	-	-	-	$1.1x10^{-6}$
Stage 2/SV	-	$3.0x10^{-5}$	-	-	-	-	$3.0x10^{-5}$
SVII	$4.3x10^{-8}$	$1.5x10^{-6}$	-	-	-	-	$1.5x10^{-6}$
Low Altitude FTS	-	$1.6x10^{-3}$	-	-	-	-	$1.6x10^{-3}$
High Altitude FTS	-	-	$2.5x10^{-3}$	-	-	-	$2.5x10^{-3}$
Suborbital Reentry	-	-	-	$6.8x10^{-3}$	-	-	$6.8x10^{-3}$
Orbital Reentry	-	-	-	-	$1.2x10^{-3}$	-	$1.2x10^{-3}$
Long-term Reentry	-	-	-	-	-	$1.4x10^{-4}$	$1.4x10^{-4}$
Total	**$1.0 x10^{-4}$**	**$1.7x10^{-3}$**	**$2.5x10^{-3}$**	**$6.8x10^{-3}$**	**$1.2x10^{-3}$**	**$1.4x10^{-4}$**	**$1.3x10^{-2}$**

Source: (SNL 2019)

Note:

(a) The table presents the accident end-state probabilities for the Atlas V 541.

Key: FSII = full stack intact impact (the entire launch vehicle impacts the ground); Low or High Altitude FTS = flight termination system (the vehicle is destroyed at low or high altitude and debris impacts the ground); Stage 2/SV = stage 2 and space vehicle (the intact stage 2 and the space vehicle impact the ground); SVII = space vehicle intact impact (the entire space vehicle impacts the ground).

A.3 MMRTG Response to Accident Environments

The nature and severity of the accident environments, the design features of the MMRTG and its components, and the operating conditions of the MMRTG determine the response of the MMRTG and its components to the accident environments. These responses are then characterized in terms of the probability of release and the source terms.

The response of the MMRTG to accident environments is based on consideration of

- prior safety testing of the General Purpose Heat Source-Radioisotope Thermoelectric Generator (GPHS-RTG) and its components (including the GPHS module and iridium clads);

- modeling of the response of the MMRTG and its components (including the GPHS module and iridium clads) to accident environments; and
- the types of launch vehicle accidents and their environments.

This information allows estimates to be made of the probability of release of plutonium dioxide and the amount of the release for the range of accident scenarios and environments that could potentially occur during the mission. The protection provided by the GPHS module, its graphite components, and the iridium clad encapsulating the plutonium dioxide reduces the potential for release in accident environments.

A.3.1 MMRTG Responses for the 2014 FEIS

Potential responses of the MMRTG and its components in accident environments are summarized in the 2014 FEIS.

A.3.2 Changes Since the 2014 FEIS

As part of DOE's ongoing safety testing and analysis efforts since the 2015 ROD, new knowledge about how the iridium cladding within the GPHS responds to impact forces, along with lessons learned derived from previous missions, led to updated computer modeling of the MMRTG's response to accident environments. The 2019 NRA also accounted for the design specifics of the selected Atlas V 541.

The description of the rover's electrical power system (the MMRTG) is the same as presented in Section 2.1.3 of the 2014 FEIS.

2019 SEIS

In the five years since the FEIS and ROD were issued, refinements in the Mars 2020 mission's operating profile and modeling data have resulted in a revised risk assessment and environmental impact radiological evaluations. These refinements reflect a better understanding of how the iridium in the MMRTG fuel clads responds to impacts (as described on page 2-23 of the 2014 FEIS) when operating at lower temperatures during launch, which is part of the new information incorporated in the 2019 NRA Update and this SEIS.

Before the 2011 Mars Science Laboratory mission, NASA relied on the General Purpose Heat Source-Radioisotope Thermoelectric Generator (GPHS-RTG) (used on the Pluto New Horizons and Cassini missions). 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. This understanding of the iridium clads was based on a number of tests conducted between 1984 and 1999.

In the early 2000s, NASA foresaw that it would need an RTG that would reliably operate on planetary surfaces with atmospheres (e.g., Mars). The GPHS-RTG was optimized for operation in the vacuum of space and had components that would degrade over time in atmospheres. This was one of the reasons NASA worked with DOE to develop the MMRTG that uses parts that can operate for many years in atmospheres. 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). Because of this, DOE performed two bare clad impact tests in 2010 designed to test the iridium clad impacting at lower temperatures. Subsequent thermal analysis showed that the intended lower temperature bare clad impact tests were performed at an iridium clad temperature higher than planned. Subsequently, DOE conducted a new bare clad impact test in May 2017, which was performed at a fuel clad temperature representative of the lower end of the operating range.

Using this new test information and previous older bare clad tests to their proper temperatures, the models used to predict clad failure under various accident conditions were updated. Because of the reduced fuel clad ductility when operating at lower temperatures, combined with changes in the air dispersion modeling and accident analysis techniques, the updated models predict increased radiological impact estimates, due to the increased frequency and magnitude of releases of plutonium dioxide.

A.4 Accident Probabilities and Source Terms

In the 2014 NRA and 2019 NRA Update, DOE evaluated each of the identified end states and estimated the accident environments to which the MMRTG would likely be exposed. From that information, conditional probabilities that a release would occur and estimated source terms were developed, based on the known response of GPHS modules to various accident environments.

The probability of a launch accident involving any release of plutonium dioxide is very small, estimated at approximately 1 in 2,600 in the 2014 FEIS and 1 in 1,000 in the 2019 SEIS. The most severe accident environments would occur during launch area accidents that might expose the MMRTG to mechanical impacts, explosion overpressures and fragments, and fire environments from burning liquid and solid propellants.

A summary of the accident and source term probabilities by mission phase, along with mean and 99th percentile source terms are presented in Table A-3 and Table A-4, for the 2014 FEIS and 2019 SEIS, respectively. “Source term” is defined as the quantity of radioisotope that is released from the fuel clads in the GPHS modules and becomes airborne. Consequences associated with the material released in an accident are driven by the portion of the release that can become airborne and be transported away from the impact site. Not all of the material released from the fuel clads is expected to become airborne; the amount that does is dependent upon the accident conditions. Several factors contribute to a reduction in the released material source term. Some of the release could become trapped in debris or slag at the MMRTG impact site. Plutonium dioxide could be retained inside the graphite components of the GPHS module, and some could be shielded from any fire environments by the graphite components and other debris, including sand. In addition, the size of the plutonium dioxide particles affects the likelihood of the plutonium dioxide becoming airborne—the larger the particles are, the less likely they are to become airborne.

Table A-3. 2014 FEIS Summary of Accident Probabilities and MMRTG Source Terms

Mission Phase[(a)]	Accident Probability[(b)]	Mean Source Term, in Curies (given an accident)	99th Percentile[(c)] Source Term, in Curies (given an accident)	Conditional Probability of Release[(d)]	Total Probability of a Release[(b)]	Mean Source Term, in Curies (given a release)	99th Percentile[(c)] Source Term[(e)], in Curies (given a release)
0: Pre-Launch[(f)]	Very Unlikely (3.3×10^{-5})	0.092	0.048	0.33	Very Unlikely (1.1×10^{-5})	0.28	6.7
1: Early Launch[(f)]							
On-Pad Explosion	Very Unlikely (9.8×10^{-5})	2.0	0.035	0.085	Very Unlikely (8.3×10^{-6})	23	40
FSII	Very Unlikely (2.2×10^{-5})	15	340	0.14	Very Unlikely (3.2×10^{-6})	110	1,800
Stage 2/SV	Very Unlikely (4.8×10^{-5})	2.8	55	0.036	Very Unlikely (1.8×10^{-6})	77	910
SVII	Extremely Unlikely (6.3×10^{-7})	2.7	40	0.054	Extremely Unlikely (3.4×10^{-8})	50	580
Low Altitude FTS	Unlikely (2.9×10^{-3})	1.5	16	0.025	Very Unlikely (7.5×10^{-5})	61	620
Overall Phase 1	Unlikely (3.1×10^{-3})	1.7	16	0.028	Very Unlikely (8.8×10^{-5})	59	630
2: Late Launch	Unlikely (3.6×10^{-3})	3.4×10^{-5}	-	0.0021	Very Unlikely (7.7×10^{-6})	0.016	0.23
3: Suborbital	1.3×10^{-2}	0.047	-	0.0013	Very Unlikely (1.5×10^{-5})	42	930
4: Orbital	Unlikely (4.7×10^{-3})	0.030	0.65	0.056	Unlikely (2.6×10^{-4})	0.53	6.2
5: Long-term Reentry	Very Unlikely (1.0×10^{-6})	0.073	1.5	0.094	Extremely Unlikely (9.4×10^{-8})	0.77	7.8
Overall Mission[(g)]	**2.5×10^{-2}**	**0.24**	**0.0095**	**0.016**	**Unlikely (3.8×10^{-4})**	**16**	**340**

Source: (SNL 2014)

Notes:

Differences in multiplications and summations are due to rounding of results as reported in SNL 2014. Probability categories (e.g., unlikely, very unlikely) defined by NASA.

(a) The table presents a composite of the results for the Atlas V 551 and the Delta IV Heavy, which were used for the 2014 FEIS, determined by taking the probability-weighted value of the two sets of results, treating the conditional probability of having a given launch vehicle as 0.5.

(b) Per launch attempt.

(c) The 99th percentile values would be expected to occur at a probability of about 100 times lower than the mean probability of release.

(d) The conditional probability of a release of plutonium dioxide given that an accident has occurred.

(e) Total source terms given. The source term is that portion of the release, which becomes airborne would represent the amounts of plutonium dioxide released that are no more than 100 microns (100 micrometers) in diameter. Particles larger than this do not generally become airborne and would remain in the vicinity of the accident.

(f) Accidents during these launch phases are relevant to a region of influence associated with the United States. Accidents during subsequent launch phases would be associated with a region of influence considered outside the United States as the “global environment” because these launch phases occur outside the jurisdiction of the United States.

(g) Overall mission values are weighted by the total probability of release for each mission phase.

Key: FSII = full stack intact impact (the entire launch vehicle impacts the ground); Low or High Altitude FTS = flight termination system (the vehicle is destroyed at low or high altitude and debris impacts the ground); Stage 2/SV = stage 2 and space vehicle (the intact stage 2 and the space vehicle impact the ground); SVII = space vehicle intact impact (the entire space vehicle impacts the ground).

Table A-4. 2019 NRA Update Summary of Accident Probabilities and MMRTG Source Terms

Mission Phase[(a)]	Accident Probability[(b)]	Mean Source Term, in Curies (given an accident)	99th Percentile[(c)] Source Term, in Curies (given an accident)	Conditional Probability of Release[(d)]	Total Probability of a Release[(b)]	Mean Source Term, in Curies (given a release)	99th Percentile[(c)] Source Term[(e)], in Curies (given a release)
0: Pre-Launch[(f)]	Unlikely ($1.0x10^{-4}$)	31.5	751	$6.02x10^{-1}$	Very Unlikely ($6.3x10^{-5}$)	52.3	1,080
1: Early Launch[(f)]							
On-Pad Explosion	Very Unlikely ($7.9x10^{-5}$)	541	6,770	$4.1x10^{-1}$	Very Unlikely ($3.2x10^{-5}$)	1,330	10,000
FSII	Very Unlikely ($1.1x10^{-6}$)	5,080	19,600	$7.8x10^{-1}$	Extremely Unlikely ($8.8x10^{-7}$)	6,540	20,200
Stage 2/SV	Very Unlikely ($3.0x10^{-5}$)	1,400	12,100	$5.3x10^{-1}$	Very Unlikely ($1.6x10^{-5}$)	2,650	13,700
SVII	Very Unlikely ($1.5x10^{-6}$)	707	6,090	$6.0x10^{-1}$	Extremely Unlikely ($8.8x10^{-7}$)	1,190	8,610
Low Altitude FTS	Unlikely ($1.6x10^{-3}$)	575	4,210	$5.3x10^{-1}$	Unlikely ($8.5x10^{-4}$)	1,090	5,550
Overall Phase 1	Unlikely ($1.7x10^{-3}$)	591	4,640	$5.2x 10^{-1}$	Unlikely ($9.0x10^{-4}$)	1,130	6,970
2: Late Launch	Unlikely ($2.5x10^{-3}$)	0.0814	-	$1.0x10^{-3}$	Very Unlikely ($2.6x10^{-6}$)	79.8	621
3: Suborbital	Unlikely $6.8x10^{-3}$	0.399	-	$1.1x10^{-3}$	Very Unlikely ($7.3x10^{-6}$)	371	3,820
4: Orbital	Unlikely ($1.2x10^{-3}$)	2.52	75.5	$5.5x10^{-2}$	Very Unlikely ($6.6X10^{-5}$)	46.1	414
5: Long-term Reentry	Unlikely ($1.4x10^{-4}$)	2.90	85.0	$6.0x10^{-2}$	Very Unlikely ($8.5x10^{-6}$)	48.7	423
Overall Mission[(g)]	**$1.3x10^{-2}$**	81.8	2,340	$8.4x10^{-2}$	**Unlikely ($1.0x10^{-3}$)**	**979**	**6,290**

Source: (SNL 2019)

Notes:

Differences in multiplications and summations are due to rounding of results as reported in SNL 2014. Probability categories (e.g., unlikely, very unlikely) defined by NASA.

(a) The table presents results for the Atlas V 541 for the 2019 NRA Update.

(b) Per launch attempt.

(c) The 99th percentile values would be expected to occur at a probability of about 100 times lower than the mean probability of release.

(d) The conditional probability of a release of plutonium dioxide given that an accident has occurred.

(e) Total source terms given. The source term is that portion of the release, which becomes airborne would represent the amounts of plutonium dioxide released that are no more than 100 micrometers (100 microns) in diameter. Particles larger than this do not generally become airborne and would remain in the vicinity of the accident.

(f) Accidents during these launch phases are relevant to a region of influence associated with the United States. Accidents during subsequent launch phases would be associated with a region of influence considered outside the United States as the "global environment" because these launch phases occur outside the jurisdiction of the United States.

(g) Overall mission values are weighted by the total probability of release for each mission phase.

Key: FSII = full stack intact impact (the entire launch vehicle impacts the ground); Low or High Altitude FTS = flight termination system (the vehicle is destroyed at low or high altitude and debris impacts the ground); Stage 2/SV = stage 2 and space vehicle (the intact stage 2 and the space vehicle impact the ground); SVII = space vehicle intact impact (the entire space vehicle impacts the ground).

As noted in Table A-3 and Table A-4, particles larger than 100 micrometers (μm) are expected to remain in the vicinity of the MMRTG impact site. The 99th percentile source term is the value predicted to be exceeded with a probability of 0.01 (1 in 100), given a release in an accident. (This percentile is derived from a statistical analysis to model the progression of the accident. In this analysis, DOE has used a computer code that performs multiple trials, typically 150,000, in which the probabilities of the parameters that affect the size of the source term are varied according to their probability distributions. The 99th percentile is therefore the value exceeded in 1 percent of these trials.) In this context, the 99th percentile value reflects the potential for higher radionuclide releases at lower probabilities. The 99th percentile releases are one to approximately 24 times the mean estimates reported in the 2014 FEIS, but at probabilities of a factor of 100 times lower than the mean probabilities.

- **Phase 0 (Pre-Launch):**
    - 2014 FEIS: During the pre-launch period, and prior to ignition of the Stage 1 liquid rocket engine, most initiating failures result in a mission abort. Those failures that result in on-pad accidents and a release have a total probability of 1.1×10^{-5} (1 in 93,000). The mean source term, given that an accident with a release has occurred, is estimated to be 0.28 curies (Ci).
    - 2019 SEIS: Pre-launch failures that result in on-pad accidents and a release have a total probability of 6.2×10^{-5} (1 in 16,000). The mean source term, given that an accident with a release has occurred, is estimated to be 52.3 Ci.
- **Phase 1 (Early Launch):**
    - 2014 FEIS: During Phase 1, during which land impacts, including near the launch complex, are possible, the accidents resulting in a release have a total probability estimated to be 8.8×10^{-5} (or 1 in 11,000). The mean source term, given that an accident with a release has occurred, is estimated to be 59 Ci.
    - 2019 SEIS : Phase 1 accidents resulting in a release have a total probability of 9.0×10^{-4} (1 in 1,100). The mean source term, given that an accident with a release has occurred, is estimated to be 1,130 Ci.

      Most initiating failures occurring in Phase 1 would lead to activation of the flight termination system (FTS). The elements of the FTS are highly redundant and reliable. As a result, the expected outcome of a Phase 1 accident is a ground impact of the spacecraft or portions thereof, including possibly the rover with attached MMRTG, the MMRTG alone, or free GPHS modules. In this case, mechanical damage and potential exposure to burning solid propellant could occur.

      For the 2014 FEIS analysis, the probability for this impact configuration with a release was estimated to be 7.5×10^{-5} (or 1 in 13,000). The mean source term, given an accident with a release has occurred, is estimated to be 61 Ci.

In the 2019 SEIS analysis, the probability is estimated to be 8.5×10^{-4} (1 in 1,200) with a release of 1,090 Ci.

A much less likely outcome of a Phase 1 accident involves failure of some or all of the FTS elements to perform properly. This could lead to ground impact of the spacecraft (with the MMRTG inside) still attached to other launch vehicle stages (Stages 1 and 2, or Stage 2). Because this would require multiple failures of safety systems, ground impact configurations that lead to a release are very unlikely, with an estimated probability of 5.0×10^{-6} (1 in 200,000) for the 2014 FEIS analysis and 1.7×10^{-5} (1 in 59,000) for the 2019 SEIS analysis, for a full stack intact impact (FSII), where the entire launch vehicle impacts the ground, plus a Stage 2 and space vehicle impact (Stage 2/SV), where the intact Stage 2 and the space vehicle impact the ground.

However, because the MMRTG could impact the ground within the spacecraft at higher velocities and with additional mass above the spacecraft due to the attached Stage(s), the potential for more severe mechanical damage is higher than with the expected accident conditions associated with normal activation of the FTS. For impact configurations leading to the largest estimated releases, such as the Stage 2/SV and the FSII, slightly larger estimated mean source terms given an accident with a release, of 77 Ci and 110 Ci, respectively, are identified in the 2014 FEIS analysis and 2,650 Ci and 6,540 Ci, respectively, in the 2019 SEIS analysis.

- **Phase 2 (Late Launch):** All accidents that could occur in Phase 2 would lead to impact of debris in the Atlantic Ocean. Most such accidents result in no release of plutonium dioxide. However, in some cases, after a command destruct of the Stage 1 and 2 propellant tanks and the solid rocket boosters, small quantities of plutonium dioxide can be released. It is possible that blast and fragment impacts could result in some at altitude releases. The total probability of a release is very unlikely—7.7×10^{-6} (1 in 130,000) with the 2014 FEIS and 2.6×10^{-6} (1 in 390,000) with the 2019 SEIS. The estimated mean source term, given an accident with a release, was determined to be 0.016 Ci in the 2014 FEIS analysis and 79.8 Ci in the 2019 SEIS analysis.
- **Phase 3 (Suborbital):** Accidents during Phase 3 include suborbital reentries. Prior to the attainment of Earth parking orbit, these conditions could lead to prompt suborbital reentry within minutes. Spacecraft breakup may or may not occur, depending on the time since launch. Following spacecraft breakup during reentry, this could result in impacts of individual GPHS modules along the vehicle flight path over the Atlantic Ocean and southern Africa. Additional suborbital land impacts are possible after crossing over Africa, depending on the launch vehicle and its mission timeline. Should the GPHS modules impact hard surfaces (e.g., rock), small releases are possible at ground level. There is a possibility that the space vehicle or portions thereof, including the rover/MMRTG or the MMRTG, would survive suborbital reentry. A command destruct during this period could result in upper-stage fragments presenting a threat to the MMRTG. The total probability of release in

Phase 3 is estimated to be 1.5 x 10^{-5} (or 1 in 67,000) in the 2014 FEIS analysis and 7.3 x 10^{-6} (1 in 136,000) in the 2019 SEIS analysis. The mean source term, given that a release has occurred, is estimated to be 42 Ci in the 2014 FEIS analysis and 371 Ci in the 2019 SEIS analysis. The principle reasons for the higher estimated releases with the 2019 SEIS accident modeling are the increased vulnerability of fuel clads to damage under high impact conditions, such as that which might occur with impacts on hard surfaces.

- **Phase 4 (Orbital):** Accidents that occur after attaining parking orbit could result in orbital decay reentries from minutes to years after the accident. In the 2014 FEIS the Earth surfaces potentially affected were between approximately 29° north latitude and 29° south latitude; in the 2019 NRA Update potentially affected Earth surfaces are anywhere between 35° north latitude and 35° south latitude. Post-reentry impact releases would be similar to those in Phase 3. The total probability of a release is estimated to be 2.6 x 10^{-4} (or 1 in 3,800) in the 2014 FEIS analysis and 6.6 x 10^{-5} (1 in 15,000) in the 2019 SEIS analysis. The space vehicle is expected to break up on reentry, allowing the MMRTG to also break up as designed, releasing the GPHS modules. The modules are designed to survive the reentry heating environment without releasing fuel in the air. The only potential threat to the module is surface impact. Only impacts of intact GPHS modules on exposed rock surfaces or similarly hard materials could lead to a fuel release in this phase. The mean source term, given that a release has occurred, is estimated to be 0.53 Ci in the 2014 FEIS analysis and 46.1 Ci in the 2019 SEIS analysis. The principle reasons for the higher estimated releases in the 2019 SEIS accident modeling are the increased vulnerability of fuel clads to damage under high impact conditions, such as that which might occur with impacts on hard surfaces.

- **Phase 5 (Long-term Reentry):** The potential exists for an inadvertent long-term (hundreds to thousands of years) reentry should the spacecraft be left in an Earth crossing orbit. Based on considerations of long-term inadvertent reentry for other missions, the probability of such an occurrence is estimated to be less than 1 x 10^{-6}. Post-reentry impact releases would be similar to those in Phase 3. The total probability of a release is estimated to be 9.4 x 10^{-8} (or 1 in 11,000,000) in the 2014 FEIS analysis and 8.5 x 10^{-6} (1 in 120,000) in the 2019 SEIS analysis. As with Phase 4 orbital reentries, only impacts of intact GPHS modules on exposed rock surfaces or similarly hard materials could lead to a fuel release in this phase. The mean source term, given that a release has occurred, is estimated to be 0.77 Ci in the 2014 FEIS analysis and 48.7 Ci in the 2019 SEIS analysis. The principle reasons for the higher estimated release probability and releases in the 2019 SEIS accident modeling are the revised modeling of the long-term reentry dynamics, the increased vulnerability of fuel clads to damage under high impact conditions, such as that which might occur with impacts on hard surfaces.

A.5 Radiological Consequences

As in the 2014 FEIS, the radiological consequences (assuming no post-accident mitigation) of a given accident with a radiological release have been calculated in terms of maximum individual dose, collective dose, health effects, and land area at risk of contamination at or above specified levels. (The 2014 FEIS provides additional information on the definitions of these consequences.) Additional information on the behavior of plutonium in the environment (environmental transport and health impact mechanisms) can be found in Appendix B of the 2014 FEIS.

A.5.1 Changes Since the 2014 FEIS

Using the best available information, DOE updated a number of models and parameter inputs for conducting the nuclear safety analysis, including:

- Solid propellant fragmentation and trajectory information:
  - The solid propellant fragment model has been updated since the 2014 FEIS. The new fragmentation model used for this SEIS generates fragments with higher speeds that travel farther than in the previous model.
  - To model solid propellant fragment velocities in the early launch phase, the force imparted to the solid propellant fragments due to the common core explosion is incorporated into the analysis for this SEIS, compared to its exclusion from the previous analysis for the Mars Science Laboratory mission.
- Plutonium release model:
  - The plutonium release model was updated to incorporate the module and iridium cladding response to impact forces, as well as to better capture the material release statistics, compared to 2014 FEIS (see the fuel clad discussion in Section 2.1.3 of the FEIS and Section 3.5.2.2.3, MMRTG Response to Accident Environments, in this SEIS).
- Potential debris impact area:
  - In the presence of the new crew tower, the potential debris impact area has changed since the 2014 FEIS.
- Blast model information:
  - The solid propellant blast model was updated, using test information and new analysis since the 2014 FEIS.
- Solid propellant fire:
  - The solid propellant fire model was updated since the 2014 FEIS, using recent multi-year test data and analysis models. For example, the maximum flame temperature is lower and the aluminum agglomerate size distribution is revised.

- Atmospheric transport modeling, weather data, propellant plume rise, and the particle tracking in plumes, including:
  - Incorporating the international standard 4D Lagrangian particle tracking model jointly developed by the National Oceanic and Atmospheric Administration (NOAA) and the Australian Meteorological Service;
  - Using updated gridded meteorological data for all possible release locations, elevations, and particle sizes, versus global means based on sparse observations that were used previously;
  - Performing complex dispersion and deposition simulations based on a proven dispersion model rather than the previous curve fits to limited data.
- Health effects modeling changes, including:
  - Age-specific dose and risk calculation improvements;
  - Health effects calculations, using specific risk coefficients for plutonium-238 and exposure pathways; and
  - Use of region-specific crop information.

The analysis conservatively assumed no mitigation actions, such as sheltering and keeping people out of potentially affected land areas.

The 2019 NRA Update accounted for the changes listed above, along with the specific design features of the Mars 2020 chosen launch vehicle (which was selected on August 25, 2016, after the 2014 FEIS ROD was published on January 27, 2015). This updated analysis indicates that the chances of some types of launch accidents with a release of plutonium are higher than estimated in the 2014 FEIS and that the potential radiological impacts from those accidents are higher than estimated in the 2014 FEIS.

A.5.2 Discussion of Consequence Results

Table A-5 and Table A-6 present a summary of DOE's risk assessment of radiological consequences, given an accident with a release, for each of the mission phases for the 2014 FEIS and the 2019 SEIS. The radiological consequences were estimated by mission phase in terms of both the mean and 99th percentile values. The 99th percentile radiological consequence is the value predicted to be exceeded 1 percent of the time for an accident with a release.

The radiological consequences summarized in Table A-5 and Table A-6 are related to the source terms listed in Table A-3 and Table A-4, respectively. Key results for the mean estimates are summarized below; the corresponding 99th percentile estimates can be found in Table A-5 and Table A-6.

Table A-5. 2014 FEIS Summary of Estimated MMRTG Accident Radiological Consequences

Mission Phase[(a)]	Total Probability of Release[(b)]	Mean Maximum Individual Dose, in rem	99th Percentile[(c)] Maximum Individual Dose, in rem	Mean Health Effects[(c)]	99th Percentile[(c)] Health Effects[(d)]	Mean Land Area Potentially Affected[(e)], in km^2	99th Percentile[(c)] Land Area Potentially Affected[(e)], in km^2
0: Pre-Launch[(f)]	Very Unlikely ($1.1x10^{-5}$)	0.00029	0.0068	0.0014	0.033	0.035	0.83
1: Early Launch[(f)]							
On-Pad Explosion	Very Unlikely ($8.3x10^{-6}$)	0.024	0.040	0.11	0.19	2.9	4.9
FSII	Very Unlikely ($3.2x10^{-6}$)	0.11	1.9	0.52	8.9	13	230
Stage 2/SV	Very Unlikely ($1.8x10^{-6}$)	0.079	0.93	0.38	4.5	9.7	110
SVII	Extremely Unlikely ($3.4x10^{-8}$)	0.051	0.59	0.25	2.9	6.3	73
Low Altitude FTS	Very Unlikely ($7.5x10^{-5}$)	0.062	0.63	0.30	3.0	7.6	77
Overall Phase 1	Very Unlikely ($8.8x10^{-5}$)	0.060	0.65	0.29	3.1	7.4	79
2: Late Launch	Very Unlikely ($7.7x10^{-6}$)	$1.6x10^{-5}$	0.0002	$7.8x10^{-5}$	0.0011	0.0020	0.029
3: Suborbital	Very Unlikely ($1.5x10^{-5}$)	0.043	0.95	0.20	4.6	5.2	120
4: Orbital	Unlikely ($2.6X10^{-4}$)	0.0005	0.0063	0.0026	0.030	0.066	0.77
5: Long-term Reentry	Extremely Unlikely ($9.4x10^{-8}$)	0.0008	0.0080	0.0038	0.038	0.097	0.98
Overall Mission[(g)]	**Unlikely ($3.8x10^{-4}$)**	**0.016**	**0.35**	**0.076**	**1.7**	**1.9**	**43**

Source: (SNL 2014)

Notes:

Differences in multiplications and summations are due to rounding of results as reported in the 2014 NRA. Probability categories (e.g., unlikely, very unlikely) are as defined by NASA.

(a) The table presents a composite of the results for the Atlas V 551 and the Delta IV Heavy, determined by taking the probability-weighted value of the two sets of results, treating the conditional probability of having a given launch vehicle as 0.5.

(b) Per launch attempt.

(c) The 99th percentile values would be expected to occur at a probability of about 100 times lower than the mean probability of release.

(d) Based on Interagency Steering Committee on Radiation Standards health effects recommendation of 6×10^{-4} health effects per person-rem for the general population.

(e) Land area potentially exceeding 0.2 $\mu Ci/m^2$; 1 km^2 = 0.386 mi^2.

(f) Accidents during these launch phases are relevant to a region of influence associated with the United States. Accidents during subsequent launch phases would be associated with a region of influence considered outside the United States as the “global environment” because these launch phases occur outside the jurisdiction of the United States.

(g) Overall mission values weighted by total probability of release for each mission phase.

Key: $\mu Ci/m^2$ = microcuries per square meter; FSII = full stack intact impact (the entire launch vehicle impacts the ground); km^2 = square kilometers; mi^2 = square miles; Low or High Altitude FTS = flight termination system (the vehicle is destroyed at low or high altitude and debris impacts the ground); NRA = Nuclear Risk Assessment; rem = roentgen equivalent in man; Stage 2/SV = stage 2 and space vehicle (the intact stage 2 and the space vehicle impact the ground); SVII = space vehicle intact impact (the entire space vehicle impacts the ground).

Table A-6. 2019 NRA Update Summary of Estimated MMRTG Accident Radiological Consequences

Mission Phase[(a)]	Total Probability of Release[(b)]	Maximum Individual Dose[(c)], in rem		Health Effects[(e)]		Land Area Potentially Affected[(f)], in km²		Cropland Potentially Affected[(g)], in km²	
		Mean	99th Percentile[(d)]	Mean	99th Percentile	Mean	99th Percentile	Mean	99th Percentile
0: Pre-Launch[(h)]	Very Unlikely ($6.2x10^{-5}$)	0.14	2.4	0.20	4.7	7.4	180	0.00076	0.00
1: Early Launch[(h)]									
On-Pad Explosion	Very Unlikely ($3.2x10^{-5}$)	0.36	8.1	1.1	21	140	2,200	0.025	0.58
FSII	Extremely Unlikely ($8.8x10^{-7}$)	1.2	26	7.0	130	660	6,400	0.12	1.7
Stage 2/SV	Very Unlikely ($1.6x10^{-5}$)	0.39	6.2	1.7	22	260	4,300	0.042	0.85
SVII	Extremely Unlikely ($8.8x10^{-7}$)	0.19	3.6	0.61	9.4	88	1,400	0.017	0.42
Low Altitude FTS	Unlikely ($8.5x10^{-4}$)	0.19	2.9	0.47	6.2	73	940	0.013	0.27
Overall Phase 1	Unlikely ($8.9x10^{-4}$)	0.21	4.1	0.52	7.1	79	1,200	0.014	0.32
2: Late Launch	Very Unlikely ($2.6x10^{-6}$)	0.048	1.3	0.017	0.39	25	410	0.010	0.27
3: Suborbital	Very Unlikely ($7.3x10^{-6}$)	2.4	55	0.32	4.1	76	970	0.0049	0.065
4: Orbital	Very Unlikely ($6.6X10^{-5}$)	1.6	19	0.14	2.7	5.9	52	0.0058	0.10
5: Long-term Reentry	Very Unlikely ($8.5x10^{-6}$)	1.0	19	0.068	1.3	4.9	41	0.0048	0.068
Overall Mission[(i)]	**Unlikely ($1.0x10^{-3}$)**	**0.31**	**5.8**	**0.47**	**6.8**	**69**	**1,000**	**0.012**	**0.28**

Notes:

Differences in multiplications and summations are due to rounding of results as reported in the 2019 NRA Update. Probability categories (e.g., unlikely, very unlikely) are as defined by NASA.

(a) The table presents the results for the Atlas V 541 as reported in the 2019 NRA Update. To facilitate comparison with the 2014 FEIS results, some of the 2019 NRA Update scenario results were combined.

(b) Per launch attempt.

(c) Based on ISCOR-60 modeling of age and organ-specific doses from exposure to plutonium.

(d) The 99th percentile values would be expected to occur at a probability of about 100 times lower than the mean probability of release.

(e) Based on ISCOR-60 modeling of health effects based on organ-specific doses from exposure to plutonium.

(f) Land area exceeding 0.2 µCi/m²; 1 km² = 0.386 mi².

(g) Cropland area exceeding Food and Drug Administration Derived Intervention Level, which is approximately 7.3 µCi/m² (per the 2019 NRA Update).

(h) Accidents during these launch phases are relevant to a region of influence associated with the United States. Accidents during subsequent launch phases would be associated with a region of influence considered outside the United States as the "global environment" because these launch phases occur outside the jurisdiction of the United States.

(i) Overall mission values weighted by total probability of release for each mission phase.

Key: µCi/m² = microcuries per square meter; FEIS = Final Environmental Impact Statement; FSII = full stack intact impact (the entire launch vehicle impacts the ground); ISCOR = Interagency Steering Committee on Radiation; km² = square kilometers; Low Altitude FTS = flight termination system (the vehicle is destroyed at low altitude and debris impacts the ground); mi² = square miles; NRA = Nuclear Risk Assessment; Stage 2/SV = stage 2 and space vehicle (the intact stage 2 and the space vehicle impact the ground); SVII = space vehicle intact impact (the entire space vehicle impacts the ground).

Should the mission be delayed, the Mars 2020 mission would be launched during the next available launch opportunity in August through September 2022. Since that launch period is in a similar season as the 2020 launch period, the projected radiological impacts associated with releases from the MMRTG (Proposed Action) would be similar to those associated with the 2020 launch, with only a small increase in population impacts due to population growth. Thus, within the overall uncertainties, the radiological impacts associated with a 2022 launch would be the same as those for the proposed 2020 launch.

- **Phase 0 (Pre-Launch):** The initiating failures that result in Phase 0 accident configurations are very unlikely, having very low probabilities of occurrence. Most problems that arise during Phase 0 can be successfully mitigated by safety systems and procedures leading to safe hold or termination of the launch countdown.

  In the very unlikely possibility that an accident were to occur during Phase 0, however, there is a potential for measurable releases and contamination. The probability of the MMRTG being close to large pieces of burning solid propellant would be higher in Phase 0 accidents than in other phases.

  - 2014 FEIS: For this very unlikely accident with a release (probability of 1.1×10^{-5} or a 1 in 91,000 chance), the mean maximum dose to an individual is estimated to be approximately 0.00029 rem (i.e., roentgen equivalent in man) (0.29 millirem), less than 0.1 percent of the dose an individual might receive annually from natural background radiation[2].

    Assuming no mitigation actions, such as sheltering and exclusion of people from affected land areas, the radiation doses to the potentially exposed population are predicted to result in 0.0014 mean health effects among the potentially exposed population.

    For Phase 0 accidents with a release, the mean area exceeding 0.2 microcuries per square meter ($\mu Ci/m^2$) (see Section 4.1.4.7 of the 2014 FEIS) is estimated to be about 0.035 square kilometers (km^2) (about 0.014 square miles [mi^2]). Detectable levels below 0.2 $\mu Ci/m^2$ would be expected over a larger area.

  - 2019 SEIS: Pre-launch failures that result in on-pad accidents and a release are characterized as very unlikely with a total probability of 6.2×10^{-5} (1 in 16,000). The mean maximum dose to an individual is estimated to be approximately 0.14 rem (140 millirem), less than half of the dose an individual might receive annually from natural background radiation.

    Assuming no mitigation actions, such as sheltering and exclusion of people from affected land areas, the radiation doses to the potentially exposed

[2] An average of about 0.31 rem per year for an individual in the United States from natural sources. Man-made sources add an additional 0.060 to 0.31 rem. The dominant man-made contribution is from medical radiological diagnosis and therapy. See Section 3.2.6 of the 2014 FEIS for further information.

population are predicted to result in 0.2 mean health effects among the potentially exposed population.

For Phase 0 accidents with a release, the mean area exceeding 0.2 μCi/m^2 (see Section 3.5, Health and Safety, of the SEIS) is estimated to be about 7.4 km^2 (2.9 mi^2). Detectable levels below 0.2 μCi/m^2 would be expected over a larger area. Cropland potentially exceeding the derived intervention level (DIL) (7.3 μCi/m^2) is estimated to be 0.00076 km^2 (0.00029 mi^2).

- **Phase 1 (Early Launch):** Phase 1 consequences consist of contributions from two types of accident scenarios. Most initiating failures occurring in Phase 1 would lead to the activation of the FTS. The elements of the FTS are highly redundant and very reliable. As a result, the expected outcome of a Phase 1 accident is that the space vehicle and MMRTG or its components could fall free to the ground and would be subject to mechanical damage and potential exposure to burning solid propellant resulting in a release of material.
    - <u>2014 FEIS</u>: For this very unlikely impact configuration (Phase 1 Low Altitude FTS), with a probability estimated to be 7.5 x 10^{-5} (or 1 in 13,000), the mean maximum individual dose is estimated to be 0.062 rem (62 millirem), equivalent to about 20 percent of the dose an individual might receive annually from natural background radiation.

      Assuming no mitigation action, such as sheltering, the radiation dose to the potentially exposed population is predicted to result in 0.30 mean health effects among the potentially exposed population over the long term.

      The 2014 NRA indicates that about 7.6 km^2 (about 2.9 mi^2) could exceed 0.2 μCi/m^2.
    - <u>2019 SEIS</u>: For this unlikely impact configuration (Phase 1 Low Altitude FTS), with a probability estimated to be 8.5 x 10^{-4} (or 1 in 1,200), the mean maximum individual dose is estimated to be 0.19 rem (190 millirem), equivalent to about 61 percent of the dose an individual might receive annually from natural background radiation.

      Assuming no mitigation action, such as sheltering, the radiation dose to the potentially exposed population is predicted to result in 0.47 mean health effects among the potentially exposed population over the long term.

      The 2019 NRA Update indicates that about 73 km^2 (about 28 mi^2) is estimated to be potentially exceed 0.2 μCi/m^2, and about 0.013 km^2 (about 0.005 mi^2) could exceed the DIL.

  A less likely outcome of a Phase 1 accident involves failure of some or all of the FTS elements to perform properly. This could lead to ground impact of the spacecraft (with the MMRTG inside) still attached to other launch vehicle stages (Stages 1 and 2, or Stage 2).

- 2014 FEIS: Because this would require multiple failures of safety systems, such ground impact configurations that could lead to a release are very unlikely, with an estimated probability of 3.2×10^{-6} (about 1 in 300,000). However, because the MMRTG could impact the ground within the spacecraft at high speed, the potential for more severe mechanical damage and exposure to burning liquid and, possibly, solid propellant, could result in higher source terms.

  In the more severe impact configurations leading to the largest estimated releases, such as the FSII, mean exposures as high as about 0.11 rem (110 millirem) to the maximum exposed individual might occur. This dose is about a third of the dose an individual might receive annually from natural background radiation. Assuming no mitigation action, such as sheltering, radiation doses to the potentially exposed population are predicted to result in an estimated 0.52 mean health effects. An estimated area of nearly 13 km^2 (about 5.0 mi^2) might exceed 0.2 $\mu Ci/m^2$. Detectable levels below 0.2 $\mu Ci/m^2$ would be expected over a larger area.

- 2019 SEIS: Accidents leading to a release are very unlikely, with an estimated probability of 8.8×10^{-7} (about 1 in 1,100,000). In the more severe impact configurations leading to the largest estimated releases, such as the FSII, mean exposures as high as about 1.2 rem (1,200 millirem) to the maximum exposed individual might occur. This dose is about four times the dose an individual might receive annually from natural background radiation. Assuming no mitigation action, such as sheltering, radiation doses to the potentially exposed population are predicted to result in an estimated 7 mean health effects. An estimated area of nearly 660 km^2 (about 250 mi^2) might exceed above 0.2 $\mu Ci/m^2$, and about 0.12 km^2 (about 0.05 mi^2) could exceed the DIL.

- **Phase 2 (Late Launch):**
  - 2014 FEIS: The total probability of a release in Phase 2, categorized as very unlikely, is estimated to be 7.7×10^{-6} (or 1 in 130,000). Accidents in this phase result in smaller releases and impacts than in any other phase. The mean maximum individual dose is estimated to be 1.6×10^{-5} rem (0.016 millirem), a very small fraction of the dose an individual might receive annually from natural background radiation.

    Assuming no mitigation action, such as sheltering, the radiation dose to the potentially exposed population is predicted to result in 7.8×10^{-5} mean health effects among the potentially exposed population over the long term.

    The 2014 NRA indicates that about 0.002 km^2 (about 0.0008 mi^2) could exceed 0.2 $\mu Ci/m^2$.

  - 2019 SEIS: The total probability of a release in Phase 2, categorized as very unlikely, is estimated to be 2.6×10^{-6} (or 1 in 390,000). Accidents in this phase result in smaller releases and impacts to people, but not potentially affected land area, than in any other phase. The mean maximum individual dose is estimated to be 0.048 rem (48 millirem), about 15 percent of the dose an individual might receive annually from natural background radiation.

Assuming no mitigation action, such as sheltering, the radiation dose to the potentially exposed population is predicted to result in 0.017 mean health effects among the potentially exposed population over the long term.

The 2019 NRA Update indicates that about 25 km^2 (about 9.6 mi^2) could exceed 0.2 $\mu Ci/m^2$, and about 0.01 km^2 (about 0.004 mi^2) could exceed the DIL.

- **Phase 3 (Suborbital):**
    - 2014 FEIS: The total probability of a release in Phase 3, categorized as very unlikely, is estimated to be 1.5 x 10^{-5} (or 1 in 68,000). Mean consequences are estimated to be 0.043 rem (43 millirem) for maximum individual dose, 0.20 health effects among the potentially exposed population, and 5.2 km^2 (about 2.0 mi^2) could exceed 0.2 $\mu Ci/m^2$.
    - 2019 SEIS: The total probability of a release in Phase 3, categorized as very unlikely, is estimated to be 7.3 x 10^{-6} (or 1 in 150,000). Mean consequences are estimated to be 2.4 rem (2,400 millirem) for maximum individual dose (about 77 percent of the average annual natural background dose, 0.32 health effects among the potentially exposed population, and 76 km^2 (about 29 mi^2) could exceed 0.2 $\mu Ci/m^2$, and about 0.0049 km^2 (about 0.002 mi^2) could exceed the DIL.
- **Phase 4 (Orbital):**
    - 2014 FEIS: The total probability of a release in Phase 4, categorized as very unlikely, is estimated to be 2.6 x 10^{-4} (or 1 in 3,800). Mean consequences are estimated to be 0.0005 rem (0.5 millirem) for the maximum individual dose, 0.0026 health effects among the potentially exposed population, and 0.066 km^2 (about 0.025 mi^2) could exceed 0.2 $\mu Ci/m^2$.
    - 2019 SEIS: The total probability of a release in Phase 4, categorized as very unlikely, is estimated to be 6.6 x 10^{-5} (or 1 in 15,000). Mean consequences are estimated to be 1.6 rem (1,600 millirem) for the maximum individual dose (about five years exposure to natural background radiation), 0.14 health effects among the potentially exposed population, 5.9 km^2 (about 2.3 mi^2) could exceed 0.2 $\mu Ci/m^2$, and about 0.0058 km^2 (about 0.002 mi^2) could exceed the DIL.
- **Phase 5 (Long-term Reentry):**
    - 2014 FEIS: The total probability of a release in Phase 5, categorized as extremely unlikely, is estimated to be 9.4 x 10^{-8} (or 1 in 11,000,000). Mean consequences are estimated to be 0.0008 rem (0.8 millirem) for the maximum

individual dose, 0.0038 health effects among the potentially exposed population, and 0.097 km^2 (about 0.037 mi^2) could exceed 0.2 μCi/m^2.

- 2019 SEIS: The total probability of a release in Phase 5, categorized as very unlikely, is estimated to be 8.5 x 10^{-6} (or 1 in 120,000). Mean consequences are estimated to be 1.0 rem (1,000 millirem) for the maximum individual dose (about three years of exposure to natural background radiation), 0.068 health effects among the potentially exposed population, and 4.9 km^2 (about 1.9 mi^2) could exceed 0.2 μCi/m^2, and about 0.0048 km^2 (about 0.004 mi^2) could exceed the DIL.

A.6 Individual Risks Comparison

Individual risk associated with the Mars 2020 mission can be interpreted as the probability of a particular individual in the exposed population incurring a fatal cancer over a period of 50 years. The 2014 NRA and 2019 NRA Update provide an estimate of the lifetime risk to the maximally exposed individual.

The revised individual risk estimates, based on the 2019 NRA Update, are still small compared to other risks. For example, Table A-7 presents information on annual individual fatality risks to residents of the United States due to various types of hazards. This data indicates that in 2017 the average annual individual risk of accidental death in the United States was about 1 in 1,900 per year, while the average annual individual risk of death due to any disease, including cancer, was about 1 in 150 per year.

Table A-7. Calculated Individual Risk and Probability of Fatality by Various Causes in the United States in 2017

Accident Type	Number of Fatalities	Approximate Individual Risk Per Year	Probability
Extremely Unlikely			
Lightning	16	4.9 x 10^{-8}	1 in 20 million
Tornadoes	35	1.1x 10^{-7}	1 in 9 million
Flood	116	3.6 x 10^{-7}	1 in 3 million
Extreme Heat or Cold	133	4.1 x 10^{-7}	1 in 2 million
Very Unlikely			
Accidental Discharge of Firearms	486	1 x 10^{-6}	1 in 670,000
All Weather	508	1.6x 10^{-6}	1 in 640,000
Legal Intervention	616	2 x 10^{-6}	1 in 530,000
Accidental Exposure to Smoke, Fires and Flames	2,812	9. x 10^{-6}	1 in 120,000
Accidental Drowning and Submersion	3,709	1.1 x 10^{-5}	1 in 88,000
All Fatal Injuries at Work	5,147	1.6 x 10^{-5}	1 in 63,000
Assault (Homicide)	19,510	6.0 x 10^{-5}	1 in 17,000
Alcohol-induced deaths	35,823	1.1 x 10^{-4}	1 in 9,100
Falls	36,338	1.12 x 10^{-4}	1 in 9,000
Motor Vehicle	40,231	1.24 x 10^{-4}	1 in 8,100

Table A-7. Calculated Individual Risk and Probability of Fatality by Various Causes in the United States in 2017

Accident Type	Number of Fatalities	Approximate Individual Risk Per Year	Probability
Suicide	47,173	1.45×10^{-4}	1 in 6,900
Accidental Poisoning and Exposure to Noxious Substances	64,795	1.99×10^{-4}	1 in 5,000
Drug-induced deaths	73,900	2.27×10^{-4}	1 in 4,400
All Accidents	169,936	5.22×10^{-4}	1 in 1,900
Unlikely			
All Diseases (2017)	2,172,682	6.67×10^{-3}	1 in 150
All Causes	**2813503**	**8.64×10^{-3}**	**1 in 120**

Sources: (BLS 2018, NOAA 2018, HHS 2019)
Note: The census population of the United States for 2017 was 325,719,178 (HHS 2019).

A.7 References

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