

Record of Decision
Final Environmental Impact Statement
Mars 2020 Mission



National Aeronautics and Space Administration
Science Mission Directorate
NASA Headquarters
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RECORD OF DECISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MARS 2020 MISSION

A. Background

The National Aeronautics and Space Administration (NASA) has prepared this Record of Decision (ROD) for the *Final Environmental Impact Statement (FEIS) for the Mars 2020 Mission* dated November 2014. This ROD includes a summary of the FEIS, public involvement in the decision-making process, synopses of alternatives considered, a summary of key environmental issues evaluated, statement of the decision made (selection of an alternative), and the basis for the decision.

Purpose and Need for the Proposed Mission

NASA's Mars Exploration Program (MEP) is fundamentally a science-driven program focused on understanding and characterizing Mars as a dynamic system and ultimately addressing whether life is or was ever a part of that system. The goals of the MEP are to determine if life exists or has ever existed on Mars, understand the processes and history of climate on Mars, determine the geological evolution of the surface and interior of Mars, and prepare for human exploration. The MEP is currently implemented as a sustained series of robotic flight missions to Mars, each of which provides important, focused scientific return. NASA is taking advantage of launch opportunities available approximately every 26 months to evolve a scientifically integrated architecture of orbiters, landers, and rovers.

To discover the possibilities for past or present life on Mars, NASA's MEP is currently following an exploration strategy known as "Seek Signs of Life." This science theme marks an evolution in the Mars exploration strategy. Because water is key to life as we know it, earlier Mars missions were designed to make discoveries under the MEP science theme of "Follow the Water." That strategy connected fundamental program goals pertaining to biological potential, climate, and the evolution of the solid planet. Progressive discoveries related to evidence of past and present water in the geologic record made it possible to take the next steps toward finding evidence of life itself.

The evolution of the MEP exploration strategy to "Seek Signs of Life" reflects a long-term process of discovery on the red planet built on strategies to understand Mars' potential as a habitat for past or present microbial life. Searching for this answer means delving into the planet's geologic and climate history to find out how, when, and why Mars underwent dramatic changes to become the planet we observe today.

The purpose of the Mars 2020 mission, the first MEP mission designed under the "Seek Signs of Life" strategy, is to both conduct comprehensive science on the surface of Mars and demonstrate technological advancements potentially useful for the future exploration of Mars. The overall scientific goal is to address in detail questions of habitability and the potential origin and evolution of life on Mars. To address this goal the following objectives have been identified for the Mars 2020 mission:

- A. Characterize the processes that formed and modified the geologic record within a field exploration area on Mars selected for evidence of an astrobiologically-relevant ancient environment and geologic diversity.
- B. Perform astrobiologically-relevant investigations on the geologic materials at the landing site:
 - 1. Determine the habitability of an ancient environment.
 - 2. For ancient environments interpreted to have been habitable, search for materials with high biosignature preservation potential.
 - 3. Search for potential evidence of past life using the observations regarding habitability and preservation as a guide.
- C. Assemble a returnable cache of samples for possible future return to Earth:
 - 1. Obtain samples that are scientifically selected, for which the field context is documented, that contain the most promising samples identified and that represent the geologic diversity of the field site.
 - 2. Ensure compliance with future needs in the areas of planetary protection and engineering so that the cache could be returned in the future if NASA chooses to do so.
- D. Contribute to the preparation for human exploration of Mars by making significant progress towards filling at least one major Strategic Knowledge Gap¹. The highest priority measurements that are synergistic with Mars 2020 science objectives and compatible with the mission concept are:
 - 1. Demonstrate In Situ Resource Utilization (ISRU) technologies to enable propellant and consumable oxygen production from the Martian atmosphere for future exploration missions.
 - 2. Characterize atmospheric dust size and morphology to understand its effects on the operation of surface systems and human health.
 - 3. Collect surface weather measurements to validate global atmospheric models.
 - 4. Demonstrate improved technical capabilities for landing and operating on the surface of Mars to benefit future Mars missions.

The form of the Mars 2020 mission—a landed rover carrying a suite of scientific instruments—is being designed to maximize the potential science return from the mission. The rover’s mobility provides access to a significantly larger area than possible with a landed, stationary mission. Mobility is essential because evidence for past or present life on Mars will very likely not be so abundant or widespread that it will be available in the immediate vicinity of the selected landing site. The Mars 2020 rover will carry a suite of complementary instruments, have an extensive range and long lifetime, and have one or more manipulative devices for acquiring and caching samples. These capabilities will allow the Mars 2020 mission to conduct comprehensive science investigations on the surface for an extensive period of time and to advance technological and operational capabilities for future missions.

¹ Gaps in knowledge or information required to reduce risk, increase effectiveness, and improve the design of robotic and human space exploration missions.

B. The Environmental Impact Statement

B.1 Introduction

NASA prepared an Environmental Impact Statement (EIS) to analyze the potential environmental impacts of the proposed Mars 2020 mission. The U.S. Department of Energy (DOE) was a cooperating agency in the EIS because the Proposed Action (Alternative 1) and Alternative 3 (see Section B.2 below) would use plutonium dioxide-fueled power systems or heater units, respectively. The Proposed Action (Alternative 1) would use a DOE-developed and owned radioisotope power system (RPS), specifically a Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) to provide electric power and heat (to maintain internal rover temperature) for the Mars 2020 rover. Alternative 3 would use DOE-developed and owned Light-Weight Radioisotope Heater Units (LWRHUs) to provide heat to maintain internal rover temperature.

On September 11, 2013, NASA published in the Federal Register (78 FR 55762) a Notice of Intent (NOI) to prepare an EIS and conduct scoping for the Mars 2020 mission. Public input and comments on alternatives, potential environmental impacts, and concerns associated with the proposed Mars 2020 mission were requested. The scoping period ended on October 30, 2013. Two scoping meetings were held in the vicinity of Kennedy Space Center (KSC), Florida; one on October 9, 2013, at the Cocoa Beach Country Club, and a second on October 10, 2013, at the Brevard County Government Center. NASA placed paid advertisements announcing the dates, times, and purpose of the scoping meetings in local and regional newspapers. Two comments were received during the scoping period—one comment submitted in writing and one comment received by telephone. The comments identified four topics to be addressed in the EIS: 1) impacts on local flora and fauna, 2) mission plans to limit the spread of radiological and non-radiological materials in the event of a launch accident, 3) results of the risk assessment and the impacts to Earth's organisms, and 4) nuclear wastes associated with using radioactive power sources. Each of these scoping comments was considered in developing the Draft EIS.

NASA published a Notice of Availability (NOA) for the Draft EIS for the Mars 2020 mission in the Federal Register on June 5, 2014 (79 FR 32577). The NOA was mailed by NASA to about 200 potentially interested individuals, organizations, and Federal, state, and local agencies. Most of the NOA recipients also received a copy of the Draft EIS. In addition, the Draft EIS was published electronically on NASA's NEPA website. The U.S. Environmental Protection Agency (EPA) published its NOA for the Draft EIS in the Federal Register on June 6, 2014 (79 FR 32729), which initiated the 45-day public review and comment period.

The public review and comment period closed on July 21, 2014. NASA received ten comments (by letter, email, and telephone) from two Federal agencies, one State agency, two private organizations, and five individuals. All comments were reviewed and considered in preparation of the FEIS. The comments received included "no comments" on the Draft EIS; general support for NASA and for the mission; objection to the mission in general and, specifically, to the use of radioactive material on the mission; and requests for additional information on specific sections of the document. All comment submissions received by NASA during the Draft EIS public comment period can be found in Appendix D of the FEIS along with NASA's responses to the specific comments.

In addition to soliciting comments for submittal by e-mail, letter, and telephone, NASA held an online meeting during which the public was invited to provide comments on the Mars 2020 mission Draft EIS. The online meeting was held on June 26, 2014. This meeting was advertised in the NOA and local (KSC area) digital and print news at the time of the NOA. Additional digital advertisements were placed shortly before the meeting. In addition, NASA announced the meeting through several of NASA's social media sites (using Twitter, Facebook, and Google+) in the week prior to the online meeting. Through a live streaming chat, members of the public were able to ask questions about the mission and the Draft EIS and to provide comments on the Draft EIS. No comments on the Draft EIS were made during the online meeting.

By letter dated July 28, 2014, the EPA provided a finding of EC-1 for the Draft EIS, which indicates there are "environmental concerns" considering the low probability of an accident involving a plutonium fuel source. EPA stated in the letter that NASA provided sufficient information in the Draft EIS regarding such low probability accidents. The EPA also requested that contingency planning and emergency response coordination be addressed in the FEIS and ROD. These activities are discussed in Section 2.1.7 and 4.1.5 in the FEIS. Section F below addresses the activities NASA proposes to mitigate the consequences of these low probability accidents.

NASA published its NOA for the FEIS in the Federal Register on November 18, 2014 (79 FR 68726) and mailed the FEIS and NOA to 72 Federal, State, and local agencies, organizations, and individuals. In addition, NASA made the FEIS available in electronic format on the NASA NEPA website. NASA sent e-mail or regular mail notifications containing the NOA to an additional 110 Federal, State, and local agencies, organizations, and individuals. All those who had submitted comments (ten comments were received) on the Draft EIS were recipients of a mailing. The EPA published its NOA in the Federal Register on November 14, 2014 (79 FR 68242), initiating the 30-day waiting period, which ended on December 15, 2014. NASA received only one comment during this period. NASA's response to this comment is discussed in Section E.2 below.

B.2 Alternatives Considered

The reasonable alternatives considered in the FEIS are:

1. The Proposed Action (Alternative 1), in which NASA would continue preparations for and implement the baseline Mars 2020 mission to the surface of Mars. The proposed Mars 2020 spacecraft would be launched on board an expendable launch vehicle from KSC or Cape Canaveral Air Force Station (CCAFS), Brevard County, Florida, during a 20-day launch opportunity that runs from July through August 2020, and would be inserted into a trajectory toward Mars. Should the mission be delayed, the proposed Mars 2020 mission would be launched during the next available launch opportunity in August through September 2022. The rover proposed for the Mars 2020 mission would utilize a radioisotope power system to continually provide heat and electrical power to the rover's battery so that the rover could operate and conduct science on the surface of Mars.

The Proposed Action (Alternative 1) is the alternative that would best accomplish the goals and objectives established for the Mars 2020 mission. The Proposed Action (Alternative 1) was designated NASA's preferred alternative in the FEIS.

2. Alternative 2, in which NASA would discontinue preparation for the Proposed Action (Alternative 1) and implement an alternative configuration for the Mars 2020 mission to Mars. The Mars 2020 rover would utilize solar arrays as its source of electrical power to operate and conduct science on the surface of Mars. The alternative Mars 2020 spacecraft would still be launched on board an expendable launch vehicle from KSC or CCAFS, Brevard County, Florida, during a 20-day launch opportunity that runs from July through August 2020, and would be inserted into a trajectory toward Mars. Should the mission be delayed, the proposed Mars 2020 mission would be launched during the next available launch opportunity in August through September 2022.
3. Alternative 3, in which NASA would discontinue preparations for the Proposed Action (Alternative 1) and implement an alternative configuration for the Mars 2020 mission to Mars. The Mars 2020 rover would utilize solar arrays as its source of electrical power to operate and conduct science on the surface of Mars. The rover thermal environment would be augmented by the thermal output from Light-Weight Radioisotope Heater Units (LWRHUs) to help keep the rover's onboard systems at proper operating temperatures. The Mars 2020 spacecraft would still be launched on board an expendable launch vehicle from KSC or CCAFS, Brevard County, Florida, during a 20-day launch opportunity that runs from July through August 2020, and would be inserted into a trajectory toward Mars. Should the mission be delayed, the proposed Mars 2020 mission would be launched during the next available launch opportunity in August through September 2022.
4. The No Action Alternative, in which NASA would discontinue preparations for a Mars 2020 mission and the spacecraft would not be launched.

B.3 Alternatives Considered But Not Evaluated Further

There were no alternatives considered but not evaluated further. Alternative radioisotope power sources to the MMRTG were considered in previous environmental impact statements. These alternatives were not considered here since no new information has been developed that would indicate that these power sources would present a viable alternative to the MMRTG.

B.4 Key Environmental Issues Evaluated

The key environmental issues of implementing the Proposed Action (Alternative 1) or Alternatives 2 or 3 are those associated with the air emissions that would accompany a normal launch of the Mars 2020 spacecraft and the environmental consequences (both non-radiological and radiological) associated with potential launch accidents.

Consideration of launch accidents involving radiological consequences under the Proposed Action (Alternative 1) and Alternative 3 was a principal focus of the Mars 2020 EIS. The proposed Mars 2020 spacecraft under the Proposed Action (Alternative 1) would have one

MMRTG that uses plutonium dioxide to provide electrical power so that the rover could operate and conduct science and heat to maintain internal rover temperature. The total plutonium dioxide inventory would be 4.8 kilograms (10.6 pounds), with approximately 60,000 curies at the time of launch. The proposed Mars 2020 spacecraft under Alternative 3 could have up to 71 LWRHUs, which use plutonium dioxide to provide heat to maintain internal rover temperature. The total plutonium dioxide inventory would be up to 190 grams (0.42 pounds), with approximately 2,360 curies at the time of launch. Depending upon the sequence of events, some launch accidents could result in release of some of the plutonium dioxide, which could have adverse impacts on human health and the environment. For Alternative 2, there would be no radiological power sources or heat sources and no launch accidents involving radiological consequences.

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

B.5 Environmental Consequences of the Alternatives

B.5.1 Normal Launch

The environmental impacts associated with a normal launch of the Mars 2020 spacecraft under the Proposed Action (Alternative 1), Alternative 2, or Alternative 3 would center largely on the exhaust products emitted from the launch vehicle's strap-on solid rockets and the short-term impacts of those emissions should a vehicle that uses solid rockets be selected. NASA plans to issue a Request for Launch Service Proposal to all NASA Launch Service approved contractors. The evaluations of potential environmental consequences for this FEIS were based upon representative configurations of launch vehicles that would have the performance capabilities necessary for the mission. The representative launch vehicles for the Mars 2020 mission described in the FEIS include the Atlas V 541, Atlas V 551, the Delta IV Heavy, and the Falcon Heavy.

High concentrations of solid rocket motor exhaust products, principally aluminum oxide particulates, carbon monoxide, hydrogen chloride, nitrogen, and water, would occur in the exhaust cloud that would form at the launch complex. First-stage liquid propellant engines that use liquid hydrogen and liquid oxygen, such as the Delta IV, would produce water vapor. First-stage liquid propellant engines that use rocket propellant-1 (RP-1) and liquid oxygen, such as the Atlas V and Falcon Heavy, would primarily produce carbon monoxide, carbon dioxide, and water vapor as combustion products. These exhaust products can cause short-term impacts on local air quality. After ignition of the first stage and the first few seconds of liftoff through launch vehicle ascent, the exhaust emissions would form a buoyant cloud at the launch pad. This cloud would rise quickly and would then dissipate through mixing with the atmosphere. The exhaust products would be distributed along the launch vehicle's trajectory as the vehicle moves through the atmosphere. Airborne emissions from a normal launch of the Mars 2020 mission at KSC or CCAFS would not be expected to result in adverse impacts to the public. For any of the launch vehicles, no long term adverse impacts to local air quality would be expected.

If rain were to occur shortly after launch, some short-term acidification of nearby water bodies could occur with the accompanying potential for some mortality of aquatic biota. Biota that

happened to be in the path of the exhaust could be damaged or killed. Threatened or endangered species would not be jeopardized nor would critical habitats be affected at KSC or CCAFS.

As the launch vehicle gains altitude, a portion of the solid rocket motor exhaust would be deposited in the stratosphere, resulting in a short-term reduction in ozone along the launch vehicle's flight path. The launch of the Mars 2020 mission would not be expected to make substantial contributions to the amounts of ozone-depleting chemicals or greenhouse gases in the atmosphere since the depletion trail would be largely temporary and dissipate within a few hours of the vehicle's passage.

Under the No Action Alternative, NASA would discontinue preparations for the Mars 2020 mission, and the spacecraft would not be launched. Thus, none of the anticipated impacts associated with a normal launch would occur.

B.5.2 Potential Accidents

Non-radiological accidents could occur during preparation for and launch of the Mars 2020 spacecraft at KSC or CCAFS. Only two types of non-radiological accidents would have potential environmental consequences: a liquid propellant spill occurring after the start of propellant loading operations and a launch accident. Under the No Action Alternative a launch would not occur, therefore there would be no potential for any accident to occur.

All of the Mars 2020 mission candidate launch vehicles use liquid propellant. An Atlas V uses rocket propellant-1 and liquid oxygen for first and second stage propellant. A Delta IV Heavy use liquid hydrogen and liquid oxygen for the first stage and second stage. The Falcon Heavy would use rocket propellant-1 and liquid oxygen for the first stage, and liquid hydrogen and liquid oxygen for the second stage. The Atlas V and Delta IV Heavy vehicles second stage and the Mars 2020 spacecraft use hydrazine.

Accidental leaks or spills of the liquid propellants could occur during propellant loading and unloading activities. USAF safety requirements specify detailed policies and procedures to be followed to ensure worker and public safety during liquid propellant fueling operations. Workers performing propellant loading (rocket propellant-1 and hydrazine) would be equipped with protective clothing and a breathing apparatus, and uninvolved workers would be excluded from the area during propellant loading. Spill containment and spill kits would be in place prior to any propellant transfer to capture any potential release. Propellant spills or releases would be minimized through remotely operated actions that close applicable valves and safe the propellant loading system. Any leakage would be held to an absolute minimum. It is expected that, because of the spill prevention and mitigation measures in place, there would be no impact to the public.

A launch vehicle accident on or near the launch area during the first few seconds of flight could result in the release of the propellants (solid and liquid) onboard the launch vehicle and the spacecraft. A launch vehicle accident would result in the prompt combustion of a portion of the liquid propellants, depending on the degree of mixing and ignition sources associated with the accident, and somewhat slower burning of the solid propellant fragments, should a vehicle that uses solid rockets be selected. The resulting emissions would resemble those from a normal

launch. Falling debris would be expected to land on or near the launch pad resulting in potential secondary ground-level explosions and localized fires. After the launch vehicle clears land, debris from an accident would be expected to fall over the Atlantic Ocean. Modeling of accident consequences with meteorological parameters that would result in the greatest concentrations of emissions over land areas indicates that the emissions would not reach levels threatening public health. Some burning solid and liquid propellants could enter surface water bodies and the ocean resulting in short-term, localized degradation of water quality and conditions toxic to aquatic life. Such chemicals entering the ocean would be dispersed and buffered, resulting in little long-term impact on water quality and resident biota.

NASA has studied the potential human health risks associated with reentry and Earth impact of spacecraft propellant tanks, including those used on prior science missions to the surface of Mars. Specifically, for the Mars Science Laboratory spacecraft, an analysis showed that under certain launch accident conditions, there was a small probability the spacecraft with a full propellant load could reenter prior to achieving orbit and impact land. The overall risk of an individual injury resulting from the land impact of a spacecraft and exposure to hydrazine was determined to be less than 1 in 100,000. In accident scenarios occurring after achievement of the park orbit, this same analysis determined that it would be extremely unlikely that there would be any residual hydrazine remaining inside the propellant tanks at the point of ground impact.

One of the primary issues addressed in the Mars 2020 EIS for the Proposed Action (Alternative 1) and Alternative 3 is the possible radiological consequences of mission accidents. DOE prepared a Nuclear Risk Assessment to support the EIS. The nuclear risk assessment for the proposed Mars 2020 mission considers (1) potential accidents associated with the launch and their probabilities and accident environments; (2) the response of the MMRTG and LWRHUs 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. Potential accidents were identified for six mission phases covering the time period from before launch to spacecraft insertion on a trajectory towards Mars. The risk assessment for the Proposed Action (Alternative 1) was based on a typical MMRTG radioactive material inventory of about 60,000 Ci of primarily plutonium-238 (an alpha-emitter with an 87.7 year half-life). The risk assessment for Alternative 3 was based on the radioactive material inventory associated with 80 LWRHUs (which envelopes the 71 LWRHUs used in the analysis for Alternative 3) with an inventory of about 2,700 curies of plutonium-238.

DOE's risk assessment was developed when the representative launch vehicles being evaluated by NASA for the Mars 2020 mission were the Atlas V 541 and 551, the Delta IV Heavy, and the Falcon Heavy. A composite approach was taken in DOE's nuclear risk assessment for accident probabilities, potential releases of plutonium dioxide in case of an accident (called source terms), radiological consequences, and mission risks. The composite approach taken in the risk assessment and reported in this FEIS reflects the state of knowledge at this early stage in the mission with respect to the candidate launch vehicles.

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 delivered to a single individual assumed to be outside 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. Health effects represent estimated additional latent cancer fatalities resulting from an exposure to a release of radioactive material. Potential environmental contamination was evaluated in terms of land areas that could be contaminated at or above a specified level ($0.2 \mu\text{curies}/\text{m}^2$) and in terms of cropland contamination at or above levels intended to ensure contaminated foodstuffs would not endanger the health and safety of the public.

Results of the DOE risk analysis show that the most likely outcome of implementing the Proposed Action (Alternative 1) or Alternative 3 would be a successful launch with no release of radioactive materials. For most launch-related problems that could occur prior to launch, the most likely result would be a safe hold or termination of the launch countdown. An unsuccessful launch could result from either a launch vehicle malfunction or other 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 risk assessment did however identify potential launch accidents that could result in a release of plutonium dioxide in the launch area, in southern Africa or Madagascar following a suborbital reentry, and other global locations following orbital or long-term reentry. However, in each of these regions an accident resulting in a release of plutonium dioxide is at worst unlikely (between a 1 in 100 and 1 in 10,000 chance of occurring). Under the Proposed Action (Alternative 1) the likelihood of an accident with a release during each mission phase ranges from 1 in 3,800 to 1 in 11 million. Under Alternative 3 they range from 1 in 16,000 to zero (accidents that occur while the spacecraft is over the Atlantic Ocean or after it has reached orbit do not result in the release of plutonium dioxide from the LWRHUs).

Under the Proposed Action (Alternative 1), the overall mission likelihood of an accident resulting in the release of plutonium dioxide from the MMRTG is 1 in 2,600. The mission human health consequences are:

- maximum dose received by an individual would have a mean of 0.016 rem (16 millirem), which is equivalent to about 5% of the natural annual background dose received by a person living in the United States during a year 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 maximum dose received by an individual ranges from 0.000016 to 0.060 rem (0.016 to 60 millirem), 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 (the time from engine start until the time just after the launch vehicle debris from an accident would be expected to impact in the launch area).

Under Alternative 3, the overall mission likelihood of an accident resulting in the release of plutonium dioxide from the LWRHUs is 1 in 15,000. The mission human health consequences are:

- maximum dose received by an individual would have a mean of 0.0041 rem (4.1 millirem) which is equivalent to about 1% of the natural annual background dose received by a person living in the United States during a year
- a mean collective dose resulting in about 0.020 additional latent cancer fatalities within the entire group of potentially exposed individuals.

For individual phases of the mission in which accidents can result in a plutonium dioxide release, the maximum dose received by an individual ranges from 0.0013 to 0.0042 rem (1.3 to 4.2 millirem) and the additional latent cancer fatalities range from 0.006 to 0.020. Accidents occurring during three of the six mission phases are not expected to release any plutonium dioxide. The largest values are both associated with accidents with releases that occur during the Early Launch Phase.

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.

Under the Proposed Action (Alternative 1), the mean land contamination is 1.9 km² (0.75 mi²). For individual phases of the mission, land contamination ranges from 0.002 to 7.5 km² (0.00077 to 2.9 mi²). The largest value is associated with accidents with releases that occur during the Early Launch Phase.

Under Alternative 3, the mean land contamination is 0.5 km² (0.19 mi²). For individual phases of the mission, land contamination ranges from 0.0 to 7.5 km² (0.0 to 0.51 mi²). The largest values are both associated with accidents with releases that occur during the Early Launch Phase.

For alternatives 1 and 3, costs associated with potential characterization and cleanup, should decontamination be required, could vary widely (\$110 million to \$611 million per km² or about \$284 million to \$1.58 billion per mi²) depending upon the characteristics and size of the contaminated area.

The risk assessment considered a second level of land contamination, a level used by the Food and Drug Administration 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 contamination above which some action (decontamination, destruction, quarantine, etc.) is required. For potential launch area accidents, DOE has estimated that crop areas contaminated above the DIL would be over 50 times smaller than the area contaminated above 0.2 µCi/m².

In summary, considering the launch accidents assessed in this EIS, the maximally exposed individual within the launch-area and global populations would face less than a 1 in 300 million chance of incurring a latent cancer fatality due to a catastrophic failure of the Mars 2020 mission under either the Proposed Action (Alternative 1) or Alternative 3.

For the Proposed Action (Alternative 1), overall population health effects risk from the release of plutonium dioxide is estimated to be about 1 in 34,000—that is, one chance in 34,000 of an additional health effect. The total probability of a health effect within the regional population is about 1 in 61,000, or about 57% of the total risk for the overall mission. For the global

population (excluding those exposed in the launch area region) the risk was estimated to be about 1 in 79,000, or about 43% of the total risk for the mission.

For Alternative 3, overall population health effects risk from the release of plutonium dioxide is estimated to be about 1 in 790,000. The total probability of a health effect within the regional population is about 1 in 1,200,000, or about 64% of the total risk for the overall mission. For the global population (excluding those exposed in the launch area region) the risk was estimated to be about 1 in 2,200,000, or about 36% of the total risk for the mission.

Under Alternative 2, the Mars 2020 rover would utilize solar energy as its primary source of electrical power. Alternative 2 would not involve any MMRTG- or LWRHU-associated radiological risks as neither radioisotope power source would be used for this mission alternative.

Under the No Action Alternative, NASA would not complete preparations for and implement the Mars 2020 mission. The No Action Alternative would, therefore, not involve any of the radiological risks associated with potential launch accidents.

C. Summary of the Analysis

The environmental impacts of a normal launch of the Mars 2020 spacecraft under the Proposed Action (Alternative 1), Alternative 2, or Alternative 3 would consist principally of short-term impacts associated with the exhaust emission from the selected launch vehicle. Such impacts of launches from CCAFS and KSC have been previously addressed and fully characterized in USAF and NASA environmental documentation. A normal launch of the Mars 2020 mission is within the scope of operations analyzed in that previous documentation and would not be expected to cause any environmental impacts beyond those of routine CCAFS and KSC launch operations.

The DOE's risk assessment for the Proposed Action (Alternative 1) and for Alternative 3 shows that in most launch accidents there would be no release of nuclear material. The environmental impacts of a launch accident with no release of nuclear material would consist principally of emission from burning propellants and from falling debris. Emission from a launch accident would resemble the emissions from a normal launch and would not be anticipated to reach levels threatening public health. Debris from a launch accident would be expected to fall in the launch site area or the Atlantic Ocean.

In the unlikely event of an accident resulting in release of nuclear material, the risk assessment indicates that for the Proposed Action (Alternative 1) and for Alternative 3 no additional latent cancer fatalities would be expected among the potentially exposed members of the population. Additionally, there are no potential launch accidents (*e.g.* a launch accident in which the launch vehicle safety systems fail to operate) that would result, in the mean, in any additional latent cancer fatalities among potentially exposed members of the population.

D. Choice of Alternatives

In view of the small risks associated with the Mars 2020 mission's use of an MMRTG as the primary electrical power source to operate and conduct science on the surface of Mars, it is NASA's intention to select the Proposed Action (Alternative 1) (see subsection B.2 above), based on the following.

The Proposed Action (Alternative 1) enables the best return of scientific and technical information and makes most effective use of fiscal, human, and material resources.

NASA established operational capabilities for the proposed Mars 2020 mission to meet the goals and objectives summarized above (see Section A). Baseline and threshold capabilities have been established. Achieving the baseline capabilities (*e.g.* operating on the surface for at least one Mars year) would maximize the potential for the mission to be most responsive to real-time discoveries and fulfill its comprehensive science objectives. The baseline operational capabilities include, but are not limited to, the following:

- be capable of landing on the surface of Mars within a 25 km x 20 km (16 mi x 12 mi) elliptical target area with an improved ability to avoid terrain hazards within the targeted landing area;
- be capable of landing between 30° north and 30° south latitudes;
- be capable of landing and operating at an elevation of up to +0.5 km (about 0.3 mi) as defined by the survey by the Mars Orbiter Laser Altimeter;
- be designed to operate for at least one Mars year (687 Earth days);
- be capable of adequate mobility to ensure representative measurement of diverse sites at distances of at least 20 km (12 mi);
- accommodate the NASA-selected science payload capable of definitively analyzing the mineralogy, chemistry, texture, and structure of surface and near-surface materials; and be capable of detecting organic material. The instrumentation suite would include the capability for context imaging, context mineralogy, fine-scale imaging, fine-scale mineralogy, fine-scale elementary chemistry, and organic detection;
- provide the capability for 31 to 38 samples to be acquired for caching or potential caching (includes: rock, regolith and/or dust, blanks/standards); and
- demonstrate a technology enabling future human missions to Mars.

The exact landing site for the Mars 2020 mission will be selected closer to the proposed launch. The site selection process will include a recommendation by mission scientists, utilizing available science data, including high resolution surface images, on the most scientifically worthy location to land the rover. The selection process will also include NASA's engineering assessment of the rover's capabilities at the proposed site. NASA will then approve the selected site.

The MMRTG-powered rover under the proposed Action (Alternative 1), the solar-powered rover under Alternative 2, and the solar-LWRHU-powered rover under Alternative 3 could accommodate the NASA-selected science payload. The MMRTG-powered rover would be capable of performing all the science experiments planned for the mission for an entire Mars year over a wide latitude range on Mars (30° north latitude to 30° south latitude). The solar-powered rover operational capability was assessed assuming currently available solar arrays performing within the operational capabilities demonstrated by the Mars Exploration Rover solar arrays. The solar-powered rover would not be capable of performing all the science experiments planned for the mission for a full Mars year at any latitude. The solar powered rover would be unable to generate sufficient power for the rover to survive the extreme cold temperatures, and thus would be able to survive for less than a full Mars year. The solar-LWRHU-powered rover would also not be capable of performing all the science experiments planned for the mission for an entire Mars year at any latitude. While full year operation is possible over a latitude range on Mars of 20° south latitude to 5° south latitude, reduced operational capabilities during portions of the Mars year (rover survives winter with periods of hibernation) limit the ability to perform science experiments. Less than a full Mars year operation (in which the rover does not survive winter, even with hibernation) in the other portions of the 30° south latitude to 30° north latitude band (30° south latitude to 20° south latitude and 30° north latitude to 5° south latitude bands) is possible with the solar-LWRHU-powered rover.

In terms of operational capabilities, the major difference between the Proposed Action (Alternative 1) and Alternatives 2 and 3 is the length of time the rover would be expected to survive and successfully operate and conduct science experiments at a selected landing site. The capability to operate the rover within a broad range of latitudes is important because doing so maintains NASA's flexibility to select the most scientifically interesting location on the surface and fulfill the purpose and need for the Mars 2020 mission defined in the FEIS.

The No Action alternative is the environmentally preferable alternative because there would be none of the environmental impacts of a launch. However, under the No Action Alternative NASA would need to reevaluate its programmatic options for the 2020 launch opportunity to Mars and beyond. Without development and implementation of a large mobile science platform such as the rover planned for the Mars 2020 mission, NASA's ability to acquire detailed scientific information on the presence of signs of past life on Mars (to answer questions of habitability and the potential origin and evolution of life on Mars) would be severely limited, and the advancements in technological and operational capabilities necessary for the future exploration of Mars may not be achieved. In summary, the No Action Alternative does not satisfy the purpose and need for the Mars 2020 mission defined in the FEIS.

The selection of the Proposed Action (Alternative 1) is fully consistent with the mandate of the National Aeronautics and Space Act to contribute to the expansion of human knowledge of phenomena in space.

E. Additional Information

E.1 Interagency Nuclear Safety Review Panel

In addition to the requirements under the National Environmental Policy Act (NEPA) and NASA policy and procedures, there is a separate and distinct Executive Branch interagency process for evaluating the nuclear launch safety of the proposed Mars 2020 mission. Pursuant to paragraph 9 of Presidential Directive/National Security Council Memorandum #25 (PD/NSC-25) a nuclear Safety Analysis Report (SAR), including an uncertainty analysis, will be prepared by the DOE and will be based on detailed reliability data for the selected launch vehicle. The SAR will be reviewed by an ad hoc Interagency Nuclear Safety Review Panel (INSRP), who will then prepare a Safety Evaluation Report (SER) for the mission. The PD/NSC-25 process will proceed in parallel with Mars 2020 mission launch preparations, and NASA will receive briefings on the results of the analyses presented in the SAR and SER. While there may be some differences in mission phase risk estimates contained in the SAR, SER, and the FEIS, the differences are not, at this time, expected to be significant with regard to potential public health consequences and are not expected to change the overall nuclear launch safety mission risk, but to reasonably bound that risk. The DOE and the INSRP will provide NASA a formal briefing on the SAR and SER, respectively, prior to NASA's decision on whether or not to request launch approval from the White House Office of Science and Technology Policy in accordance with PD/NSC-25.

E.2 Comments Received on the FEIS

NASA received one comment from an individual since the publication of the FEIS requesting information on the return on investment of the Mars 2020 mission. NASA provided additional information to the individual commenter regarding the economic, technological, and scientific benefit from NASA's exploration efforts. Additionally, the EPA provided a letter dated December 9, 2014, confirming that the FEIS adequately addresses the contingency planning and emergency response coordination cited in their letter dated July 28, 2014.

F. Mitigation

The only expected or immediate environmental impacts of launching the Mars 2020 mission are the same as those for the launch of every currently-available Atlas, Delta, and Falcon class vehicle, and mitigation will accordingly be the same. Range Safety at CCAFS monitors launch surveillance areas (including KSC) to ensure that risks to people, aircraft, and surface vessels are within acceptable limits. Models which take into account current meteorological conditions, the probability of a launch failure, and emergency preparedness procedures, are used to predict launch hazards. Launches are postponed if the predicted public risks of injury from toxic gases, debris, or blast overpressure exceed acceptable limits.

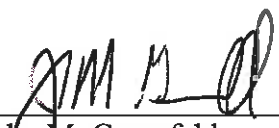
The EIS primarily addressed possible radiological consequences of mission accidents. Regarding such possible radiological impacts, for any launch of radioactive materials a comprehensive set of radiological contingency response plans are developed by NASA in coordination with Federal, State, and local representatives. Such plans are put in place prior to

launch to ensure that any launch accident can be met with a well-developed and thoroughly tested response. NASA's plans would be developed in accordance with the National Response Framework (NRF) and the NRF Nuclear/Radiological Incident Annex and applicable State and county emergency plans, and in coordination with the Federal agencies participating in the NRF, the State of Florida, Brevard County, and local launch site response organizations. At the time of launch, emergency response personnel and equipment would be pre-deployed both within the launch area and in the surrounding communities to continuously monitor for a potential release of radioactive material in the unlikely event of a launch accident. Post-accident mitigation activities, if required, would be based upon detailed monitoring information and assessments.

The selection of the types and capabilities of response personnel and equipment would be a product of the radiological contingency planning effort. The radiological contingency response plan for the Mars 2020 mission is expected to be similar to the one put in place for the previously launched Mars Science Laboratory mission. NASA is confident that all practicable means to avoid or minimize environmental harm from the Mars 2020 mission have been adopted or are in the process of development.

Decision

Based upon all of the foregoing, it is NASA's decision to complete preparations for and implement the proposed Mars 2020 mission during July – August 2020 or during the next available launch opportunity in August through September 2022, and to operate the mission using an MMRTG as the primary power source for the rover.



John M. Grunsfeld
Associate Administrator
Science Mission Directorate

27 JAN 2015
Date