Appendix A Air Quality

Air Quality and Greenhouse Gas Emissions Technical Report

Falcon Program Expansion at Space Launch Complex-40

Cape Canaveral Space Force Station, Florida

MARCH 2025

Prepared for:

SPACEX
1 Rocket Road
Hawthorne, California 90250

Prepared by:

DUDEK
3760 State Street, Suite 101
Santa Barbara, California 93105
Contact: Adam Poll

Printed on 30% post-consumer recycled material.

Table of Contents

SECTION **PAGE NO.**

TABLES

APPENDICES

Acronyms and Abbreviations

Acronym/Abbreviation	Definition
ACAM	Air Conformity Applicability Model
CAA	Clean Air Act
CCSFS	Cape Canaveral Space Force Station
CEQ	White House Council on Environmental Quality
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
DAF	Department of the Air Force
EA	environmental assessment
EPA	U.S. Environmental Protection Agency
GHG	greenhouse gas
GWP	global warming potential
HAP	hazardous air pollutant
KSC	Kennedy Space Center
MMT	million metric tons
MT	metric ton
N_2O	nitrous oxide
NAAQS	National Ambient Air Quality Standards
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NO_2	nitrogen dioxide
NO_x	oxides of nitrogen
O_3	ozone
PERCORP	Performance Correlation Program
PM_{10}	particulate matter with an aerodynamic diameter less than or equal to 10 microns
$PM_{2.5}$	particulate matter with an aerodynamic diameter less than or equal to 2.5 microns
Proposed Action	Falcon Program Expansion and construction of a landing zone at Space Launch Complex 40
SLC	Space Launch Complex
SO_2	sulfur dioxide
TDK	two-dimensional kinetics
VOC	volatile organic compound

INTENTIONALLY LEFT BLANK

Executive Summary

The purpose of this technical report is to assess the potential air quality emissions impacts associated with implementation of the Falcon Program Expansion and construction of a landing zone at Space Launch Complex (SLC)-40 (Proposed Action) and alternatives at Cape Canaveral Space Force Station (CCSFS), Florida.

Proposed Action and Approach Overview

The Proposed Action is to increase the annual Falcon launch cadence at CCSFS and to construct a landing zone at SLC-40. The Proposed Action site is at CCSFS in Brevard County, Florida. Construction and operational criteria air pollutant emissions were estimated using the Air Conformity Applicability Model and spreadsheet models.

Air Quality

Criteria air pollutants are defined as pollutants for which the federal and state governments have established ambient air quality standards, or criteria, for outdoor concentrations to protect public health. Criteria air pollutants include ozone, nitrogen dioxide, carbon monoxide, sulfur dioxide, particulate matter with an aerodynamic diameter less than or equal to 10 microns (PM_{10}), particulate matter with an aerodynamic diameter less than or equal to 2.5 microns ($PM_{2.5}$), and lead. Pollutants that were evaluated include reactive organic gases, oxides of nitrogen, carbon monoxide, sulfur oxides, PM_{10}, and $PM_{2.5}$. Reactive organic gases and oxides of nitrogen are important because they are precursors to ozone.

Insignificance Criteria

For air quality impact assessments, significance is defined by the degree to which the effects of the Proposed Action potentially could affect public health or safety. Effects on air quality are based on estimated direct and indirect emissions associated with the Proposed Action. Air quality impacts would be significant if the action would cause pollutant concentrations to exceed one or more of the National Ambient Air Quality Standards (NAAQS), as established by the United States Environmental Protection Agency (USEPA) under the Clean Air Act (CAA), for any of the time periods analyzed, or to increase the frequency or severity of any such existing violations as set forth in the United States Department of Transportation Federal Aviation Administration (US FAA) Order 1050.1F. For the Proposed Action, only small quantities of hazardous air pollutants are expected to be emitted with very low potential exposure and health risk. A quantitative evaluation of hazardous air pollutant emissions is therefore not warranted and was not conducted. Emissions of Criteria Pollutant were compared to de minimis levels to ensure that the project meets the CAA General Conformity Rule requirements. As Brevard County is in attainment for all NAAQS, the *de minimis* thresholds for nonattainment or maintenance areas do not apply. Therefore, the federal Prevention of Significant Deterioration (PSD) thresholds were utilized.

The U.S. Air Force conducts National Environmental Policy Act and General Conformity Rule air quality impact assessments in tandem within the Environmental Impact Analysis Process (HQ AFCEC/CZTQ 2023a).

The U.S. Air Force insignificance thresholds are annual emission rates established by the U.S. Environmental Protection Agency that, if exceeded, would trigger a regulatory requirement. Insignificance indicators are rate thresholds established by the U.S. Environmental Protection Agency that are partially applied or applied out of context to their intended use; however, they can provide a direct gauge of potential impact. Although indicators do not trigger a regulatory requirement, they do provide an indication or a warning that the action is potentially approaching a threshold that would trigger a significant regulatory requirement.

The air quality impact evaluation for this Proposed Action requires two separate analyses: the Clean Air Act General Conformity Analysis and an analysis under the National Environmental Policy Act. Impacts of air pollutants emitted by activities in the Atlantic Ocean, bays, and inland locations in state waters are assessed under the General Conformity Rule. Impacts of air pollutants emitted by activities in the Atlantic Ocean, bays, and inland locations in U.S. territorial seas are assessed under the National Environmental Policy Act.

The Proposed Action construction and operational emissions are below the FAA and Department of the Air Force insignificance thresholds. The Proposed Action is not expected to result in any new violations of the National Ambient Air Quality Standards.

Greenhouse Gas Emissions

The Proposed Action would generate greenhouse gas (GHG) emissions during construction and operation. During construction, GHGs would be generated from off-road equipment, worker vehicles, and haul trucks. During operation, GHGs would be generated from launch and landings, boost-back, fairing recovery, transport to the launch facility, personnel, energy use, and water and wastewater.

The Proposed Action would not have an adverse effect on water, ecosystem and ecosystem services, the coast, indigenous peoples, energy, food, or human health. In terms of climate change impacts on the Proposed Action, it may adapt to changing conditions of water supplies, keep employees safe by following relevant Occupational Safety and Health Administration regulations, and prepare for major storm and flooding events and adjust operations accordingly.

1 Introduction

1.1 Report Purpose and Scope

The purpose of this technical report is to assess the potential air emissions associated with implementation of the Falcon Program Expansion and construction of a landing zone at Space Launch Complex (SLC) 40 (Proposed Action) at Cape Canaveral Space Force Station (CCSFS), Florida. This assessment uses Department of the Air Force (DAF) insignificance thresholds and indicators to determine if the Proposed Action would result in an adverse effect.

This introductory section provides a description of the Proposed Action and its location. Chapter 2, Air Quality, describes the air quality–related environmental setting, regulatory setting, existing air quality conditions, and threshold and analysis methodology, and presents an air quality impact analysis. Chapter 3, Greenhouse Gases, describes the greenhouse gas (GHG)–related environmental setting, regulatory setting, existing conditions, and threshold and analysis methodology, and presents a GHG impact analysis. Chapter 4, References Cited, provides a list of the references used in this report.

1.2 Regional and Local Setting

The Proposed Action would be located at SLC-40 at CCSFS in Brevard County, Florida. CCSFS occupies approximately 15,800 acres of land on Florida's Cape Canaveral barrier island. The island approximately 4.5 miles wide at its widest point. CCSFS is adjacent to Kennedy Space Center (KSC) and has approximately 81 miles of paved roads connecting various launch support facilities. SpaceX has been conducting Falcon 9 launches at KSC and CCSFS, including launch activities at SLC-40, for several years.

1.3 Project Description

The Proposed Action is to increase the annual Falcon launch cadence at SLC-40 and construct a landing zone at SLC-40. The purpose of the Proposed Action is to provide greater mission capability to the Department of Defense, the National Aeronautics and Space Administration (NASA), and commercial customers by increasing Falcon's flight opportunities. This increase in flight opportunities and construction of a new landing zone would support future United States (U.S.) Government and commercial missions that require or benefit from a Falcon 9 vehicle.

The Proposed Action is needed to meet current and anticipated near-term future U.S. Government launch requirements for national security, space exploration, science, and the Assured Access to Space process of the National Security Space Launch program.

1.3.1 Launch Vehicle

Falcon 9 is approximately 229 feet tall with a diameter of 12 feet and produces approximately 1.7 million pounds of thrust at liftoff. A detailed discussion of Falcon 9, including the first and second stages, can be found in the 2020 environmental assessment (EA), *Final Environmental Assessment and Finding of No Significant Impact for SpaceX Falcon Launches at Kennedy Space Center and Cape Canaveral Air Force Station* (FAA 2020). Falcon 9 launches from SLC-40 with either a payload fairing or with a Dragon capsule. As discussed in the 2020 EA, Dragon is a spacecraft that delivers crew and cargo to the International Space Station.

1.3.2 Launch

SpaceX proposes to launch Falcon up to 120 times annually from SLC-40. SpaceX would conduct launch operations in the same way as described in the 2020 EA and previous environmental documents (FAA 2020; DAF 2023). One to three days before each launch, an engine static fire test, which lasts a few seconds, may be performed. The need to conduct a static fire test depends on the mission, but there would be no more than 40 static fire test events per year. Launch operations would occur day or night, at any time during the year. Following each launch, SpaceX would perform a series of first stage burns and landing of the first stage, either downrange on a droneship or at a landing zone at CCSFS. Mission objectives may occasionally require expending the first stage booster in the Atlantic Ocean, as the 2020 EA described. If expended, the first stage would break up upon atmospheric re-entry and there would be no residual propellant or explosion upon impact with the Atlantic Ocean. The first stage remnants would sink to the bottom of the ocean.

1.3.3 Launch Frequency

SpaceX proposes to increase its launch cadence at SLC-40 from a maximum of 50 (cited in the 2020 EA) to up to 120 times annually. SpaceX has continued to improve its turnaround time between launches, which has provided more opportunities for launches at SLC-40.

1.3.4 Trajectories and Landing

Trajectories from SLC-40 would remain within the azimuth range previously analyzed in the 2020 EA. As discussed in the 2020 EA, each trajectory is provided in SpaceX's Flight Safety Data Package and submitted to the Federal Aviation Administration and Space Launch Delta (SLD) 45 in advance of launch. SpaceX would land first stage boosters at SLC-40 or downrange on a drone ship as described in the 2020 EA. Launches from SLC-40 and those landing downrange on a drone ship would occur as described in the 2020 EA (FAA 2020). Downrange landing and fairing recovery locations would be the same as those analyzed in the 2020 EA. SpaceX anticipates up to 34 boosters would land at SLC-40 each year.

1.3.5 Payloads

Payloads would continue to be processed at existing facilities at CCSFS and KSC. Payloads and their associated materials/fuels/volumes are mission dependent but would be similar to current U.S. Government and commercial payloads as described in the 2011 Environmental Assessment for Launch of NASA Routine Payloads (NASA 2011). Novel payloads, such as reentry capsules, may require a separate review under the National Environmental Policy Act (NEPA) and require their own FAA Vehicle Operator License under Title 14 of the Code of Federal Regulations.

1.3.6 Utilities

Existing water supply and electricity services are adequate to support launch operations.

1.3.7 Transport and Vehicle Refurbishment

Following flight and downrange recovery of a vehicle, it would be transported to Port Canaveral and then overland to SpaceX's existing refurbishment facilities at CCSFS and KSC. Similarly, first stage boosters landing at SLC-40 would be transported from the landing zone to the refurbishment facility. SpaceX would continue to coordinate with CCSFS and KSC for scheduling of these movements to limit impacts to other operations on-base.

1.3.8 Landing Zone

SpaceX would construct a landing zone east of SLC-40 for the landing of Falcon first stage boosters. The landing zone would be made up of a 280-foot-diameter concrete pad surrounded by a 60-foot-wide gravel apron, for a total diameter of 400 feet. Rocket Road would remain paved and traversable outside of landing events. SpaceX would construct a new nitrogen gas line from the existing metering station to a fluids bay at the landing zone. A 30-foot by 30-foot pedestal would be constructed adjacent to the landing pad to support post-landing vehicle processing. Crane storage is proposed along the existing SLC-40 fence line. Approximately 4 acres would be cleared for construction and operation of the landing zone.

1.3.9 No Action Alternative

Under the No Action Alternative, SpaceX would not increase the annual cadence for Falcon operations from CCSFS or develop a landing zone at SLC-40. This would mean that SpaceX would not meet the Department of Defense requirements for Assured Access to Space. The National Space Transportation Policy goals of providing low-cost reliable access to and from space would also be negatively affected, as would the more short-term need to meet the increase in current and future manifest demands. The No Action Alternative includes no landings after the LZ-1 and LZ-2 lease ends in 2025. Therefore, the No Action Alternative does not meet the purpose and need.

1.3.10 Alternatives Considered but Eliminated from Further Analysis

Various alternatives to the Proposed Action were considered but eliminated from further analysis due to various factors. Alternative launch and landing sites were evaluated at CCSFS, KSC, and Vandenberg Space Force Base. However, these sites were dismissed from detailed review based on the following reasons:

- Launch Complex 39A (LC-39A) at KSC already supports a variety of missions for the U.S. Government and SpaceX, leaving insufficient capacity for additional Falcon launches.
- Non-SpaceX sites at CCSFS and KSC have been allocated to other launch operators and/or would require extensive construction to support Falcon operations.
- Vandenberg Space Force Base already supports SpaceX launches of Falcon 9 and Falcon Heavy rockets but does not support the eastward launches possible from CCSFS and KSC and necessary for the Proposed Action.
- Alternative landing zone locations around SLC-40 were evaluated but would impact Florida scrub jay (*Aphelocoma coerulescens*) and southeastern beach mouse (*Peromyscus polionotus niveiventris*) habitat;

would be sited predominantly in wetlands; and/or would have flight safety concerns over potential impacts to the SLC-40 hangar, crew tower, and lightning protection system.

2 Air Quality

2.1 Environmental Setting

The Proposed Action site is within Brevard County, Florida.

2.1.1 Meteorological and Topographical Conditions

The primary factors that determine air quality are the locations of air pollutant sources and the amounts of pollutants emitted. Meteorological and topographical conditions, however, also are important. Factors such as wind speed and direction, air temperature gradients and sunlight, and precipitation and humidity interact with physical landscape features to determine the movement and dispersal of criteria air pollutants.

CCSFS occupies 15,800 acres of Cape Canaveral barrier island, on the east coast of central Florida. The island is approximately 4.5 miles wide at its widest point. CCSFS has 81 miles of paved roads connecting various launch support facilities within the centralized industrial area.

Climate

Brevard County experiences a subtropical climate of hot, humid summers with distinct wet and dry seasons. From 1981 to 2010, precipitation averaged 54 inches per year, with August and September being high precipitation months and December being the driest month, averaging 2.3 inches (US Climate Data 2024). During the same period, temperatures varied between an average high of 71.4°F in January to an average of 90.6°F in July and August.

At the coast, mean sea level is defined as the height of the sea with respect to a local land benchmark, averaged over a period of time long enough to eliminate the effects of wave, tidal, and seasonal fluctuations. Changes in mean sea level as measured by coastal tide gauges are called “relative sea level changes,” because they can come about either by movement of the land on which the tide gauge is situated or by changes in the height of the adjacent sea surface. The National Oceanic and Atmospheric Administration establishes mean sea level at CCSFS as 19.9 feet. The average high tide for CCSFS is 21.5 feet, while the average low tide is 18.2 feet. The highest observed water level at CCSFS was 25.9 feet on September 26, 2004 (NASA 2013). According to the International Panel on Climate Change, global mean sea level continues to rise due to thermal expansion of the oceans in addition to the loss of mass from glaciers, ice caps, and the Greenland and Antarctic Ice Sheets (IPCC 2023).

Inclement weather for Brevard County is characterized by large storm cells moving west to east across North America in the cool, winter months and local or tropical systems during the hot, summer months. Occasional hurricanes do affect the area, with storm surge and wind playing a dominant factor in the damage incurred. Hurricane season extends from June through November. The central Florida region has the highest number of thunderstorms in the United States during the summer months (May–September), and over 70% of the annual 48 inches of rain occurs in the summer. During thunderstorms, wind gusts of more than 60 miles per hour and rainfall of over 1.0 inch often occur in a 1-hour period, and there are numerous cloud-to-ground lightning strikes (FAA 2020).

During the last two decades, erosion along the coastline bordering CCSFS has increased as a result of frequent storm surges from nor’easters, tropical storms, and hurricanes. Erosion may have been exacerbated by effects from rising sea levels, which have exceeded 5 inches in the last 20 years as measured at the Trident Pier in the adjacent Port Canaveral. As a result, the area has been categorized as "critically eroded" by the Florida Department of Environmental Protection (FDEP 2016). Nearly 3 miles of artificial dune have been created along the local coastline to protect space program assets and important wildlife habitat; additional dune creation is planned. The coastal dune along CCSFS has not experienced the same erosion as the beaches along the border of the nearby KSC and is accreting in most areas.

Criteria Air Pollutants

Criteria air pollutants are defined as pollutants for which the federal and state governments have established ambient air quality standards, or criteria, for outdoor concentrations to protect public health. The national standards have been set, with an adequate margin of safety, at levels above which concentrations could be harmful to human health and welfare. These standards are designed to protect the most sensitive persons from illness or discomfort. Pollutants of concern include ozone (O_3), nitrogen dioxide (NO_2), carbon monoxide (CO), sulfur dioxide (SO_2), particulate matter with an aerodynamic diameter less than or equal to 10 microns (PM_{10}), particulate matter with an aerodynamic diameter less than or equal to 2.5 microns ($PM_{2.5}$), and lead.

Ozone (O3). O_3 is a strong-smelling, pale blue, reactive, toxic chemical gas consisting of three oxygen atoms. It is a secondary pollutant formed in the atmosphere by a photochemical process involving the sun's energy and O_3 precursors. These precursors are mainly oxides of nitrogen (NO_x) and volatile organic compounds (VOCs). The maximum effects of precursor emissions on O_3 concentrations usually occur several hours after they are emitted and many miles from the source. Meteorology and terrain play major roles in O_3 formation, and ideal conditions occur during summer and early autumn on days with low wind speeds or stagnant air, warm temperatures, and cloudless skies. O_3 exists in the upper atmosphere O_3 layer (stratospheric O_3) and at the Earth's surface in the troposphere (ground-level O_3).[1] The O_3 that the U.S. Environmental Protection Agency (EPA) and the Florida Department of Environmental Protection regulate as a criteria air pollutant is produced close to the ground level, where people live, exercise, and breathe. Ground-level O_3 is a harmful air pollutant that causes numerous adverse health effects, described below, and is thus considered "bad" O_3. Stratospheric, or "good," O_3 occurs naturally in the upper atmosphere, where it reduces the amount of ultraviolet light (i.e., solar radiation) entering the Earth's atmosphere. Without the protection of the beneficial stratospheric O_3 layer, plant and animal life would be seriously harmed.

O_3 in the troposphere (near the surface) causes numerous adverse health effects; short-term exposures (lasting for a few hours) to O_3 at levels exceeding national air quality standards can result in breathing pattern changes, reduction of breathing capacity, increased susceptibility to infections, inflammation of the lung tissue, and some immunological changes (EPA 2013).

Inhalation of O_3 causes inflammation and irritation of the tissues lining human airways, causing and worsening a variety of symptoms. Exposure to O_3 can reduce the volume of air that the lungs breathe in, thereby causing shortness of breath. O_3 in sufficient doses increases the permeability of lung cells, rendering them more susceptible to toxins and microorganisms. The occurrence and severity of health effects from O_3 exposure vary widely among individuals, even when the dose and the duration of exposure are the same. Research shows adults and children who spend more time outdoors participating in vigorous physical activities are at greater risk from the harmful

1 The troposphere is the layer of the Earth's atmosphere nearest to the surface of the Earth. The troposphere extends outward about 5 miles at the poles and about 10 miles at the equator.

health effects of O_3 exposure. While there are relatively few studies on the effects of O_3 on children, the available studies show that children are no more or less likely to suffer harmful effects than adults. However, there are a number of reasons why children may be more susceptible to O_3 and other pollutants. Children and teens spend nearly twice as much time outdoors and engaged in vigorous activities as adults. Children breathe more rapidly than adults and inhale more pollution per pound of their body weight than adults. Also, children are less likely than adults to notice their own symptoms and avoid harmful exposures. Further research may be able to better distinguish between health effects in children and adults. Children, adolescents, and adults who exercise or work outdoors, where O_3 concentrations are the highest, are at the greatest risk of harm from this pollutant (EPA 2023a).

Nitrogen Dioxide (NO2). NO_2 is a brownish, highly reactive gas that is present in all urban atmospheres. The major mechanism for the formation of NO_2 in the atmosphere is the oxidation of the primary air pollutant nitric oxide, which is a colorless, odorless gas. NO_x plays a major role, together with VOCs, in the atmospheric reactions that produce O_3. NO_x is formed from fuel combustion under high temperature or pressure. In addition, NO_x is an important precursor to acid rain and may affect both terrestrial and aquatic ecosystems. The two major emissions sources are transportation and stationary fuel combustion sources such as electric utility and industrial boilers.

A large body of health science literature indicates that exposure to NO_2 can induce adverse health effects. The strongest health evidence, and the health basis for the ambient air quality standards for NO_2, results from controlled human exposure studies that show that NO_2 exposure can intensify responses to allergens in allergic asthmatics. In addition, a number of epidemiological studies have demonstrated associations between NO_2 exposure and premature death, cardiopulmonary effects, decreased lung function growth in children, respiratory symptoms, emergency room visits for asthma, and intensified allergic responses. Infants and children are particularly at risk because they have disproportionately higher exposure to NO_2 than adults due to their greater breathing rate for their body weight and their typically greater outdoor exposure duration. Several studies have shown that long-term NO_2 exposure during childhood, the period of rapid lung growth, can lead to smaller lungs at maturity in children with higher levels of exposure compared to children with lower exposure levels. In addition, children with asthma have a greater degree of airway responsiveness compared with adult asthmatics. In adults, the greatest risk is to people who have chronic respiratory diseases, such as asthma and chronic obstructive pulmonary disease (EPA 2023b).

Carbon Monoxide (CO). CO is a colorless, odorless gas formed by the incomplete combustion of hydrocarbon, or fossil fuels. CO is emitted almost exclusively from motor vehicles, power plants, refineries, industrial boilers, ships, aircraft, and trains. In urban areas, such as the Proposed Action location, automobile exhaust accounts for the majority of CO emissions. CO is a nonreactive air pollutant that dissipates relatively quickly; therefore, ambient CO concentrations generally follow the spatial and temporal distributions of vehicular traffic. CO concentrations are influenced by local meteorological conditions—primarily wind speed, topography, and atmospheric stability. CO from motor vehicle exhaust can become locally concentrated when surface-based temperature inversions are combined with calm atmospheric conditions, which is a typical situation at dusk in urban areas from November to February. The highest levels of CO typically occur during the colder months of the year, when inversion conditions are more frequent.

CO is harmful because it binds to hemoglobin in the blood, reducing the ability of blood to carry oxygen. This interferes with oxygen delivery to the body's organs. The most common effects of CO exposure are fatigue, headaches, confusion and reduced mental alertness, light-headedness, and dizziness due to inadequate oxygen delivery to the brain. For people with cardiovascular disease, short-term CO exposure can further reduce their body's already compromised ability to respond to the increased oxygen demands of exercise, exertion, or stress. Inadequate oxygen delivery to the heart muscle leads to chest pain and decreased exercise tolerance. Unborn babies whose mothers experience high levels of CO exposure during pregnancy are at risk of adverse developmental effects. Unborn babies, infants, elderly people, and people with anemia or with a history of heart or respiratory disease are most likely to experience health effects with exposure to elevated levels of CO (EPA 2023c).

Sulfur Dioxide (SO2). SO_2 is a colorless, pungent gas formed primarily from incomplete combustion of sulfur-containing fossil fuels. The main sources of SO_2 are coal and oil used in power plants and industries; as such, the highest levels of SO_2 are generally found near large industrial complexes. In recent years, SO_2 concentrations have been reduced by the increasingly stringent controls placed on stationary source emissions of SO_2 and limits on the sulfur content of fuels.

Controlled human exposure and epidemiological studies show that children and adults with asthma are more likely to experience adverse responses with SO_2 exposure, compared with the non-asthmatic population. Effects at levels near the 1-hour standard are those of asthma exacerbation, including bronchoconstriction accompanied by symptoms of respiratory irritation such as wheezing, shortness of breath, and chest tightness, especially during exercise or physical activity. Also, exposure at elevated levels of SO_2 (above 1 part per million) results in increased incidence of pulmonary symptoms and disease, decreased pulmonary function, and increased risk of mortality. Older people and people with cardiovascular disease or chronic lung disease (such as bronchitis or emphysema) are most likely to experience these adverse effects (EPA 2024a).

SO_2 is of concern both because it is a direct respiratory irritant and because it contributes to the formation of sulfate and sulfuric acid in particulate matter (NRC 2005). People with asthma are of particular concern, both because they have increased baseline airflow resistance and because their SO_2-induced increase in airflow resistance is greater than in healthy people and SO_2 increases with the severity of their asthma (NRC 2005). SO_2 is thought to induce airway constriction via neural reflexes involving irritant receptors in the airways (NRC 2005).

Particulate Matter. Particulate matter pollution consists of very small liquid and solid particles floating in the air, which can include smoke, soot, dust, salts, acids, and metals. Particulate matter can form when gases emitted from industries and motor vehicles undergo chemical reactions in the atmosphere. $PM_{2.5}$ and PM_{10} represent fractions of particulate matter. Coarse particulate matter (PM_{10}) consists of particulate matter that is 10 microns or less in diameter, which is about 1/7 the thickness of a human hair. Major sources of PM_{10} include crushing or grinding operations; dust stirred up by vehicles traveling on roads; wood-burning stoves and fireplaces; dust from construction, landfills, and agriculture; wildfires and brush/waste burning; industrial sources; windblown dust from open lands; and atmospheric chemical and photochemical reactions. Fine particulate matter ($PM_{2.5}$) consists of particulate matter that is 2.5 microns or less in diameter, which is roughly 1/28 the diameter of a human hair. $PM_{2.5}$ results from fuel combustion (e.g., from motor vehicles and power generation and industrial facilities), residential fireplaces, and woodstoves. In addition, $PM_{2.5}$ can be formed in the atmosphere from gases such as sulfur oxides, NO_x, and VOCs.

$PM_{2.5}$ and PM_{10} pose a greater health risk than larger-size particles. When inhaled, these tiny particles can penetrate the human respiratory system's natural defenses and damage the respiratory tract. $PM_{2.5}$ and PM_{10} can increase the number and severity of asthma attacks, cause or aggravate bronchitis and other lung diseases, and reduce the body's ability to fight infections. Very small particles of substances such as lead, sulfates, and nitrates can cause lung damage directly or be absorbed into the bloodstream, causing damage elsewhere in the body. Additionally, these substances can transport adsorbed gases such as chlorides or ammonium into the lungs, also causing injury. Whereas PM_{10} tends to collect in the upper portion of the respiratory system, $PM_{2.5}$ is so tiny that it can penetrate deeper into the lungs and damage lung tissue. Suspended particulates also damage and discolor surfaces on which they settle and produce haze and reduce regional visibility.

A number of adverse health effects have been associated with exposure to both $PM_{2.5}$ and PM_{10}. For $PM_{2.5}$, short-term exposures (up to 24-hour duration) have been associated with premature mortality, increased hospital admissions for heart or lung causes, acute and chronic bronchitis, asthma attacks, emergency room visits, respiratory symptoms, and restricted activity days. These adverse health effects have been reported primarily in infants, children, and older adults with preexisting heart or lung diseases. In addition, of all of the common air pollutants, $PM_{2.5}$ is associated with the greatest proportion of adverse health effects related to air pollution, both in the United States and worldwide based on the World Health Organization's Global Burden of Disease Project. Short-term exposures to PM_{10} have been associated primarily with worsening of respiratory diseases, including asthma and chronic obstructive pulmonary disease, leading to hospitalization and emergency department visits (EPA 2023d).

Long-term exposure (months to years) to $PM_{2.5}$ has been linked to premature death, particularly in people who have chronic heart or lung diseases, and reduced lung function growth in children. The effects of long-term exposure to PM_{10} are less clear, although several studies suggest a link between long-term PM_{10} exposure and respiratory mortality (EPA 2023d).

Lead. Lead in the atmosphere occurs as particulate matter. Sources of lead include leaded gasoline; the manufacturing of batteries, paints, ink, ceramics, and ammunition; and secondary lead smelters. Prior to 1978, mobile emissions were the primary source of atmospheric lead. Between 1978 and 1987, the phaseout of leaded gasoline reduced the overall inventory of airborne lead by nearly 95%. With the phaseout of leaded gasoline, secondary lead smelters, battery recycling, and manufacturing facilities are becoming lead-emissions sources of greater concern.

Prolonged exposure to atmospheric lead poses a serious threat to human health. Health effects associated with exposure to lead include gastrointestinal disturbances, anemia, kidney disease, and, in severe cases, neuromuscular and neurological dysfunction. Of particular concern are low-level lead exposures during infancy and childhood. Such exposures are associated with decrements in neurobehavioral performance, including intelligence quotient (IQ) performance, psychomotor performance, reaction time, and growth. Children are highly susceptible to the effects of lead.

Non-Criteria Air Pollutants

Hazardous Air Pollutants (HAPs). A substance is considered toxic if it has the potential to cause adverse health effects in humans, including increasing the risk of cancer upon exposure or acute and/or chronic non-cancer health effects. A toxic substance released into the air is considered a HAP. HAPs are identified by federal and state agencies based on a review of available scientific evidence. The National Emissions Standards regulate 188 HAPs based on available control technologies (EPA 2023e). Examples of HAPs include diesel particulate matter, certain aromatic and chlorinated hydrocarbons, certain metals, VOCs, and asbestos. HAPs are generated by numerous sources, including stationary sources, such as dry cleaners, gas stations, combustion sources, and laboratories; mobile sources, such as automobiles; and area sources, such as landfills and oil and gas facilities. Adverse health effects associated with exposure to HAPs may include carcinogenic (i.e., cancer-causing) and non-carcinogenic effects. Non-carcinogenic effects typically affect one or more target organ systems and may be experienced on either short-term (acute) or long-term (chronic) exposure to a given HAP.

Ambient Air Quality

Florida Department of Environmental Protection maintains Florida's Air Quality System, which continuously monitors ambient air quality across the state. EPA's AirData system also provides information on criteria pollutant levels monitored at stations throughout the region. Air quality monitoring stations usually measure pollutant concentrations 10 feet above ground level; therefore, air quality is often referred to in terms of ground-level concentrations. The most recent background ambient air quality data from 2021 to 2023 are presented in Table 1.

Of the available monitoring stations in the region, the station located at 400 S. 4th Street, Cocoa Beach, is the closest to CCSFS; this station measures O_3 and PM_{10} concentrations. The station located at 401 Florida Avenue, Melbourne, is the closest air quality monitor to CCSFS that provides $PM_{2.5}$ concentrations. The Winter Park station, located at 466 Harper Street, Orange County, is the closest air quality monitoring station that measures the remaining criteria pollutant concentrations. The ambient data presented in Table 1 reflect the highest concentrations reported at the monitoring stations. Table 1 also shows the number of days exceeding the ambient air quality standards. In the past three years, there has been one noted exceedance at these monitoring stations in 2023, of NO_2.

Table 1. Local Ambient Air Quality Data

Averaging Time	Unit	Agency/ Method	Ambient Air Quality Standard	Measured Concentration by Year			Exceedances by Year		
				2021	2022	2023	2021	2022	2023
Ozone (O_3) – Cocoa Beach – 4th Street (Site ID 120094001)									
Maximum 8-hour concentration	ppm	National	0.070	0.062	0.064	0.065	0	0	0
Nitrogen Dioxide (NO_2) – Winter Park – Harper Street (Site ID 120952002)									
Maximum 1-hour concentration	ppm	National	0.1	0.036	0.036	0.11	0	0	1
Annual concentration	ppm	National	0.053	0.004	0.004	0.003	0	0	0
Carbon Monoxide (CO) – Winter Park – Harper Street (Site ID 120952002)									
Maximum 1-hour concentration	ppm	National	35	1.2	1.1	2.9	0	0	0
Maximum 8-hour concentration	ppm	National	9	1	1	1.7	0	0	0
Sulfur Dioxide (SO_2) – Winter Park – Harper Street (Site ID 120952002)									
Maximum 1-hour concentration	ppm	National	0.075	0.004	0.024	0.005	0	0	0
Maximum 3-hour concentration	ppm	National	0.5	—	—	—	—	—	—

Table 1. Local Ambient Air Quality Data

Averaging Time	Unit	Agency/ Method	Ambient Air Quality Standard	Measured Concentration by Year			Exceedances by Year		
				2021	2022	2023	2021	2022	2023
Coarse Particulate Matter (PM_{10})[a] – Cocoa Beach – 4th Street (Site ID 120094001)									
Maximum 24-hour concentration	μg/m³	National	150	73	72	75	0	0	0
Fine Particulate Matter ($PM_{2.5}$)[a] – Melbourne – Florida Ave (Site ID 120090007)									
Maximum 24-hour concentration	μg/m³	National	35	27	22.5	18	0	0	0
Annual concentration	μg/m³	National	15.0	8.3	7.4	7.2	0	0	0

Sources: EPA 2024e, FDEP 2024.

Notes: ppm = parts per million by volume; — = not available; μg/m³ = micrograms per cubic meter.

Data taken from EPA AirData (https://www.epa.gov/outdoor-air-quality-data/monitor-values-report) and Florida Department of Environmental Protection Air Monitor Site (https://floridadep.gov/air/air-monitoring/content/single-site-data) represent the highest concentrations experienced over a given year.

Exceedances of national standards are only shown for O_3 and particulate matter. Daily exceedances for particulate matter are estimated days because PM_{10} and $PM_{2.5}$ are not monitored daily. All other criteria pollutants did not exceed national standards during the years shown.

[a] Measurements of PM_{10} and $PM_{2.5}$ are usually collected every 6 days and every 1 to 3 days, respectively. Number of days exceeding the standards is a mathematical estimate of the number of days concentrations would have been greater than the level of the standard had each day been monitored. The numbers in parentheses are the measured number of samples that exceeded the standard.

2.2 Regulatory Setting

2.2.1 Federal Regulations

2.2.1.1 Criteria Air Pollutants

The federal Clean Air Act (CAA), passed in 1970 and last amended in 1990, forms the basis for the national air pollution control effort. EPA is responsible for implementing most aspects of the CAA, including setting National Ambient Air Quality Standards (NAAQS) for major air pollutants; setting HAP standards; approving state attainment plans; setting motor vehicle emission standards; issuing stationary source emission standards and permits; and establishing acid rain control measures, stratospheric O_3 protection measures, and enforcement provisions. Under the CAA, NAAQS are established for the following criteria pollutants: O_3, CO, NO_2, SO_2, PM_{10}, $PM_{2.5}$, and lead.

The NAAQS describe acceptable air quality conditions designed to protect the health and welfare of the citizens of the United States. The NAAQS (other than for O_3, NO_2, SO_2, PM_{10}, $PM_{2.5}$, and those based on annual averages or arithmetic mean) are not to be exceeded more than once per year. NAAQS for O_3, NO_2, SO_2, PM_{10}, and $PM_{2.5}$ are based on statistical calculations over 1- to 3-year periods, depending on the pollutant. The CAA requires the EPA to reassess the NAAQS at least every 5 years to determine whether adopted standards are adequate to protect public health based on current scientific evidence. States with areas that exceed the NAAQS must prepare a state implementation plan that demonstrates how those areas will attain the NAAQS within mandated time frames. The NAAQS are presented in Table 2.

The CAA contains milestones for states to develop air pollution control plans. Areas within states that do not meet the NAAQS, usually identified at the county level, are designated as nonattainment areas. For areas designated as nonattainment areas, the state must develop a plan to implement pollution control strategies to attain the NAAQS. Once attainment is achieved, a state must develop a plan to maintain air quality.

Ozone is not emitted directly to the atmosphere by industrial or combustion processes. Rather, O_3 is formed through the reaction between VOCs and NO_x. VOCs and NO_x are known as O_3 precursors, and these precursor emissions are regulated by the EPA to achieve O_3 reductions. Airborne particulate matter is not a single pollutant, but rather a mixture of many chemical species. PM_{10}, and $PM_{2.5}$ are derived from different emission sources and also have different chemical compositions.

Emissions from the combustion of gasoline, oil, diesel fuel, and wood produce much of the $PM_{2.5}$ pollution found in outdoor air, as well as a significant portion of PM_{10}. PM_{10} also includes dust from construction sites, landfills, and agriculture; wildfires and brush/waste burning; industrial sources; wind-blown dust from open lands; pollen; and fragments of bacteria. Particulate matter may be either directly emitted from sources (primary particles) or formed in the atmosphere through chemical reactions of gases (secondary particles) such as SO_2, NO_x, VOCs, and ammonia. These organic compounds can be emitted by both natural sources, such as trees and vegetation, and anthropogenic sources, such as industrial processes and motor vehicle exhaust. Particulate matter emissions are regulated to achieve ambient $PM_{2.5}$ reductions.

The NAAQS represent the maximum levels of pollution that are considered acceptable, with an adequate margin of safety, to protect public health and welfare (Table 2). Short-term standards (1-, 3-, 8-, and 24-hour periods) are established for pollutants contributing to acute health effects, while long-term standards (quarterly and annual averages) are established for pollutants contributing to chronic health effects.

Based on measured ambient criteria pollutant data, the EPA designates all areas of the United States as having air quality better than the NAAQS (attainment), worse than the NAAQS (nonattainment), or unclassifiable (40 CFR Part 81, Subpart C, Section 107). The designation of attainment for any NAAQS is based on the evaluation of ambient air quality monitoring data collected through federal, state, and/or local monitoring networks. According to the EPA, Brevard County is in attainment for all criteria pollutants (EPA 2024b). Florida's air monitoring effort is concentrated on the six criteria pollutants. In 2024, Florida continued to be in attainment for all criteria pollutants (EPA 2024b).

Table 2. Ambient Air Quality Standards

Pollutant	Averaging Time	National Standards[a]	
		Primary[b,c]	Secondary[d]
O_3	1 hour	—	Same as Primary Standard[e]
	8 hours	0.070 ppm (137 μg/m^3)[e]	
NO_2[f]	1 hour	0.100 ppm (188 μg/m^3)	Same as Primary Standard
	Annual Arithmetic Mean	0.053 ppm (100 μg/m^3)	
CO	1 hour	35 ppm (40 mg/m^3)	None
	8 hours	9 ppm (10 mg/m^3)	
SO_2[g]	1 hour	0.075 ppm (196 μg/m^3)	—
	3 hours	—	0.5 ppm (1,300 μg/m^3)

Table 2. Ambient Air Quality Standards

Pollutant	Averaging Time	National Standards[a]	
		Primary[b,c]	Secondary[d]
PM_{10}[h]	24 hours	150 μg/m³	Same as Primary Standard
	Annual Arithmetic Mean	—	
$PM_{2.5}$[h]	24 hours	35 μg/m³	Same as Primary Standard
	Annual Arithmetic Mean	9.0 μg/m³	15.0 μg/m³
Lead[i]	30-day Average	—	—
	Calendar Quarter	1.5 μg/m³ (for certain areas)[k]	Same as Primary Standard
	Rolling 3-Month Average	0.15 μg/m³	

Source: EPA 2024c.

Notes: O_3 = ozone; ppm = parts per million by volume; μg/m³ = micrograms per cubic meter; NO_2 = nitrogen dioxide; CO = carbon monoxide; mg/m³= milligrams per cubic meter; SO_2 = sulfur dioxide; PM_{10} = particulate matter with an aerodynamic diameter less than or equal to 10 microns; $PM_{2.5}$ = particulate matter with an aerodynamic diameter less than or equal to 2.5 microns.

a National standards (other than O_3, NO_2, SO_2, particulate matter, and those based on annual averages or annual arithmetic mean) are not to be exceeded more than once per year. The O_3 standard is attained when the fourth highest 8-hour concentration measured at each site in a year, averaged over three years, is equal to or less than the standard. For PM_{10}, the 24-hour standard is attained when the expected number of days per calendar year with a 24-hour average concentration above 150 μg/m³ is equal to or less than one. For $PM_{2.5}$, the 24-hour standard is attained when 98% of the daily concentrations, averaged over 3 years, are equal to or less than the standard.

b Concentration expressed first in units in which it was promulgated. Equivalent units given in parentheses are based on a reference temperature of 25°C and a reference pressure of 760 torr. Most measurements of air quality are to be corrected to a reference temperature of 25°C and a reference pressure of 760 torr; ppm in this table refers to ppm by volume, or micromoles of pollutant per mole of gas.

c National Primary Standards: The levels of air quality necessary, with an adequate margin of safety, to protect the public health.

d National Secondary Standards: The levels of air quality necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant.

e On October 1, 2015, the national 8-hour O_3 primary and secondary standards were lowered from 0.075 to 0.070 ppm.

f To attain the national 1-hour standard, the three-year average of the annual 98th percentile of the one-hour daily maximum concentrations at each site must not exceed 100 parts per billion (ppb). Note that the national 1-hour standard is in units of ppb.

g The previous SO_2 standards (0.14 ppm 24-hour and 0.03 ppm annual) will additionally remain in effect in certain areas: (1) any area for which it is not yet 1 year since the effective date of designation under the current (2010) standards, and (2)any area for which an implementation plan providing for attainment of the current (2010) standard has not been submitted and approved and which is designated nonattainment under the previous SO_2 standards or is not meeting the requirements of a state implementation plan call under the previous SO_2 standards (40 CFR 50.4(3)). A state implementation plan call is an EPA action requiring a state to resubmit all or part of its State Implementation Plan to demonstrate attainment of the required NAAQS.

h In 2024, the national annual $PM_{2.5}$ primary standard was lowered from 12 μg/m³ to 9 μg/m³. The existing national 24-hour $PM_{2.5}$ standards (primary and secondary) were retained at 35 μg/m³, as was the annual secondary standard of 15 μg/m³. The existing 24-hour PM_{10} standards (primary and secondary) of 150 μg/m³ were also retained. The form of the annual primary and secondary standards is the annual mean averaged over three years.

i The national standard for lead was revised on October 15, 2008, to a rolling three-month average. The 1978 lead standard (1.5 μg/m³ as a quarterly average) remains in effect until one year after an area is designated for the 2008 standard, except that in areas designated nonattainment for the 1978 standard, the 1978 standard remains in effect until implementation plans to attain or maintain the 2008 standard are approved.

2.2.1.2 Hazardous Air Pollutants

The 1977 federal CAA amendments required the EPA to identify national emission standards for HAPs to protect public health and welfare. HAPs include certain volatile organic chemicals, pesticides, herbicides, and radionuclides that present a tangible hazard based on scientific studies of exposure to humans and other mammals. Under the 1990 federal CAA Amendments, which expanded the control program for HAPs, 187 substances and chemical families were identified as HAPs (40 CFR Parts 61 and 63). The majority of HAPs are VOCs. Mobile sources of air emissions include launch vehicles, commercial ships, recreational boats, cruise ships, and aircraft. HAPs emitted from mobile sources are called Mobile Source Air Toxics. Mobile Source Air Toxics are compounds emitted from highway vehicles and non-road equipment that are known or suspected to cause cancer or other serious health and environmental effects. In 2001, EPA issued its first Mobile Source Air Toxics Rule, which identified 21 compounds as being HAPs that required regulation. A subset of six of these Mobile Source Air Toxic compounds were identified as having the greatest influence on health and included benzene, 1,3-butadiene, formaldehyde, acrolein, acetaldehyde, and diesel particulate matter. EPA issued a second Mobile Source Air Toxics Rule in February 2007, which generally supported the findings in the first rule and provided additional recommendations of compounds having the greatest impact on health. The rule also identified several engine emission certification standards that must be implemented (EPA 2007).

2.2.1.3 General Conformity Determination

The General Conformity Rule applies to all federal actions for projects except highway and transit programs. Title I, Section 176(c)(1), of the CAA defines conformity as the upholding of “an implementation plan’s purpose of eliminating or reducing the severity and number of violations of the NAAQS and achieving expeditious attainment of such standards.”

Conformity determinations are not required for launch operations in Florida since both launch facilities (LC-39A and LC-40) are located within NAAQS attainment area for all regulated criteria pollutants. The ambient air quality at both facilities is predominantly influenced by daily operations such as vehicle traffic, utilities, fuel combustion, and standard refurbishment and maintenance operations. Other operations occurring infrequently throughout the year, including launches and prescribed fires, also play a role in the quality of air as episodic events (FAA 2020). The Proposed Action is occurring in an Attainment area and will therefore not need a general conformity determination.

2.3 Insignificance Criteria and Methodology

2.3.1 Insignificance Thresholds and Indicators

Effects on air quality are based on estimated direct and indirect emissions associated with the Proposed Action. Air quality impacts would be significant if the action would cause pollutant concentrations to exceed one or more of the National Ambient Air Quality Standards (NAAQS), as established by the United States Environmental Protection Agency (USEPA) under the Clean Air Act (CAA), for any of the time periods analyzed, or to increase the frequency or severity of any such existing violations as set forth in the United States Department of Transportation Federal Aviation Administration (US FAA) Order 1050.1F. For the Proposed Action, only small quantities of hazardous air pollutants are expected to be emitted with very low potential exposure and health risk. A quantitative evaluation of hazardous air pollutant emissions is therefore not warranted and was not conducted. Emissions of Criteria Pollutant were compared to de minimis levels to ensure that the project meets the CAA General Conformity Rule requirements. As Brevard County is in attainment for all NAAQS, the *de minimis* thresholds for nonattainment or maintenance areas do not apply. Therefore, the federal Prevention of Significant Deterioration (PSD) thresholds were utilized as shown in Table 3.

For air quality impact assessments, significance is defined by the degree to which the effects of the Proposed Action potentially could affect public health or safety. The DAF conducts NEPA and General Conformity Rule air quality impact assessments in tandem within the Environmental Impact Analysis Process (HQ AFCEC/CZTQ 2023a). The air quality Environmental Impact Analysis Process is broken into three progressive levels of assessment: Level I, Exempt Action Screening (determine if a formal air quality assessment is required); Level II, Quantitative Air Quality Assessment (a formal emissions quantifying assessment to eliminate insignificant air impacts from further assessment); and Level III, Advanced Air Quality Assessment (part science and part art, both quantitative and qualitative assessments of air impact). These levels are designed to ensure completion of an air quality assessment at the lowest level possible, with each level of assessment having a specific significance threshold or indicator that, if not exceeded, allows exiting the assessment. Table 3 lists the DAF insignificance thresholds for Brevard County.

If an action is not exempt from Level I of the air quality Environmental Impact Analysis Process, it must proceed to a Level II, Quantitative Air Quality Assessment. A Level II assessment is a quantification of annual net change in emissions that are compared against levels of annual emissions (i.e., thresholds or indicator) that are known to have de minimis (insignificant) effects on public health or safety. De minimis values were established in the General Conformity Rule (40 CFR 93 Subpart B) as definitive insignificance thresholds for actions occurring within areas designated as nonattainment or maintenance for one or more NAAQS. However, for Level II NEPA air impact assessments, the USAF had to establish legally defensible insignificance values (indicators) for actions occurring within attainment areas. Insignificance thresholds are EPA-established annual emission rates that, if exceeded, would trigger a regulatory requirement. Insignificance indicators are EPA-established rate thresholds that are partially applied or applied out of context to their intended use; however, they can provide a direct gauge of potential impact. Although indicators do not trigger a regulatory requirement, they do provide an indication or a warning that the action is potentially approaching a threshold that would trigger a significant regulatory requirement.

The air quality impact evaluation for this Proposed Action requires two separate analyses: the CAA general conformity analysis, discussed in section 2.2.1.3, and an analysis under NEPA. Impacts of air pollutants emitted by activities in the Pacific Ocean, bays, and inland locations in state waters (i.e., up to 3 nautical miles from the coast) are assessed under the General Conformity Rule. Impacts of air pollutants emitted by activities in the Pacific Ocean, bays, and inland locations in U.S. territorial seas (i.e., up to 12 nautical miles from the coast) are assessed under NEPA (NOAA 2017). Each coastal state may claim the territorial sea that extends seaward up to 12 nautical miles from its shores and exercise sovereignty over its territorial sea, the air space above it, and the seabed and subsoil beneath it (NOAA 2017). The state jurisdictions may extend the full distance of territorial seas or may retain historical limits.

Table 3. Department of the Air Force Insignificance Thresholds/Indicators

Pollutant	Brevard County
	Tons Per Year
Ozone (NO_x or VOC)	250
Carbon Monoxide (CO)	250
SO_2 or NO_x	250
PM_{10}	250
$PM_{2.5}$ (NO_x, VOC, SO_x, or NH_3)	250
Lead (Pb)	25

Source: HQ AFCEC/CZTQ 2023a.
Notes: NOx = oxides of nitrogen; SO_2 = sulfur dioxide; NO_2 = nitrogen dioxide; VOC = volatile organic compound; CO = carbon monoxide; PM_{10} = particulate matter with an aerodynamic diameter less than or equal to 10 microns; $PM_{2.5}$ = particulate matter with an aerodynamic diameter less than or equal to 2.5 microns; NH_3 = ammonia; Pb = lead.

2.3.2 Approach and Methodology

An air quality impact assessment is accomplished with a net-change analyses for each regulatory area the action will occur within. In accordance with DAF guidance, NEPA (40 CFR 1508), and the General Conformity Rule (40 CFR 93 Subpart B), a net-change inventory analyses is an evaluation of the total action-related annual increased emissions (direct and indirect emissions) of the criteria pollutant (or their precursors) combined with the total action-related annual decreased emissions, resulting in an overall annual net change in emissions for the entire action. The Proposed Action's worst-year (highest emission year) annual net change in emissions for each pollutant (or precursors) are screened against the applicable insignificance indicators or thresholds. If the results of net-change inventory analyses indicate all criteria pollutant (or precursors) are below the insignificance indicators or thresholds, the action is considered to have an insignificant impact on air quality for NEPA. If the results of net-change inventory analyses indicate one or more criteria pollutants (or precursors) are equal to or above the insignificance indicators or thresholds, the action is considered to have a potentially significant impact on air quality and further assessment is required.

2.3.2.1 Construction Activities

Emissions from the construction phase of the Proposed Action were estimated using the Air Conformity Applicability Model (ACAM) Version 5.023a (AFCEC 2013). Construction scenario assumptions, including phasing, equipment mix, and vehicle trips, were based on information provided by the applicant and relevant experience with similar projects when Proposed Action specifics were not known.

For purposes of estimating Proposed Action emissions, and based on information provided by the applicant, it is assumed that construction of the Proposed Action would commence in August 2024 and would last approximately 4 months, ending in December 2024. The Proposed Action would consist of a 280-foot-diameter pad surrounded by a 60-foot-wide gravel apron. The analysis contained herein is based on the construction schedule shown in Table 4.

Table 4. Construction Schedule

Phase	Start Date	End Date	Total Workdays
Grading	9/2024	12/2024	80
Building Construction	9/2024	12/2024	80
Paving	11/2024	12/2024	40

The construction equipment required for Proposed Action construction was provided by ACAM defaults. Table 5 provides the anticipated construction equipment list. All of the equipment was assumed to be diesel-powered. All vehicle emissions during construction assumed defaults from ACAM.

Table 5. Construction Off-Road Equipment

Phase	Equipment List	Quantity	Hours Per Day
Grading	Grader Composite	1	8
	Other Construction Equipment Composite	1	8
	Excavator Composite	1	8

Table 5. Construction Off-Road Equipment

Phase	Equipment List	Quantity	Hours Per Day
	Rubber Tired Dozer Composite	1	8
	Tractor/Loader/Backhoes Composite	3	8
Building Construction	Cranes Composite	1	4
	Forklifts Composite	2	6
	Tractors/Loaders/Backhoes Composite	1	8
Paving	Cement and Mortar Mixers Composite	4	6
	Pavers Composite	1	7
	Paving Equipment Composite	2	8
	Tractors/Loaders/Backhoes Composite	1	7
	Rollers Composite	1	7

Source: ACAM 2024.

2.3.2.2 Operational Activities

Baseline

Baseline operational activity emissions from SLC-40 were taken from the 2020 EA for SpaceX Falcon Launches at Kennedy Space Center and Cape Canaveral Air Force Station (FAA 2020). These include emissions from launches and landings, payload fairing recovery, booster roll-on/roll-off, and operation of SLC-40. Water and electricity consumption data for baseline operational activities were provided by SpaceX.

Proposed Action

The Proposed Action would generate criteria air pollutant emissions during operation from launches and landings, payload and fairing recovery, booster roll-on/roll-off, and operation of SLC-40. The following section discusses the emission calculation methodology for each activity.

Falcon 9 Launch

SpaceX would launch Falcon 9 rockets up to 120 times per year from SLC-40 in the same manner as described in the 2020 EA (FAA 2020). It is estimated that a Falcon 9 takes 23 seconds to reach 3,000 feet elevation after a launch. Static fire tests last a duration of 7 seconds. The emission factors for estimating emissions from Falcon 9 launches were taken from the Exhaust Plume Calculations for SpaceX Merlin5 Booster Engine by Sierra Engineering & Software Inc. (included as Appendix B). The analysis was done using a single engine firing into a stable environment within 516 feet of the engine exhaust. This assumes the gas generator exhaust is efficiently entrained into the rocket exhaust. The analysis from the single engine was then extrapolated to estimate the emissions for all 9 engines for the Falcon 9.

The Performance Correlation Program (PERCORP) is a model that uses known engine performance to estimate mixing and vaporization efficiencies in liquid rocket engines and provide a simple method of predicting nozzle exit-plane flow constituents and properties. The PERCORP analysis model was used to estimate the oxidizer/fuel mixture ratio variations that exist within the M1D thrust chamber. The fuel-rich combustion model in PERCORP was also used to estimate the gas generator exhaust constituents. PERCORP was run iteratively with VIPER (version 4.5 Beta Apr-2018) until the VIPER output specific impulse (ISP) matched the target value. The VIPER output includes details of the pressure, temperature, velocity and species concentration across the nozzle exit plane. The SPF III code (Version 4.2.3a Patch 2) was used to predict the flow structure of the free exhaust plume and the entrainment of ambient air. The M8 chemical system was augmented with methane (CH_4), C_2H_2, and C_2H_4. However, there were several chemical species in the PERCORP-generated exhaust ($C_{12}H_{23}$, C_7H_{14}, C_3H_6, C_2H_6) that were not included in the SPF DATABANK. Rather than trying to add the chemical species, Sierra's kerosene cracking reactions, plus some judicious chemistry analogs, were used to convert these chemical species into simpler constituents the code can handle. The subsequent two-dimensional kinetics (TDK) simulation of the plume chemistry requires an approximate fit of the air entrainment rate. The SPF air entrainment profile was fit to an "availability profile" for the TDK simulations, allowing ambient air to be "mixed" into the plume flow. Achieving a good fit of the entrainment with the simple availability model within TDK requires running the 1-D analysis in three pieces, restarting the simulation with temperature and species information from the previous analysis and updating the air availability rate parameters. The one-dimensional kinetic model in the TDK code was used to model chemical reactions within the evolving plume flow field. The pollutant flow rates were calculated in terms of lb_m generated per second of steady engine operation.

Although the exhaust is fuel-rich and contains high concentrations of CO, subsequent entrainment of ambient air results in complete conversion of the CO into carbon dioxide (CO_2) and oxidation of the soot from the gas generator exhaust. A small amount of thermal NO_x is formed as nitric oxide. Each takeoff may be preceded by a static fire test of the engines, which lasts a few seconds. The need to conduct a static fire test is mission dependent, but for emissions modeling purposes it was conservatively assumed there would be up to 40 static fire events per year. Emissions were estimated using a spreadsheet model (Appendix A).

Payload Fairing Recovery

After each launch, the fairing is recovered from the Atlantic Ocean via a support marine vessel. The fairing and parafoil would be recovered by a salvage ship stationed in the proposed landing area near the anticipated splashdown site, but no closer than 12 nautical miles offshore. One recovery vessel is required for each half of the fairing. As in the 2020 EA, it was assumed that the vessels would be within the boundary of Florida's Coastal Zone for approximately 2 hours of the total transit time (1 hour outbound and 1 hour inbound). Emissions from the support vessel were calculated using a spreadsheet model and emission factors based on the engine tier and the activity data for the recovery (Appendix A).

Landings

Similar to launch operations, there are emissions of NO_x during the landing of the Falcon first stage boosters. Landings occur both on land at SLC-40 in the landing zone for the Falcon fist stage boosters and on water in the Atlantic Ocean. During landing, only three of the nine engines are used in a Falcon 9 booster. The engines burn 18 seconds during a landing below 3,000 feet.

Marine landings would require three vessels: a drone ship, support vessel, and ocean tug. Vessels would travel from Port Canaveral to a position near the landing location. It was assumed that vessels would be within the boundary of Florida's Coastal Zone for approximately 8 hours of the total transit time (4 hours outbound and 4 hours inbound). Following downrange recovery of a vehicle, it would be transported to Port Canaveral and then overland to SpaceX's existing refurbishment facilities at CCSFS and KSC. First stage boosters landing at SLC-40 would also be transported to the refurbishment facility. Emissions were estimated using a spreadsheet model with emission factors based on the engine tier and activity data (Appendix A).

Dragon Recovery

For modeling purposes, recovery efforts were assumed to follow existing operational procedures outlined in the 2020 EA (FAA 2020). Recovery of the Dragon capsule payloads would require a recovery vessel equipped with a helideck and six small rigid-hulled inflatable boats to track down, collect, and transport the Dragon and potentially six parachute recovery teams back to shore. A helicopter would be used to monitor parachute recovery efforts and to transfer crew and critical cargo to the closest airport, which would not exceed 150 miles. Total annual recovery emissions were estimated using a spreadsheet model with emission factors based on engine tier and activity data (Appendix A).

Payload Processing, Refurbishment, and Operations

Payloads and their associated materials/fuels/volumes are mission dependent but would be similar to current commercial and government payloads. In November 2011, NASA, with the USAF as a cooperating agency, prepared an EA for Launch of NASA Routine Payloads on Expendable Launch Vehicles (NASA 2011). SpaceX would continue to process payloads at existing SpaceX facilities on CCSFS and KSC. Operations include refurbishing the recovered first stage and fairing for reuse in future missions. Up to four boosters and six fairings may be refurbished concurrently. Up to 120 boosters and 120 fairings would be refurbished each year. Solvents such as isopropyl alcohol, isopar, and Simple Green would be used during these operations, as well for launch pad operations, facility maintenance, and system flushing. Emissions were estimated using a spreadsheet model and ACAM (Appendix A).

2.3.3 Air Quality Impact Assessment

Construction and operational emissions were estimated for the Proposed Action and are discussed separately below.

2.3.3.1 Construction Emissions

Construction of the Proposed Action would result in the temporary addition of pollutants to the local airshed caused by on-site sources (i.e., off-road construction equipment, soil disturbance) and off-site sources (i.e., haul trucks and worker vehicle trips). Construction emissions can vary substantially from day to day, depending on the level of activity; the specific type of operation; and, for dust, the prevailing weather conditions. Therefore, such emission levels can only be approximately estimated with a corresponding uncertainty in precise ambient air quality impacts.

As discussed previously, criteria air pollutant emissions associated with temporary construction activities were quantified using the ACAM. Annual construction emissions were calculated for the Proposed Action, assuming 2024 as the year of construction activities would occur. Construction schedule assumptions, including phase type, duration, and sequencing, were based on information provided by the applicant and are intended to represent a reasonable scenario based on the best information available.

Implementation of the Proposed Action would generate air pollutant emissions from entrained dust, off-road equipment, vehicle emissions, architectural coatings, and asphalt pavement application. Entrained dust results from the exposure of earth surfaces to wind from the direct disturbance and movement of soil, resulting in PM_{10} and $PM_{2.5}$ emissions.

Table 6 presents the estimated annual construction emissions generated during construction of the Proposed Action. Details of the emission calculations are provided in Appendix A.

Table 6. Estimated Annual Construction Criteria Air Pollutant Emissions

Source	VOC	NO_x	CO	SO_x	PM_{10}	$PM_{2.5}$
	Tons Per Year					
Construction (2024)	0.14	1.23	1.48	<0.01	14.38	0.05
DAF Insignificance Threshold	*250*	*250*	*250*	*250*	*250*	*250*
Threshold Exceeded?	**No**	**No**	**No**	**No**	**No**	**No**

Notes: VOC = volatile organic compound; NO_x = oxides of nitrogen; CO = carbon monoxide; SO_x = sulfur oxides; PM_{10} = coarse particulate matter; $PM_{2.5}$ = fine particulate matter; <0.01 = reported value less than 0.01.
See Appendix A for complete results.
Totals may not sum due to rounding.

As shown in Table 6, annual construction emissions would not exceed the DAF insignificance thresholds; accordingly, the Proposed Action would not have an adverse effect on air quality.

2.3.3.2 Operational Emissions

Operation of the Proposed Action would generate criteria pollutant and HAP emissions from mobile sources, including vehicle trips from passenger vehicles and heavy-duty trucks, marine vessels, booster launches and landings, launch vehicle processing, and off-road equipment used for maintenance. Table 7 presents the annual operational emissions associated with the Proposed Action (year 2025) as estimated as described in Section 2.3.2.2 within Brevard County. Operational emissions were calculated in a spreadsheet model, using the same methodology for the Proposed Action and the baseline activity levels described in the 2020 EA. Baseline emissions are included to show the net change in operational emissions. Details of the emission calculations are provided in Appendix A.

Table 7. Annual Operational Emissions

Emission Source	VOC	NO_x	CO	SO_x	PM_{10}	$PM_{2.5}$	Pb	NH_3
	Tons Per Year							
Marine Recovery Operations	7.00	129.69	38.60	3.94	2.78	2.53	0.00	0.00
Launch Facility Operations	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Falcon Launches and Landings	0.00	18.68	0.00	0.00	0.00	0.00	0.00	0.00
Total	**7.00**	**148.36**	**38.60**	**3.94**	**2.78**	**2.53**	**0.00**	**0.00**
Baseline	4.21	80.06	32.20	1.86	1.53	1.41	0.00	0.00
Net (Proposed Action−Baseline)	2.80	68.30	6.40	2.08	1.25	1.12	0.00	0.00
DAF Insignificance Threshold	*250*	*250*	*250*	*250*	*250*	*250*	*25*	*250*

Table 7. Annual Operational Emissions

Emission Source	VOC	NO_x	CO	SO_x	PM_{10}	$PM_{2.5}$	Pb	NH_3
	Tons Per Year							
Threshold Exceeded?	**No**	**No**	**No**	**No**	**No**	**No**	**No**	**No**

Notes: VOC = volatile organic compound; NO_x = oxides of nitrogen; CO = carbon monoxide; SO_x = sulfur oxides; PM_{10} = coarse particulate matter; $PM_{2.5}$ = fine particulate matter; Pb = lead; NH_3 = ammonia; DAF = Department of the Air Force.
Marine Recovery Operations include Dragon capsule recovery operations, fairing recovery, and booster recovery.
See Appendix A for complete results.
Totals may not sum due to rounding.

As shown in Table 7, net annual emissions from the Proposed Action would not exceed the DAF insignificance thresholds. As such, the Proposed Action would not have an adverse effect on air quality within Brevard County.

2.3.3.3 General Conformity Analysis

The general conformity determination process is intended to demonstrate that a proposed federal action will not (1) cause or contribute to new violations of an NAAQS, (2) interfere with provisions in the applicable state implementation plan for maintenance of any NAAQS, (3) increase the frequency or severity of existing violations of any standard, or (4) delay the timely attainment of any standard. As such, for general conformity determination, the proposed federal action needs to conform to the latest approved state implementation plan/air quality management plan. As discussed in Section 2.2.1, Brevard County is in attainment for all NAAQS; therefore, general conformity does not apply.

No Action Alternative

Under the No Action Alternative, the Proposed Action would not be built. There would be no criteria air pollutant emissions generated because construction and operation would not occur. Therefore, there would be no emissions resulting from the No Action Alternative compared to the Proposed Action. There would be no impact on air quality.

INTENTIONALLY LEFT BLANK

3 Greenhouse Gases

3.1 Environmental Setting

A GHG is any gas that absorbs infrared radiation in the atmosphere; in other words, GHGs trap heat in the atmosphere. Some GHGs, such as CO_2, CH_4, and nitrous oxide (N_2O), occur naturally and are emitted into the atmosphere through natural processes and human activities. Of these gases, CO_2 and CH_4 are emitted in the greatest quantities from human activities. Manufactured GHGs, which have a much greater heat-absorption potential than CO_2, include fluorinated gases, such as hydrochlorofluorocarbons, perfluorocarbons, and sulfur hexafluoride, which are associated with certain industrial products and processes.

CO_2 is the primary anthropogenic (human-caused) GHG and has been established as the reference gas to demonstrate the relative effect of different GHGs of equal mass. The effect that each of the GHGs has on global warming is the product of the mass of their emissions and their global warming potential (GWP). GWP indicates how much a gas is predicted to contribute to global warming relative to how much warming would be predicted to be caused by the same mass of CO_2. For example, CH_4 and N_2O are substantially more potent GHGs than CO_2, with GWPs of 25 and 298 times that of CO_2 respectively, which has a GWP of 1, as the reference gas.

In emissions inventories, GHG emissions are typically reported as metric tons (MT) of CO_2 equivalent (CO_2e). CO_2e is calculated as the product of the mass emitted of a given GHG and its specific GWP.CO_2e = (metric tons of a GHG) × (GWP of the GHG).

Climate change refers to any significant change in measures of climate, such as temperature, precipitation, or wind patterns, lasting for an extended period of time (decades or longer). The greenhouse effect, which is the trapping and build-up of heat in the atmosphere near the Earth's surface, is a natural process that contributes to regulating the Earth's temperature. Human activities that emit additional GHGs to the atmosphere increase the amount of infrared radiation that gets absorbed before escaping into space, thus enhancing the greenhouse effect and causing the Earth's surface temperature to rise.

Potential Effects of Climate Change

Globally, climate change has the potential to affect numerous environmental resources through uncertain impacts related to future air temperatures and precipitation patterns. The 2014 International Panel on Climate Change Synthesis Report (IPCC 2014) indicated that warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. Signs that global climate change has occurred include warming of the atmosphere and ocean, diminished amounts of snow and ice, rising sea levels, and ocean acidification (IPCC 2014). As global temperatures rise, the county's historically arid climate could intensify, exacerbating water scarcity, and sea level rise could pose problems for communities along the county's coastline.

Sources of Greenhouse Gas Emissions

Per the EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2022 (EPA 2024d), total United States GHG emissions were approximately 6,343.3 million metric tons (MMT) CO_2e in 2022 (EPA 2024d). The primary GHG emitted by human activities in the United States was CO_2, which represented approximately 79.7% of total GHG emissions (5,053.0 MMT CO_2e). The largest source of CO_2, and of overall GHG emissions, was fossil-fuel combustion, which accounted for approximately 93.0% of gross CO_2 emissions in 2022 (4,699.0 MMT CO_2e). Relative to 1990, gross United States GHG emissions in 2022 were 3.0% lower; however, the gross emissions were down from a high of 15.6% above 1990 levels in 2007. Net GHG emissions increased from 2021 to 2022 by 1.3%, and overall, net emissions in 2019 were 16.7% below 2005 levels (EPA 2024d).

According to the Florida Climate Institute, Florida emitted 304.8 MMT CO_2e in 2018, including emissions resulting from out-of-state electrical generation (Florida Climate Institute 2022). The sources of GHG emissions in Florida evaluated in the inventory include transportation, industry, electric power production, agriculture, and recycling and waste. The Florida GHG emission source categories and their relative contributions in 2018 are presented in Table 8.

Table 8. Greenhouse Gas Emissions Sources in Florida

Source Category	Annual GHG Emissions (MMT CO_2e)	Percent of Total[a]
Transportation	128.55	42.18%
Industrial	27.05	8.88%
Electric power	122.76	40.28%
Agriculture	9.42	3.09%
Recycling and waste	16.97	5.57%
Total	**304.77**	**100%**

Source: Florida Climate Institute 2022.
Notes: GHG = greenhouse gas; MMT CO_2e = million metric tons of carbon dioxide equivalent.
Emissions reflect the 2018 Florida GHG inventory.
[a] Percentage of total has been rounded, and total may not sum due to rounding.

3.2 Federal Regulatory Setting

Greenhouse Gas Endangerment

On April 2, 2007, in *Massachusetts v. USEPA*, 549 US 497, the Supreme Court found that GHGs are air pollutants covered by the CAA. The court held that EPA must determine whether emissions of GHGs from new motor vehicles cause or contribute to air pollution, which may reasonably be anticipated to endanger public health or welfare, or whether the science is too uncertain to make a reasoned decision. In making these decisions, EPA is required to follow the language of Section 202(a) of the CAA.

On April 17, 2009, EPA Administrator signed proposed "endangerment" and "cause or contribute" findings for GHGs under Section 202(a) of the CAA. EPA held a 60-day public comment period, considered public comments, and issued final findings. EPA found that six GHGs taken in combination endanger both the public health and the public welfare of current and future generations. EPA also found that the combined emissions of these GHGs from new motor vehicles and new motor vehicle engines contribute to the greenhouse effect as air pollution that endangers public health and welfare under CAA Section 202(a).

Mandatory Reporting of Greenhouse Gases

The Consolidated Appropriations Act of 2008, passed in December 2007, requires the establishment of mandatory GHG reporting requirements. On September 22, 2009, EPA issued the Final Mandatory Reporting of Greenhouse

Gases Rule, which became effective January 1, 2010. The rule requires reporting of GHG emissions from large sources and suppliers in the United States and is intended to collect accurate and timely emissions data to inform future policy decisions. Under the rule, suppliers of fossil fuels or industrial GHGs, manufacturers of vehicles and engines, and facilities that emit 25,000 metric tons or more per year of GHG emissions are required to submit annual reports to EPA.

Executive Order 13990

On January 20, 2021, President Biden issued Executive Order 13990, Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis. Section 7(e) of this Executive Order directs the White House Council on Environmental Quality (CEQ) to rescind the 2019 Draft GHG Guidance and review, revise, and update its 2016 GHG Guidance. Among its key provisions, the order directed federal agencies to review and potentially revise a range of policies, regulations, and actions that were inconsistent with the Biden administration's commitment to combatting climate change and promoting environmental sustainability. The order also sought to reestablish interagency working groups and committees that had been disbanded or sidelined during the previous administration, with a focus on restoring evidence-based decision-making processes.

Inflation Reduction Act

The Inflation Reduction Act was signed into law by President Biden in August 2022. The bill includes specific investment in energy and climate reform and is projected to reduce GHG emissions within the United States by 40% as compared to 2005 levels by 2030. The bill allocates funds to boost renewable energy infrastructure (e.g., solar panels and wind turbines), includes tax credits for the purchase of electric vehicles, and includes measures that will make homes more energy efficient.

The Inflation Reduction Act authorized EPA to implement the Greenhouse Gas Reduction Fund program, which a is a historic, $27 billion investment to mobilize financing and private capital to combat the climate crisis and ensure American economic competitiveness. The Greenhouse Gas Reduction Fund will be designed to achieve the following program objectives: reduce GHG emissions and other air pollutants; deliver the benefits of GHG- and air-pollution-reducing projects to American communities, particularly low-income and disadvantaged communities; and mobilize financing and private capital to stimulate additional deployment of GHG- and air-pollution-reducing projects (EPA 2023f).

Interim Guidance on Consideration of Greenhouse Gas Emissions and Climate Change

On January 6, 2023, the CEQ released new guidance to disclose climate impacts in environmental reviews under NEPA. The guidance replaces 2016 emissions guidance that was withdrawn by the previous administration. CEQ's new climate change guidance recommends that agencies account for GHG emissions in NEPA reviews. It provides federal agencies a common approach for assessing their proposed actions, while recognizing each agency's unique circumstances and authorities.

3.3 Insignificance Criteria and Methodology

3.3.1 Insignificance Thresholds and Indicators

The CEQ Guidance recognizes that global climate change is a cumulative impact; a project participates in this potential impact through its incremental contribution combined with the cumulative increase of all other sources of GHGs. There are no federal numeric thresholds that delineate when a proposed action may have an adverse impact. As discussed in the interim CEQ Guidance, when conducting climate change analyses in NEPA, agencies should consider (1) the potential effects of a proposed action on climate change, including by assessing both GHG emissions and reductions from the proposed action, and (2) the effects of climate change on a proposed action and its environmental impacts. The CEQ guidance recommends quantifying GHG emissions, understanding that GHG are a cumulative impact and not project-only impacts, including indirect emissions when relevant to the proposed action, such as for fossil fuel supply or transport projects, and providing context for GHG emissions using the best available SC-GHG estimates to translate climate impacts into the more accessible metric of dollars.

There is no established dollar-value threshold for the SC-GHG. However, by assigning a dollar value to the damages associated with GHG emissions, policymakers and decision-makers can better evaluate the costs and benefits of actions aimed at reducing emissions. The SC-GHG provides a tool to make more informed choices about climate-related policies, regulations, and investments.

The USAF has adopted the Prevention of Significant Deterioration threshold for GHG of 75,000 tons per year of CO_2e (or 68,039 metric tons per year) as an indicator or threshold of insignificance for NEPA air quality impacts in all areas (HQ AFCEC/CZTQ 2023b). This indicator does not define a significant impact; however, it provides a threshold to identify actions that are insignificant (de minimis, too trivial or minor to merit consideration). Actions with a net change in GHG (CO_2e) emissions below the insignificance indicator (threshold) are considered too insignificant on a global scale to warrant any further analysis beyond that presented in the ACAM GHG & Climate Change Reports. Actions (or alternatives) with a net change in GHG (CO_2e) emissions above the insignificance indicator (threshold) are considered potentially significant and require further assessment (usually qualitative) to determine if the action poses a significant impact.

3.3.2 Approach and Methodology

Emissions of GHGs were estimated for construction and operation of the Proposed Action consistent with the methodology presented in Section 2.3.2. Emissions of CO_2, CH_4, and N_2O were estimated from Falcon launches and landings, marine recovery operations, and Proposed Action–related facility operations.

Energy Sources

The estimation of GHG emissions related to operational energy consumption was based on facility-specific data provided by the Proposed Action applicant.

Water and Wastewater

Supply, conveyance, treatment, and distribution of water for the Proposed Action require the use of electricity, which would result in associated indirect GHG emissions. Similarly, wastewater generated by the Proposed Action requires the use of electricity for conveyance and treatment, along with GHG emissions generated during wastewater treatment. Water and wastewater data were provided by the Proposed Action applicant.

Falcon 9 Launches and Landings

Emissions from launches of Falcon 9 rockets produce CO_2, which is converted from CO from gas generator exhaust and from boost-back during landings at CCSFS and off-shore on drone ships. (See Section 2.3.2.2, Operational Activities, for a more detailed explanation of emissions generated by Falcon launches.)

Marine Recovery Operations

Emission-generating activities include boat and helicopter use to recover and transport Dragon capsule payloads, fairings, and boosters back to CCSFS, which would result in CO_2, CH_4, and NO_2 emissions from vessel operation. Data on engine tier were provided by the Proposed Action applicant, and operational time was consistent with the previous 2020 CCSFS EA.

3.3.3 Greenhouse Gas Emissions Impact Assessment

3.3.3.1 Construction Emissions

Construction would result in GHG emissions, which are primarily associated with use of off-road construction equipment, on-road haul trucks, on-road vendor trucks, and worker vehicles.

ACAM was used to calculate the annual GHG emissions based on the construction scenario discussed in Section 2.3.2.1. Table 9 presents the estimated GHG emissions generated during construction of the Proposed Action. Details of the emission calculations are provided in Appendix A.

Table 9. Estimated Annual Construction GHG Emissions

CO_2	CH_4	N_2O	CO_2e
Metric Tons			
217.87	0.01	<0.01	219.13

Notes: CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxide; CO_2e = carbon dioxide equivalent; <0.01 = reported value less than 0.01. See Appendix A for complete results.
ACAM presents GHG emissions in tons and they were converted to metric tons as is the industry standard.

As shown in Table 9, the estimated total GHG emissions during construction would be approximately 219 MT CO_2e over the construction period.

3.3.3.2 Operational Emissions

Operation of the Proposed Action would generate GHG emissions through Falcon 9 launches and landings at CCSFS and on drone ships; electricity and water use at SpaceX facilities; and marine recovery operations for boosters, payloads, and fairings. A spreadsheet model was used to calculate the annual GHG emissions based on the operational assumptions described in Section 2.3.2.2. The estimated operational unmitigated GHG emissions are shown in Table 10.

Table 10. Proposed Action Operational GHG Emissions

Emission Source	CO_2	CH_4	N_2O	CO_2e
	Metric Tons per Year			
Marine Recovery Operations	9,336.90	0.24	0.30	9,432.23
Launch Facility Operations	14,793.71	0.00	0.00	14,793.71
Falcon Launches and Landings	47,527.68	0.00	0.00	47,527.68
			Total	71,753.62
			Baseline	32,070.56
			Delta (Proposed Action−Baseline)	39,683.06

Notes: GHG = greenhouse gas; CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxide; CO_2e = carbon dioxide equivalent.
See Appendix A for complete results.

As shown in Table 10, estimated operational GHG emissions from the Proposed Action would be approximately 71,754 MT CO_2e per year. When accounting for the baseline emissions, the Proposed Action would result in an additional 39,683 MT CO_2e per year, which is below the DAF Insignificance Threshold of 68,039 MT CO_2e per year.

Climate Change Impacts

The analysis provided above shows the Proposed Action's GHG contributions. As noted previously, the Proposed Action would not exceed the DAF insignificance threshold for GHG emissions. The impact of the Proposed Action is further evaluated considering climate change effects and whether the Proposed Action would exacerbate climate change effects and how climate change may impact the Proposed Action.

Proposed Action Impact on the Environment Considering Climate Change Effects

As described in the CEQ Guidance document (CEQ 2023), the analysis of climate change effects should focus on those aspects of the human environment that are impacted by the potential action (i.e., the Proposed Action or its alternatives) on climate change. The Fourth National Climate Assessment (USGCRP 2018) describes key areas where climate change will affect resources that impact human environment. EPA has published state-specific fact sheets outlining the impacts of climate change regionally, including for the State of Florida (EPA 2016). The following assesses how the Proposed Action may affect those areas.

- **Water Resources**. Water for humans and nature has declined because of climate change. There have been floods, which will worsen throughout the state. The demand on water resources will become problematic as populations increase and infrastructure deteriorates, and as groundwater is depleted, saltwater intrusion from the ocean can accelerate, which will necessitate flexible water management techniques. The Proposed Action would use water for facility needs and launch support. Water usage is anticipated to be minimal and would not contribute to drought conditions or exacerbate climate change effects. The Proposed Action would not have an adverse effect on water.
- **Ecosystems and Ecosystem Services.** Ocean acidification, sea level rise, and habitat fragmentation/loss have contributed to the decline in the state's ecosystems' ability to provide natural habitat, clean water, and economic livelihoods. The Proposed Action would not contribute to these issues. The Proposed Action does not include chemicals that would pollute water, soil, or air. Impacts to the ecosystem would be contained within the Proposed Action boundaries. In addition, the Proposed Action includes best management practices

to protect water quality, enhance native plantings (as reclamation activities occur), and minimize air emissions. The Proposed Action would have no effect on ecosystems and ecosystem services.

- **The Coast.** This resource area involves sea level rise, ocean warming, and reduce ocean oxygen. The Proposed Action is near the Atlantic Ocean and would potentially be threatened by sea level rise. The Proposed Action would indirectly contribute to the effects on rising sea levels due to an increase in GHGs. However, the contribution to global GHGs from the Proposed Action would be minimal, and the Project is leaving intact adjacent ecosystems including sand dunes and wetlands, which provide a buffer against sea level rise and intensifying tropical storms.
- **Indigenous Peoples.** This area involves impacts on the ecosystems indigenous people depend on for their traditional existence and livelihood because of drought, wildfire, and changing oceans. As discussed above, the Proposed Action would not contribute to drought conditions and would not impact ecosystems or oceans.
- **Energy.** This area relates to the ability of hydropower and fossil fuel electricity generation to meet growing energy demands as result of the drought (decreasing hydropower) and rising temperatures (increasing energy demand). The Proposed Action would demand electricity from the grid for facility needs and launch support. The Proposed Action would include on-site generators to provide necessary power as well; thus, it would not have adverse effect on energy demand. Employee vehicles would demand gasoline fuel. The Proposed Action's action fuel demand would not be substantial.
- **Food.** This area relates to the ability of the region to produce food considering water shortages and heat impacts to crops and livestock. There will be increased competition among agricultural, energy, and municipal uses for water, which may result in food insecurity. As noted above, the Proposed Action would not demand a substantial amount of water that would contribute to drought conditions.
- **Human Health.** This area relates to impacts to human health because of extreme heat, poor air quality, and conditions that foster pathogen growth and spread. Air quality emissions from the Proposed Action are summarized in Section 2.3.3 and are well below federal de minimis levels, which are established to determine if an action will confirm with the applicable state implementation plan for meeting air quality standards. Moreover, the majority of the emissions from the Proposed Action would not be not near any populated areas. It can be reasonably concluded that the Proposed Action would not contribute to poor air quality on a regional basis and would not jeopardize the attainment status of the region. Based on the evaluation, the Proposed Action would not have an adverse effect on human health or ambient air quality standards.

Impacts of Climate Change on the Proposed Action

The CEQ Guidance (CEQ 2023) recommends evaluating how climate change may affect a Proposed Action so that it may be developed to be resilient to climate change effects. The following summarizes the impacts of climate change on the Proposed Action and resiliency/adaptation measures that can be incorporated into the Proposed Action.

- **Drought conditions, lack of water.** The Proposed Action would use water supplied by CCSFS. As a private enterprise, the market would determine whether additional costs (if supplies were limited) for water imports would be financially acceptable. The Proposed Action would adapt to changing conditions by either limiting production to decrease water use, identifying additional conservation measures, or identifying additional water supplies as the market conditions dictate, either on-site or through imports.
- **Rising temperatures/prolonged heatwaves.** As a private operation, the Proposed Action may implement additional safety measures to protect employee health and ensure continued production. Those measures

may include additional rest/cooling areas and drinking water stations. The operator of the facility would comply with applicable state and local regulations. Under the Occupational Safety and Health Act, employers are responsible for providing workplaces free of known safety and health hazards including heat-related hazards. The facility would have flexibility to adapt to changing conditions by increasing measures on site to protect employee health or delaying work if conditions became too extreme.

- **Major storm events/flooding.** Climate change will affect how precipitation occurs in the region, with some prolonged storm events potentially causing localized flooding. As a private operation, if the Proposed Action site becomes flooded, the operator has flexibility to adapt operations to adjust to flood conditions by delaying work until the site is operable again.

In summary, many of the climate change effects on the Proposed Action may be addressed through changes in production and/or enhanced/changed operational measures. As a private operation, the Proposed Action has flexibility to adapt to these climate change stressors, such that no adverse effect would occur.

3.3.3.4 Relevant Climate Action Plans

The following provides a discussion of how the Proposed Action would help meet or detract from achieving relevant climate action goals and commitments within the applicable plans. This section discusses the Long-Term Strategy of the United States, Pathways to Net-Zero Greenhouse Gas Emissions by 2050.

White House Long Term Strategy of the United States, Pathways to Net-Zero Greenhouse Gas Emissions by 2050

This 2021 Long-Term Strategy represents the next step: it lays out how the United States can reach its ultimate goal of net-zero emissions no later than 2050. Achieving net-zero emissions is how the United States—and nations around the globe—will keep a 1.5°C limit on global temperature rise within reach and prevent unacceptable climate change impacts and risks. The Long-Term Strategy shows that reaching net zero no later than 2050 will require actions spanning every sector of the economy. There are many potential pathways to get there, and all pathways start with delivering on our 2030 Nationally Determined Contribution. This will put the United States firmly on track to reach net-zero by 2050 and support the overarching vision of building a more sustainable, resilient, and equitable economy. The United States can deliver net-zero emissions across all sectors and GHGs through multiple pathways, but all viable routes to net-zero involve five key transformations:

1. **Decarbonize Electricity.** Electricity delivers diverse services to all sectors of the American economy. The transition to a clean electricity system has been accelerating in recent years—driven by plummeting costs for solar and wind technologies, federal and subnational policies, and consumer demand. Building on this success, the United States has set a goal of 100% clean electricity by 2035, a crucial foundation for net-zero emissions no later than 2050. The Proposed Action and alternatives would not inhibit the decarbonization of the electric grid.
2. **Electrify End Uses and Switch to Other Clean Fuels.** The United States can affordably and efficiently electrify most of the economy, from cars to buildings and industrial processes. In areas where electrification presents technology challenges—for instance aviation, shipping, and some industrial processes—clean fuels like carbon-free hydrogen and sustainable biofuels can be prioritized. The Proposed Action and alternatives would utilize advanced Tier 3 and Tier 4 engines and as technological advances are commercialized will adopt use of clean fuels and/or technology as applicable.

3. **Cut Energy Waste.** Moving to cleaner sources of energy is made faster, cheaper, and easier when existing and new technologies use less energy to provide the same or better service. This can be achieved through diverse, proven approaches, ranging from more efficient appliances and the integration of efficiency into new and existing buildings, to sustainable manufacturing processes. The Proposed Action and alternatives would not inhibit the transition to cleaner sources of energy.
4. **Reduce Methane and Other Non-CO2 Emissions.** Non-CO_2 gases such as CH_4, hydrofluorocarbons, N_2O, and others contribute significantly to warming—with CH_4 alone contributing fully half of current net global warming of 1.0°C. There are many profitable or low-cost options to reduce non-CO_2 sources, such as implementing methane leak detection and repair for oil and gas systems and shifting from hydrofluorocarbons to climate-friendly working fluids in cooling equipment. The United States is committed to taking comprehensive and immediate actions to reduce methane domestically. And through the Global Methane Pledge, the United States and partners seek to reduce global methane emissions by at least 30% by 2030, which would eliminate over 0.2°C of warming by 2050. The United States will also prioritize research and development to unlock the innovation needed for deep emissions reductions beyond currently available technologies. The Proposed Action and alternatives predominantly generate emissions of CO_2. However, the Proposed Action and alternatives would not inhibit the reduction in non-CO_2 gases.
5. **Scale up CO2 Removal.** In the three decades to 2050, our emissions from energy production can be brought close to zero, but certain emissions such as non-CO_2 from agriculture will be difficult to decarbonize completely by mid-century. Reaching net-zero emissions will therefore require removing carbon dioxide from the atmosphere, using processes and technologies that are rigorously evaluated and validated. This requires scaling up land carbon sinks, as well as engineered strategies. The Proposed Action and alternatives would not inhibit the removal of carbon dioxide from the atmosphere.

The Proposed Action and alternatives would not conflict with the goals within the White House' Long-Term Strategy to remove GHGs.

No Action Alternative

Under the No Action Alternative, the Proposed Action would not be built. Construction and operation would not occur, therefore no GHG emissions would be generated. Therefore, there would be no GHG emissions resulting from the No Action Alternative compared to the Proposed Action. There would be no impact on climate and meteorology.

INTENTIONALLY LEFT BLANK

4 References Cited

AFCEC (Air Force Civil Engineer Center). 2013. Air Conformity Applicability Model. Solutionenv.com.

CEQ (Council on Environmental Quality). 2023. *Guidance: National Environmental Policy Act Guidance on Consideration of Greenhouse Gas Emissions and Climate Change*. January 2023. https://www.regulations.gov/document/CEQ-2022-0005-0001.

DAF (Department of the Air Force). 2023. *Falcon 9 Cadence Increase at Vandenberg Space Force Base, California*. March 31, 2023. https://files.ceqanet.opr.ca.gov/2867611/attachment/b65kIGAAnH5v0R0m9xim5ACNy4OW3 UJBvzdugC_vULNIpHPljaMsC7nzfrnw2oKE3tX42zCgoZJsItQp0.

EPA (U.S. Environmental Protection Agency). 2007. *Control of Hazardous Air Pollutants from Mobile Sources*. U.S. Environmental Protection Agency EPA-HQ-OAR-2005-0036.

EPA. 2013. *Integrated Science Assessment for Ozone and Related Photochemical Oxidants*. EPA/600/R-10/076F. February 2013. Accessed May 2019. https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=247492.

EPA. 2016. "What Climate Change Means for Florida." EPA 430-F-16-011. August 2016. https://www.aqhelp.com/Documents/CCFactSheets/climate-change-FL_AUG2016.pdf.

EPA. 2023a. "Health Effects of Ozone and Particulate Matter." Updated June 21, 2023. Accessed March 2024. https://www.epa.gov/advance/health-effects-ozone-and-particulate-matter.

EPA. 2023b. "Nitrogen Dioxide (NO_2) Pollution." Updated July 25, 2023. https://www.epa.gov/no2-pollution/basic-information-about-no2#What%20is%20NO2.

EPA. 2023c. "Carbon Monoxide (CO) Pollution in Outdoor Air." Updated July 13, 2023. https://www.epa.gov/co-pollution/basic-information-about-carbon-monoxide-co-outdoor-air-pollution#Effects.

EPA. 2023d. "Particulate Matter (PM) Pollution." Updated July 11, 2023. https://www.epa.gov/pm-pollution/particulate-matter-pm-basics#PM.

EPA. 2023e. "What are Hazardous Air Pollutants?" Updated December 7, 2023. https://www.epa.gov/haps/what-are-hazardous-air-pollutants.

EPA. 2023f. "Current Nonattainment Counties for All Criteria Pollutants." Updated February 28, 2021. Accessed March 2021. https://www3.epa.gov/airquality/greenbook/ancl.html.

EPA. 2024a. "Sulfur Dioxide (SO_2) Pollution." Updated January 31, 2024. https://www.epa.gov/so2-pollution/sulfur-dioxide-basics#effects.

EPA. 2024b. "Current Nonattainment Counties for All Criteria Pollutants." Updated February 29, 2024. https://www3.epa.gov/airquality/greenbook/ancl.html.

EPA. 2024c. "NAAQS Table." Updated February 7, 2024. https://www.epa.gov/criteria-air-pollutants/naaqs-table#3.

EPA. 2024d. *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990–2022*. EPA 430-R-24-004. April 2024. Accessed April 2024 at https://www.epa.gov/system/files/documents/2024-04/us-ghg-inventory-2024-main-text_04-18-2024.pdf.

EPA. 2024e. "AirData: Access to Air Pollution Data." https://www.epa.gov/outdoor-air-quality-data/monitor-values-report.

EPA. 2024f. "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review." March 8, 2024. https://www.federalregister.gov/documents/2024/03/08/2024-00366/standards-of-performance-for-new-reconstructed-and-modified-sources-and-emissions-guidelines-for

FAA (Federal Aviation Administration). 2020. *Final Assessment and Finding of No Significant Impact for SpaceX Falcon Launches at Kennedy Space Center and Cape Canaveral Air Force Station, Brevard County, Florida*. July 8, 2020.

FDEP (Florida Department of Environmental Protection). 2016. *Critically Eroded Beaches in Florida*. Division of Water Resource Management. https://www.dep.state.Florida.us/beaches/publications/pdf/CriticalErosionReport.pdf.

FDEP. 2024. Florida Air Quality System, Single Site Data. https://floridadep.gov/air/air-monitoring/content/single-site-data

Florida Climate Institute. 2022. "Laying the Groundwork for 'Getting to Neutral' in the State of Florida." April 2022. https://floridaclimateinstitute.org/images/reports/GettingtoNeutralinFlorida_FCI_2022_reduced.pdf

HQ AFCEC/CZTQ (Air Force Civil Engineer Center, Compliance Technical Support Branch). 2023a. *Level II, Air Quality Quantitative Assessment, Insignificance Indicators*. April 2023. https://www.aqhelp.com/Documents/FINAL%20-%20Level%20II%20Air%20Quality%20Quantitative%20Assessment%20Insignificance%20Indicators%20-%20April%202023%20v2.pdf.

HQ AFCEC/CZTQ. 2023b. *DAF Greenhouse Gas (GHG) & Climate Change Assessment Guide*. December 2023. https://www.aqhelp.com/Documents/FINAL-%20GHG-CLIMATE%20CHANGE%20ASSESSMENT%20GUIDANCE%20Dec%202023.pdf.

IPCC (Intergovernmental Panel on Climate Change). 2014. "Summary for Policymakers." In *Climate Change 2014 Synthesis Report.* Contribution of Working Groups I, II and III to the *Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Accessed March 10, 2017. http://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf.

IPCC. 2023. *Climate Change 2023: Synthesis Report.* Contribution of Working Groups I, II and III to the *Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, pp. 35-115 [Core Writing Team, H. Lee and J. Romero (eds.)]. Geneva, Switzerland: IPCC. doi: 10.59327/IPCC/AR6-9789291691647.

NASA (National Aeronautics and Space Administration). 2011. 2011 *Environmental Assessment for Launch of NASA Routine Payloads. https://repository.library.noaa.gov/view/noaa/12540*

NASA. 2013. Environmental Assessment for Multi-Use of Launch Complexes 39A and 39B, John F. Kennedy Space Center, Florida.

NOAA (National Oceanic and Atmospheric Administration). 2017. Maritime Zones and Boundaries. https://www.noaa.gov/maritime-zones-and-boundaries.

NRC (National Research Council). 2005. *Interim Report of the Committee on Changes in New Source Review Programs for Stationary Sources of Air Pollutants*. Washington, DC: The National Academies Press. https://doi.org/10.17226/11208.

US Climate Data. 2024. "Climate Melbournce Beach – Florida." https://www.usclimatedata.com/climate/melbourne-beach/florida/united-states/usfl0312

USGCRP (U.S. Global Change Research Program). 2018. *Fourth National Climate Assessment, Volume II: Impacts, Risks, and Adaptation in the United States*. November 2018. https://nca2018.globalchange.gov/downloads/NCA4_2018_FullReport.pdf.

INTENTIONALLY LEFT BLANK

Appendix A
Modeling Files

Table of Contents

DETAIL AIR CONFORMITY APPLICABILITY MODEL REPORT

1. General Information

- Action Location
Base: CAPE CANAVERAL AFS
State: Florida
County(s): Brevard
Regulatory Area(s): NOT IN A REGULATORY AREA

- Action Title: SpaceX Falcon Operations at Space Launch Complex-40, Cape Canaveral Space Force Station

- Project Number/s (if applicable):

- Projected Action Start Date: 8 / 2024

- Action Purpose and Need:
The purpose of the Proposed Action is to provide greater mission capability to the DOD, NASA, and commercial customers by increasing Falcon's flight opportunities. This increase in flight opportunities and construction of a new landing zone would support future U.S. Government and commercial missions, which require or benefit from a Falcon 9 vehicle. A new landing zone is proposed because SLD 45 has implemented a policy that phases out dedicated landing zones in order to maximize opportunities for the number of Commercial Launch Service Providers, maximize the launch capacity of the Eastern Range, and minimize impacts that Commercial Launch Service Providers create for other users or government programs during operations . SLD 45 policy now requires Commercial Launch Service Providers to conduct landing operations at their allocated launch complexes.
The Proposed Action is needed to meet current and anticipated near-term future U.S. Government launch requirements for national security, space exploration, science, and the Assured Access to Space process of the National Security Space Launch (NSSL) program. It is the policy of the U.S. to ensure that the U.S. has the capabilities necessary to launch and insert national security payloads into space whenever needed, as described in 10 U.S.C. § 2773. The proposed increased cadence at SLC-40 is needed so that SpaceX can continue to implement U.S. Government missions while simultaneously meeting its increasing commercial launch demands. The new landing zone is needed because the USSF has allocated Launch Complex-13 to other user(s) beginning in January 2025 at the conclusion of SpaceX's lease. SpaceX must build a new landing zone at SLC-40 to retain the ability to land first stage boosters at CCSFS. Landing boosters at the launch site allows refurbishment to begin earlier, enabling an increased launch cadence. Additionally, landing at the launch site removes potential weather issues downrange that could delay a launch and reduces flight hardware exposure to corrosive environments.

- Action Description:
The Proposed Action is to increase the annual Falcon launch cadence at SLC-40 to support future U.S. Government and commercial launch service needs, as well as the construction of a landing zone at SLC 40. The proposed development of a Falcon landing zone at SLC-40 would occur through the execution of a real property agreement between USSF and SpaceX.SpaceX proposes to launch Falcon up to 120 times annually from SLC-40. SpaceX would conduct launch operations in the same way as described in the 2020 EA. One to three days before each launch, an engine static fire test, which lasts a few seconds, may be performed. The need to conduct a static fire test depends on the mission, but there would be no more than 40 static fire test events per year. Launch operations would occur day or night, at any time during the year. Following each launch, SpaceX would perform a series of first stage burns and landing of the first stage, either downrange on a droneship or at a landing zone at CCSFS. SpaceX would construct a landing zone east of SLC-40 for the landing of Falcon first stage boosters. The landing zone would be made up of a 280-foot diameter concrete pad surrounded by a 60-foot-wide gravel apron, for a total diameter of 400 feet. Rocket Road would remain paved and traversable outside of landing events. SpaceX would construct a new nitrogen gas line from the existing metering station to a fluids bay at the landing zone. A 30 foot by 30-foot pedestal would be constructed adjacent to the landing pad to support post-landing vehicle processing. Crane storage is proposed along the existing SLC-40 fence line. Approximately four acres would be cleared for construction and operation of the landing zone.

DETAIL AIR CONFORMITY APPLICABILITY MODEL REPORT

- Point of Contact

Name: Adam Poll
Title: Civilian
Organization: Dudek
Email: apoll@dudek.com
Phone Number: 805-308-8516

Report generated with ACAM version: 5.0.23a

- Activity List:

	Activity Type	Activity Title
2.	Construction / Demolition	Landing Pad Construction

Emission factors and air emission estimating methods come from the United States Air Force's Air Emissions Guide for Air Force Stationary Sources, Air Emissions Guide for Air Force Mobile Sources, and Air Emissions Guide for Air Force Transitory Sources.

2. Construction / Demolition

2.1 General Information & Timeline Assumptions

- Activity Location
County: Brevard
Regulatory Area(s): NOT IN A REGULATORY AREA

- Activity Title: Landing Pad Construction

- Activity Description:
The landing zone would be made up of a 280-foot diameter concrete pad surrounded by a 60-foot-wide gravel apron, for a total diameter of 400 feet.

- Activity Start Date
Start Month: 8
Start Month: 2024

- Activity End Date
Indefinite: False
End Month: 12
End Month: 2024

- Activity Emissions:

Pollutant	Total Emissions (TONs)
VOC	0.138730
SO_x	0.002087
NO_x	1.231650
CO	1.475710

Pollutant	Total Emissions (TONs)
PM 10	14.382499
PM 2.5	0.052830
Pb	0.000000
NH_3	0.002593

- Activity Emissions of GHG:

Pollutant	Total Emissions (TONs)
CH_4	0.009370
N_2O	0.003870

Pollutant	Total Emissions (TONs)
CO_2	240.164501
CO_2e	241.551519

- Global Scale Activity Emissions for SCGHG:

DETAIL AIR CONFORMITY APPLICABILITY MODEL REPORT

Pollutant	Total Emissions (TONs)
CH_4	0.009370
N_2O	0.003870

Pollutant	Total Emissions (TONs)
CO_2	240.164501
CO_2e	241.551519

2.1 Site Grading Phase

2.1.1 Site Grading Phase Timeline Assumptions

- Phase Start Date
Start Month: 9
Start Quarter: 1
Start Year: 2024

- Phase Duration
Number of Month: 4
Number of Days: 0

2.1.2 Site Grading Phase Assumptions

- General Site Grading Information
Area of Site to be Graded (ft^2): 360000
Amount of Material to be Hauled On-Site (yd^3): 10000
Amount of Material to be Hauled Off-Site (yd^3): 0

- Site Grading Default Settings
Default Settings Used: Yes
Average Day(s) worked per week: 5 (default)

- Construction Exhaust (default)

Equipment Name	Number Of Equipment	Hours Per Day
Excavators Composite	1	8
Graders Composite	1	8
Other Construction Equipment Composite	1	8
Rubber Tired Dozers Composite	1	8
Tractors/Loaders/Backhoes Composite	3	8

- Vehicle Exhaust
Average Hauling Truck Capacity (yd^3): 20 (default)
Average Hauling Truck Round Trip Commute (mile): 20 (default)

- Vehicle Exhaust Vehicle Mixture (%)

	LDGV	LDGT	HDGV	LDDV	LDDT	HDDV	MC
POVs	0	0	0	0	0	100.00	0

- Worker Trips
Average Worker Round Trip Commute (mile): 20 (default)

- Worker Trips Vehicle Mixture (%)

	LDGV	LDGT	HDGV	LDDV	LDDT	HDDV	MC
POVs	50.00	50.00	0	0	0	0	0

2.1.3 Site Grading Phase Emission Factor(s)

DETAIL AIR CONFORMITY APPLICABILITY MODEL REPORT

- Construction Exhaust Criteria Pollutant Emission Factors (g/hp-hour) (default)

Excavators Composite [HP: 36] [LF: 0.38]						
	VOC	**SO_x**	**NO_x**	**CO**	**PM 10**	**PM 2.5**
Emission Factors	0.41507	0.00542	3.50127	4.19664	0.11916	0.10962
Graders Composite [HP: 148] [LF: 0.41]						
	VOC	**SO_x**	**NO_x**	**CO**	**PM 10**	**PM 2.5**
Emission Factors	0.36076	0.00489	3.17634	3.40450	0.17539	0.16136
Other Construction Equipment Composite [HP: 82] [LF: 0.42]						
	VOC	**SO_x**	**NO_x**	**CO**	**PM 10**	**PM 2.5**
Emission Factors	0.34346	0.00488	3.24084	3.56285	0.20853	0.19184
Rubber Tired Dozers Composite [HP: 367] [LF: 0.4]						
	VOC	**SO_x**	**NO_x**	**CO**	**PM 10**	**PM 2.5**
Emission Factors	0.40864	0.00491	4.01022	3.25251	0.17852	0.16424
Tractors/Loaders/Backhoes Composite [HP: 84] [LF: 0.37]						
	VOC	**SO_x**	**NO_x**	**CO**	**PM 10**	**PM 2.5**
Emission Factors	0.21500	0.00489	2.19159	3.49485	0.09716	0.08939

- Construction Exhaust Greenhouse Gasses Pollutant Emission Factors (g/hp-hour) (default)

Excavators Composite [HP: 36] [LF: 0.38]				
	CH_4	**N_2O**	**CO_2**	**CO_2e**
Emission Factors	0.02382	0.00476	587.31685	589.33237
Graders Composite [HP: 148] [LF: 0.41]				
	CH_4	**N_2O**	**CO_2**	**CO_2e**
Emission Factors	0.02151	0.00430	530.17041	531.98982
Other Construction Equipment Composite [HP: 82] [LF: 0.42]				
	CH_4	**N_2O**	**CO_2**	**CO_2e**
Emission Factors	0.02144	0.00429	528.45375	530.26726
Rubber Tired Dozers Composite [HP: 367] [LF: 0.4]				
	CH_4	**N_2O**	**CO_2**	**CO_2e**
Emission Factors	0.02159	0.00432	532.20301	534.02939
Tractors/Loaders/Backhoes Composite [HP: 84] [LF: 0.37]				
	CH_4	**N_2O**	**CO_2**	**CO_2e**
Emission Factors	0.02150	0.00430	529.93313	531.75173

- Vehicle Exhaust & Worker Trips Criteria Pollutant Emission Factors (grams/mile)

	VOC	**SO_x**	**NO_x**	**CO**	**PM 10**	**PM 2.5**	**NH_3**
LDGV	0.31287	0.00178	0.15174	4.94075	0.00384	0.00340	0.05485
LDGT	0.27556	0.00220	0.20340	4.45877	0.00436	0.00385	0.04644
HDGV	1.00405	0.00480	0.72186	12.67463	0.02085	0.01845	0.09731
LDDV	0.08501	0.00134	0.14279	6.03046	0.00324	0.00298	0.01679
LDDT	0.20078	0.00154	0.47191	5.96927	0.00587	0.00540	0.01813
HDDV	0.13925	0.00434	2.62491	1.70896	0.06430	0.05916	0.06420
MC	3.23022	0.00193	0.54883	12.80710	0.02290	0.02026	0.05095

- Vehicle Exhaust & Worker Trips Greenhouse Gasses Emission Factors (grams/mile)

	CH_4	**N_2O**	**CO_2**	**CO_2e**
LDGV	0.01600	0.00544	352.50072	354.51700
LDGT	0.01669	0.00796	436.10061	438.88415
HDGV	0.06154	0.02903	949.67357	959.84346
LDDV	0.04146	0.00073	397.80789	399.06271
LDDT	0.03182	0.00108	454.67599	455.79460
HDDV	0.02052	0.15850	1288.82285	1336.55551
MC	0.11576	0.00333	390.93995	394.82642

2.1.4 Site Grading Phase Formula(s)

- Fugitive Dust Emissions per Phase
$PM10_{FD} = (20 * ACRE * WD) / 2000$

$PM10_{FD}$: Fugitive Dust PM 10 Emissions (TONs)
20: Conversion Factor Acre Day to pounds (20 lb / 1 Acre Day)
ACRE: Total acres (acres)
WD: Number of Total Work Days (days)
2000: Conversion Factor pounds to tons

- Construction Exhaust Emissions per Phase
$CEE_{POL} = (NE * WD * H * HP * LF * EF_{POL} * 0.002205) / 2000$

CEE_{POL}: Construction Exhaust Emissions (TONs)
NE: Number of Equipment
WD: Number of Total Work Days (days)
H: Hours Worked per Day (hours)
HP: Equipment Horsepower
LF: Equipment Load Factor
EF_{POL}: Emission Factor for Pollutant (g/hp-hour)
0.002205: Conversion Factor grams to pounds
2000: Conversion Factor pounds to tons

- Vehicle Exhaust Emissions per Phase
$VMT_{VE} = (HA_{OnSite} + HA_{OffSite}) * (1 / HC) * HT$

VMT_{VE}: Vehicle Exhaust Vehicle Miles Travel (miles)
HA_{OnSite}: Amount of Material to be Hauled On-Site (yd^3)
$HA_{OffSite}$: Amount of Material to be Hauled Off-Site (yd^3)
HC: Average Hauling Truck Capacity (yd^3)
(1 / HC): Conversion Factor cubic yards to trips (1 trip / HC yd^3)
HT: Average Hauling Truck Round Trip Commute (mile/trip)

$V_{POL} = (VMT_{VE} * 0.002205 * EF_{POL} * VM) / 2000$

V_{POL}: Vehicle Emissions (TONs)
VMT_{VE}: Vehicle Exhaust Vehicle Miles Travel (miles)
0.002205: Conversion Factor grams to pounds
EF_{POL}: Emission Factor for Pollutant (grams/mile)
VM: Vehicle Exhaust On Road Vehicle Mixture (%)
2000: Conversion Factor pounds to tons

- Worker Trips Emissions per Phase
$VMT_{WT} = WD * WT * 1.25 * NE$

VMT_{WT}: Worker Trips Vehicle Miles Travel (miles)
WD: Number of Total Work Days (days)
WT: Average Worker Round Trip Commute (mile)
1.25: Conversion Factor Number of Construction Equipment to Number of Works
NE: Number of Construction Equipment

$V_{POL} = (VMT_{WT} * 0.002205 * EF_{POL} * VM) / 2000$

V_{POL}: Vehicle Emissions (TONs)

VMT_{WT}: Worker Trips Vehicle Miles Travel (miles)
0.002205: Conversion Factor grams to pounds
EF_{POL}: Emission Factor for Pollutant (grams/mile)
VM: Worker Trips On Road Vehicle Mixture (%)
2000: Conversion Factor pounds to tons

2.2 Building Construction Phase

2.2.1 Building Construction Phase Timeline Assumptions

- Phase Start Date
Start Month: 9
Start Quarter: 1
Start Year: 2024

- Phase Duration
Number of Month: 4
Number of Days: 0

2.2.2 Building Construction Phase Assumptions

- General Building Construction Information
Building Category: Office or Industrial
Area of Building (ft^2): 1800
Height of Building (ft): 15
Number of Units: N/A

- Building Construction Default Settings
Default Settings Used: Yes
Average Day(s) worked per week: 5 (default)

- Construction Exhaust (default)

Equipment Name	Number Of Equipment	Hours Per Day
Cranes Composite	1	4
Forklifts Composite	2	6
Tractors/Loaders/Backhoes Composite	1	8

- Vehicle Exhaust
Average Hauling Truck Round Trip Commute (mile): 20 (default)

- Vehicle Exhaust Vehicle Mixture (%)

	LDGV	LDGT	HDGV	LDDV	LDDT	HDDV	MC
POVs	0	0	0	0	0	100.00	0

- Worker Trips
Average Worker Round Trip Commute (mile): 20 (default)

- Worker Trips Vehicle Mixture (%)

	LDGV	LDGT	HDGV	LDDV	LDDT	HDDV	MC
POVs	50.00	50.00	0	0	0	0	0

- Vendor Trips
Average Vendor Round Trip Commute (mile): 40 (default)

- Vendor Trips Vehicle Mixture (%)

	LDGV	LDGT	HDGV	LDDV	LDDT	HDDV	MC
POVs	0	0	0	0	0	100.00	0

2.2.3 Building Construction Phase Emission Factor(s)

- Construction Exhaust Criteria Pollutant Emission Factors (g/hp-hour) (default)

Cranes Composite [HP: 367] [LF: 0.29]						
	VOC	SO_x	NO_x	CO	PM 10	PM 2.5
Emission Factors	0.21025	0.00487	2.13057	1.68023	0.08573	0.07887
Forklifts Composite [HP: 82] [LF: 0.2]						
	VOC	SO_x	NO_x	CO	PM 10	PM 2.5
Emission Factors	0.29170	0.00487	2.75083	3.61458	0.15732	0.14473
Tractors/Loaders/Backhoes Composite [HP: 84] [LF: 0.37]						
	VOC	SO_x	NO_x	CO	PM 10	PM 2.5
Emission Factors	0.21500	0.00489	2.19159	3.49485	0.09716	0.08939

- Construction Exhaust Greenhouse Gasses Pollutant Emission Factors (g/hp-hour) (default)

Cranes Composite [HP: 367] [LF: 0.29]				
	CH_4	N_2O	CO_2	CO_2e
Emission Factors	0.02140	0.00428	527.53174	529.34210
Forklifts Composite [HP: 82] [LF: 0.2]				
	CH_4	N_2O	CO_2	CO_2e
Emission Factors	0.02138	0.00428	527.03976	528.84843
Tractors/Loaders/Backhoes Composite [HP: 84] [LF: 0.37]				
	CH_4	N_2O	CO_2	CO_2e
Emission Factors	0.02150	0.00430	529.93313	531.75173

- Vehicle Exhaust & Worker Trips Criteria Pollutant Emission Factors (grams/mile)

	VOC	SO_x	NO_x	CO	PM 10	PM 2.5	NH_3
LDGV	0.31287	0.00178	0.15174	4.94075	0.00384	0.00340	0.05485
LDGT	0.27556	0.00220	0.20340	4.45877	0.00436	0.00385	0.04644
HDGV	1.00405	0.00480	0.72186	12.67463	0.02085	0.01845	0.09731
LDDV	0.08501	0.00134	0.14279	6.03046	0.00324	0.00298	0.01679
LDDT	0.20078	0.00154	0.47191	5.96927	0.00587	0.00540	0.01813
HDDV	0.13925	0.00434	2.62491	1.70896	0.06430	0.05916	0.06420
MC	3.23022	0.00193	0.54883	12.80710	0.02290	0.02026	0.05095

- Vehicle Exhaust & Worker Trips Greenhouse Gasses Emission Factors (grams/mile)

	CH_4	N_2O	CO_2	CO_2e
LDGV	0.01600	0.00544	352.50072	354.51700
LDGT	0.01669	0.00796	436.10061	438.88415
HDGV	0.06154	0.02903	949.67357	959.84346
LDDV	0.04146	0.00073	397.80789	399.06271
LDDT	0.03182	0.00108	454.67599	455.79460
HDDV	0.02052	0.15850	1288.82285	1336.55551
MC	0.11576	0.00333	390.93995	394.82642

2.2.4 Building Construction Phase Formula(s)

- Construction Exhaust Emissions per Phase

CEE_{POL} = (NE * WD * H * HP * LF * EF_{POL}* 0.002205) / 2000

CEE_{POL}: Construction Exhaust Emissions (TONs)

DETAIL AIR CONFORMITY APPLICABILITY MODEL REPORT

NE: Number of Equipment
WD: Number of Total Work Days (days)
H: Hours Worked per Day (hours)
HP: Equipment Horsepower
LF: Equipment Load Factor
EF_{POL}: Emission Factor for Pollutant (g/hp-hour)
0.002205: Conversion Factor grams to pounds
2000: Conversion Factor pounds to tons

- Vehicle Exhaust Emissions per Phase
VMT_{VE} = BA * BH * (0.42 / 1000) * HT

VMT_{VE}: Vehicle Exhaust Vehicle Miles Travel (miles)
BA: Area of Building (ft^2)
BH: Height of Building (ft)
(0.42 / 1000): Conversion Factor ft^3 to trips (0.42 trip / 1000 ft^3)
HT: Average Hauling Truck Round Trip Commute (mile/trip)

V_{POL} = (VMT_{VE} * 0.002205 * EF_{POL} * VM) / 2000

V_{POL}: Vehicle Emissions (TONs)
VMT_{VE}: Vehicle Exhaust Vehicle Miles Travel (miles)
0.002205: Conversion Factor grams to pounds
EF_{POL}: Emission Factor for Pollutant (grams/mile)
VM: Worker Trips On Road Vehicle Mixture (%)
2000: Conversion Factor pounds to tons

- Worker Trips Emissions per Phase
VMT_{WT} = WD * WT * 1.25 * NE

VMT_{WT}: Worker Trips Vehicle Miles Travel (miles)
WD: Number of Total Work Days (days)
WT: Average Worker Round Trip Commute (mile)
1.25: Conversion Factor Number of Construction Equipment to Number of Works
NE: Number of Construction Equipment

V_{POL} = (VMT_{WT} * 0.002205 * EF_{POL} * VM) / 2000

V_{POL}: Vehicle Emissions (TONs)
VMT_{WT}: Worker Trips Vehicle Miles Travel (miles)
0.002205: Conversion Factor grams to pounds
EF_{POL}: Emission Factor for Pollutant (grams/mile)
VM: Worker Trips On Road Vehicle Mixture (%)
2000: Conversion Factor pounds to tons

- Vender Trips Emissions per Phase
VMT_{VT} = BA * BH * (0.38 / 1000) * HT

VMT_{VT}: Vender Trips Vehicle Miles Travel (miles)
BA: Area of Building (ft^2)
BH: Height of Building (ft)
(0.38 / 1000): Conversion Factor ft^3 to trips (0.38 trip / 1000 ft^3)
HT: Average Hauling Truck Round Trip Commute (mile/trip)

V_{POL} = (VMT_{VT} * 0.002205 * EF_{POL} * VM) / 2000

V_{POL}: Vehicle Emissions (TONs)
VMT_{VT}: Vender Trips Vehicle Miles Travel (miles)
0.002205: Conversion Factor grams to pounds
EF_{POL}: Emission Factor for Pollutant (grams/mile)
VM: Worker Trips On Road Vehicle Mixture (%)
2000: Conversion Factor pounds to tons

2.3 Paving Phase

2.3.1 Paving Phase Timeline Assumptions

- Phase Start Date
Start Month: 11
Start Quarter: 1
Start Year: 2024

- Phase Duration
Number of Month: 2
Number of Days: 0

2.3.2 Paving Phase Assumptions

- General Paving Information
Paving Area (ft^2): 61544

- Paving Default Settings
Default Settings Used: Yes
Average Day(s) worked per week: 5 (default)

- Construction Exhaust (default)

Equipment Name	Number Of Equipment	Hours Per Day
Cement and Mortar Mixers Composite	4	6
Pavers Composite	1	7
Paving Equipment Composite	1	8
Rollers Composite	1	7
Tractors/Loaders/Backhoes Composite	1	7

- Vehicle Exhaust
Average Hauling Truck Round Trip Commute (mile): 20 (default)

- Vehicle Exhaust Vehicle Mixture (%)

	LDGV	LDGT	HDGV	LDDV	LDDT	HDDV	MC
POVs	0	0	0	0	0	100.00	0

- Worker Trips
Average Worker Round Trip Commute (mile): 20 (default)

- Worker Trips Vehicle Mixture (%)

	LDGV	LDGT	HDGV	LDDV	LDDT	HDDV	MC
POVs	50.00	50.00	0	0	0	0	0

2.3.3 Paving Phase Emission Factor(s)

DETAIL AIR CONFORMITY APPLICABILITY MODEL REPORT

- Construction Exhaust Criteria Pollutant Emission Factors (g/hp-hour) (default)

Cement and Mortar Mixers Composite [HP: 10] [LF: 0.56]						
	VOC	**SO_x**	**NO_x**	**CO**	**PM 10**	**PM 2.5**
Emission Factors	0.55375	0.00854	4.20177	3.25651	0.16410	0.15097
Pavers Composite [HP: 81] [LF: 0.42]						
	VOC	**SO_x**	**NO_x**	**CO**	**PM 10**	**PM 2.5**
Emission Factors	0.24765	0.00486	2.70778	3.42266	0.14436	0.13282
Paving Equipment Composite [HP: 89] [LF: 0.36]						
	VOC	**SO_x**	**NO_x**	**CO**	**PM 10**	**PM 2.5**
Emission Factors	0.22632	0.00488	2.40974	3.44725	0.10918	0.10044
Rollers Composite [HP: 36] [LF: 0.38]						
	VOC	**SO_x**	**NO_x**	**CO**	**PM 10**	**PM 2.5**
Emission Factors	0.61835	0.00541	3.81402	4.19473	0.19185	0.17650
Tractors/Loaders/Backhoes Composite [HP: 84] [LF: 0.37]						
	VOC	**SO_x**	**NO_x**	**CO**	**PM 10**	**PM 2.5**
Emission Factors	0.21500	0.00489	2.19159	3.49485	0.09716	0.08939

- Construction Exhaust Greenhouse Gasses Pollutant Emission Factors (g/hp-hour) (default)

Cement and Mortar Mixers Composite [HP: 10] [LF: 0.56]				
	CH_4	**N_2O**	**CO_2**	**CO_2e**
Emission Factors	0.02313	0.00463	570.16676	572.12342
Pavers Composite [HP: 81] [LF: 0.42]				
	CH_4	**N_2O**	**CO_2**	**CO_2e**
Emission Factors	0.02135	0.00427	526.33172	528.13796
Paving Equipment Composite [HP: 89] [LF: 0.36]				
	CH_4	**N_2O**	**CO_2**	**CO_2e**
Emission Factors	0.02142	0.00428	528.11469	529.92704
Rollers Composite [HP: 36] [LF: 0.38]				
	CH_4	**N_2O**	**CO_2**	**CO_2e**
Emission Factors	0.02380	0.00476	586.79790	588.81164
Tractors/Loaders/Backhoes Composite [HP: 84] [LF: 0.37]				
	CH_4	**N_2O**	**CO_2**	**CO_2e**
Emission Factors	0.02150	0.00430	529.93313	531.75173

- Vehicle Exhaust & Worker Trips Criteria Pollutant Emission Factors (grams/mile)

	VOC	**SO_x**	**NO_x**	**CO**	**PM 10**	**PM 2.5**	**NH_3**
LDGV	0.31287	0.00178	0.15174	4.94075	0.00384	0.00340	0.05485
LDGT	0.27556	0.00220	0.20340	4.45877	0.00436	0.00385	0.04644
HDGV	1.00405	0.00480	0.72186	12.67463	0.02085	0.01845	0.09731
LDDV	0.08501	0.00134	0.14279	6.03046	0.00324	0.00298	0.01679
LDDT	0.20078	0.00154	0.47191	5.96927	0.00587	0.00540	0.01813
HDDV	0.13925	0.00434	2.62491	1.70896	0.06430	0.05916	0.06420
MC	3.23022	0.00193	0.54883	12.80710	0.02290	0.02026	0.05095

- Vehicle Exhaust & Worker Trips Greenhouse Gasses Emission Factors (grams/mile)

	CH_4	**N_2O**	**CO_2**	**CO_2e**
LDGV	0.01600	0.00544	352.50072	354.51700
LDGT	0.01669	0.00796	436.10061	438.88415
HDGV	0.06154	0.02903	949.67357	959.84346
LDDV	0.04146	0.00073	397.80789	399.06271
LDDT	0.03182	0.00108	454.67599	455.79460
HDDV	0.02052	0.15850	1288.82285	1336.55551
MC	0.11576	0.00333	390.93995	394.82642

2.3.4 Paving Phase Formula(s)

- Construction Exhaust Emissions per Phase
$CEE_{POL} = (NE * WD * H * EF_{POL}) / 2000$

- Construction Exhaust Emissions per Phase
$CEE_{POL} = (NE * WD * H * HP * LF * EF_{POL} * 0.002205) / 2000$

CEE_{POL}: Construction Exhaust Emissions (TONs)
NE: Number of Equipment
WD: Number of Total Work Days (days)
H: Hours Worked per Day (hours)
HP: Equipment Horsepower
LF: Equipment Load Factor
EF_{POL}: Emission Factor for Pollutant (g/hp-hour)
0.002205: Conversion Factor grams to pounds
2000: Conversion Factor pounds to tons

- Vehicle Exhaust Emissions per Phase
$VMT_{VE} = PA * 0.25 * (1 / 27) * (1 / HC) * HT$

VMT_{VE}: Vehicle Exhaust Vehicle Miles Travel (miles)
PA: Paving Area (ft^2)
0.25: Thickness of Paving Area (ft)
(1 / 27): Conversion Factor cubic feet to cubic yards (1 yd^3 / 27 ft^3)
HC: Average Hauling Truck Capacity (yd^3)
(1 / HC): Conversion Factor cubic yards to trips (1 trip / HC yd^3)
HT: Average Hauling Truck Round Trip Commute (mile/trip)

$V_{POL} = (VMT_{VE} * 0.002205 * EF_{POL} * VM) / 2000$

V_{POL}: Vehicle Emissions (TONs)
VMT_{VE}: Vehicle Exhaust Vehicle Miles Travel (miles)
0.002205: Conversion Factor grams to pounds
EF_{POL}: Emission Factor for Pollutant (grams/mile)
VM: Vehicle Exhaust On Road Vehicle Mixture (%)
2000: Conversion Factor pounds to tons

- Worker Trips Emissions per Phase
$VMT_{WT} = WD * WT * 1.25 * NE$

VMT_{WT}: Worker Trips Vehicle Miles Travel (miles)
WD: Number of Total Work Days (days)
WT: Average Worker Round Trip Commute (mile)
1.25: Conversion Factor Number of Construction Equipment to Number of Works
NE: Number of Construction Equipment

$V_{POL} = (VMT_{WT} * 0.002205 * EF_{POL} * VM) / 2000$

V_{POL}: Vehicle Emissions (TONs)
VMT_{VE}: Worker Trips Vehicle Miles Travel (miles)
0.002205: Conversion Factor grams to pounds
EF_{POL}: Emission Factor for Pollutant (grams/mile)
VM: Worker Trips On Road Vehicle Mixture (%)
2000: Conversion Factor pounds to tons

DETAIL AIR CONFORMITY APPLICABILITY MODEL REPORT

- Off-Gassing Emissions per Phase
VOC_P = (2.62 * PA) / 43560 / 2000

VOC_P: Paving VOC Emissions (TONs)
2.62: Emission Factor (lb/acre)
PA: Paving Area (ft^2)
43560: Conversion Factor square feet to acre (43560 ft2 / acre)^2 / acre)
2000: Conversion Factor square pounds to TONs (2000 lb / TON)

AIR CONFORMITY APPLICABILITY MODEL REPORT
RECORD OF AIR ANALYSIS (ROAA)

1. General Information: The Air Force's Air Conformity Applicability Model (ACAM) was used to perform a net change in emissions analysis to assess the potential air quality impact/s associated with the action. The analysis was performed in accordance with the Air Force Manual 32-7002, *Environmental Compliance and Pollution Prevention*; the *Environmental Impact Analysis Process* (EIAP, 32 CFR 989); the *General Conformity Rule* (GCR, 40 CFR 93 Subpart B); and the *USAF Air Quality Environmental Impact Analysis Process (EIAP) Guide*. This report provides a summary of the ACAM analysis.

Report generated with ACAM version: 5.0.23a

a. Action Location:
Base: CAPE CANAVERAL AFS
State: Florida
County(s): Brevard
Regulatory Area(s): NOT IN A REGULATORY AREA

b. Action Title: SpaceX Falcon Operations at Space Launch Complex-40, Cape Canaveral Space Force Station

c. Project Number/s (if applicable):

d. Projected Action Start Date: 8 / 2024

e. Action Description:

The Proposed Action is to increase the annual Falcon launch cadence at SLC-40 to support future U.S. Government and commercial launch service needs, as well as the construction of a landing zone at SLC 40. The proposed development of a Falcon landing zone at SLC-40 would occur through the execution of a real property agreement between USSF and SpaceX.SpaceX proposes to launch Falcon up to 120 times annually from SLC-40. SpaceX would conduct launch operations in the same way as described in the 2020 EA. One to three days before each launch, an engine static fire test, which lasts a few seconds, may be performed. The need to conduct a static fire test depends on the mission, but there would be no more than 40 static fire test events per year. Launch operations would occur day or night, at any time during the year. Following each launch, SpaceX would perform a series of first stage burns and landing of the first stage, either downrange on a droneship or at a landing zone at CCSFS. SpaceX would construct a landing zone east of SLC-40 for the landing of Falcon first stage boosters. The landing zone would be made up of a 280-foot diameter concrete pad surrounded by a 60-foot-wide gravel apron, for a total diameter of 400 feet. Rocket Road would remain paved and traversable outside of landing events. SpaceX would construct a new nitrogen gas line from the existing metering station to a fluids bay at the landing zone. A 30 foot by 30-foot pedestal would be constructed adjacent to the landing pad to support post-landing vehicle processing. Crane storage is proposed along the existing SLC-40 fence line. Approximately four acres would be cleared for construction and operation of the landing zone.

f. Point of Contact:

Name: Adam Poll
Title: Civilian
Organization: Dudek
Email: apoll@dudek.com
Phone Number: 805-308-8516

2. Air Impact Analysis: Based on the attainment status at the action location, the requirements of the GCR are:

____ applicable
_X_ not applicable

AIR CONFORMITY APPLICABILITY MODEL REPORT
RECORD OF AIR ANALYSIS (ROAA)

Total reasonably foreseeable net direct and indirect emissions associated with the action were estimated through ACAM on a calendar-year basis for the start of the action through achieving “steady state” (hsba.e., no net gain/loss in emission stabilized and the action is fully implemented) emissions. The ACAM analysis uses the latest and most accurate emission estimation techniques available; all algorithms, emission factors, and methodologies used are described in detail in the *USAF Air Emissions Guide for Air Force Stationary Sources*, the *USAF Air Emissions Guide for Air Force Mobile Sources*, and the *USAF Air Emissions Guide for Air Force Transitory Sources*.

"Insignificance Indicators" were used in the analysis to provide an indication of the significance of the proposed Action’s potential impacts to local air quality. The insignificance indicators are trivial (de minimis) rate thresholds that have been demonstrated to have little to no impact to air quality. These insignificance indicators are the 250 ton/yr Prevention of Significant Deterioration (PSD) major source threshold and 25 ton/yr for lead for actions occurring in areas that are "Attainment" (hsba.e., not exceeding any National Ambient Air Quality Standard (NAAQS)). These indicators do not define a significant impact; however, they do provide a threshold to identify actions that are insignificant. Any action with net emissions below the insignificance indicators for all criteria pollutants is considered so insignificant that the action will not cause or contribute to an exceedance on one or more NAAQS. For further detail on insignificance indicators, refer to *Level II, Air Quality Quantitative Assessment, Insignificance Indicators*.

The action’s net emissions for every year through achieving steady state were compared against the Insignificance Indicators and are summarized below.

Analysis Summary:

2024

Pollutant	Action Emissions (ton/yr)	INSIGNIFICANCE INDICATOR	
		Indicator (ton/yr)	Exceedance (Yes or No)
NOT IN A REGULATORY AREA			
VOC	0.139	250	No
NOx	1.232	250	No
CO	1.476	250	No
SOx	0.002	250	No
PM 10	14.382	250	No
PM 2.5	0.053	250	No
Pb	0.000	25	No
NH3	0.003	250	No

2025 - (Steady State)

Pollutant	Action Emissions (ton/yr)	INSIGNIFICANCE INDICATOR	
		Indicator (ton/yr)	Exceedance (Yes or No)
NOT IN A REGULATORY AREA			
VOC	0.000	250	No
NOx	0.000	250	No
CO	0.000	250	No
SOx	0.000	250	No
PM 10	0.000	250	No
PM 2.5	0.000	250	No
Pb	0.000	25	No
NH3	0.000	250	No

None of the estimated annual net emissions associated with this action are above the insignificance indicators; therefore, the action will not cause or contribute to an exceedance of one or more NAAQSs and will have an insignificant impact on air quality. No further air assessment is needed.

AIR CONFORMITY APPLICABILITY MODEL REPORT
RECORD OF AIR ANALYSIS (ROAA)

Adam Poll, Civilian	Jul 08 2024
Name, Title	**Date**

AIR CONFORMITY APPLICABILITY MODEL REPORT
GREENHOUSE GAS (GHG) EMISSIONS

1. General Information: The Air Force's Air Conformity Applicability Model (ACAM) was used to perform an analysis to estimate GHG emissions and assess the theoretical Social Cost of Greenhouse Gases (SC GHG) associated with the action. The analysis was performed in accordance with the Air Force Manual 32-7002, Environmental Compliance and Pollution Prevention; the Environmental Impact Analysis Process (EIAP, 32 CFR 989); and the USAF Air Quality Environmental Impact Analysis Process (EIAP) Guide. This report provides a summary of GHG emissions and SC GHG analysis.

Report generated with ACAM version: 5.0.23a

a. Action Location:
Base: CAPE CANAVERAL AFS
State: Florida
County(s): Brevard
Regulatory Area(s): NOT IN A REGULATORY AREA

b. Action Title: SpaceX Falcon Operations at Space Launch Complex-40, Cape Canaveral Space Force Station

c. Project Number/s (if applicable):

d. Projected Action Start Date: 8 / 2024

e. Action Description:

The Proposed Action is to increase the annual Falcon launch cadence at SLC-40 to support future U.S. Government and commercial launch service needs, as well as the construction of a landing zone at SLC 40. The proposed development of a Falcon landing zone at SLC-40 would occur through the execution of a real property agreement between USSF and SpaceX.SpaceX proposes to launch Falcon up to 120 times annually from SLC-40. SpaceX would conduct launch operations in the same way as described in the 2020 EA. One to three days before each launch, an engine static fire test, which lasts a few seconds, may be performed. The need to conduct a static fire test depends on the mission, but there would be no more than 40 static fire test events per year. Launch operations would occur day or night, at any time during the year. Following each launch, SpaceX would perform a series of first stage burns and landing of the first stage, either downrange on a droneship or at a landing zone at CCSFS. SpaceX would construct a landing zone east of SLC-40 for the landing of Falcon first stage boosters. The landing zone would be made up of a 280-foot diameter concrete pad surrounded by a 60-foot-wide gravel apron, for a total diameter of 400 feet. Rocket Road would remain paved and traversable outside of landing events. SpaceX would construct a new nitrogen gas line from the existing metering station to a fluids bay at the landing zone. A 30 foot by 30-foot pedestal would be constructed adjacent to the landing pad to support post-landing vehicle processing. Crane storage is proposed along the existing SLC-40 fence line. Approximately four acres would be cleared for construction and operation of the landing zone.

f. Point of Contact:
Name: Adam Poll
Title: Civilian
Organization: Dudek
Email: apoll@dudek.com
Phone Number: 805-308-8516

2. Analysis: Total combined direct and indirect GHG emissions associated with the action were estimated through ACAM on a calendar-year basis from the action start through the expected life cycle of the action. The life cycle for Air Force actions with "steady state" emissions (SS, net gain/loss in emission stabilized and the action is fully implemented) is assumed to be 10 years beyond the SS emissions year or 20 years beyond SS emissions year for aircraft operations related actions.

AIR CONFORMITY APPLICABILITY MODEL REPORT
GREENHOUSE GAS (GHG) EMISSIONS

GHG Emissions Analysis Summary:

GHGs produced by fossil-fuel combustion are primarily carbon dioxide (CO2), methane (CH4), and nitrous oxide (NO2). These three GHGs represent more than 97 percent of all U.S. GHG emissions. Emissions of GHGs are typically quantified and regulated in units of CO2 equivalents (CO2e). The CO2e takes into account the global warming potential (GWP) of each GHG. The GWP is the measure of a particular GHG's ability to absorb solar radiation as well as its residence time within the atmosphere. The GWP allows comparison of global warming impacts between different gases; the higher the GWP, the more that gas contributes to climate change in comparison to CO2. All GHG emissions estimates were derived from various emission sources using the methods, algorithms, emission factors, and GWPs from the most current Air Emissions Guide for Air Force Stationary Sources, Air Emissions Guide for Air Force Mobile Sources, and/or Air Emissions Guide for Air Force Transitory Sources.

The Air Force has adopted the Prevention of Significant Deterioration (PSD) threshold for GHG of 75,000 ton per year (ton/yr) of CO2e (or 68,039 metric ton per year, mton/yr) as an indicator or "threshold of insignificance" for NEPA air quality impacts in all areas. This indicator does not define a significant impact; however, it provides a threshold to identify actions that are insignificant (de minimis, too trivial or minor to merit consideration). Actions with a net change in GHG (CO2e) emissions below the insignificance indicator (threshold) are considered too insignificant on a global scale to warrant any further analysis. Note that actions with a net change in GHG (CO2e) emissions above the insignificance indicator (threshold) are only considered potentially significant and require further assessment to determine if the action poses a significant impact. For further detail on insignificance indicators see Level II, Air Quality Quantitative Assessment, Insignificance Indicators (April 2023).

The following table summarizes the action-related GHG emissions on a calendar-year basis through the projected life cycle of the action.

Action-Related Annual GHG Emissions (mton/yr)						
YEAR	CO2	CH4	N2O	CO2e	Threshold	Exceedance
2024	218	0.00850055	0.00351075	219	68,039	No
2025 [SS Year]	0	0	0	0	68,039	No

The following U.S. and State's GHG emissions estimates (next two tables) are based on a five-year average (2016 through 2020) of individual state-reported GHG emissions (Reference: State Climate Summaries 2022, NOAA National Centers for Environmental Information, National Oceanic and Atmospheric Administration. https://statesummaries.ncics.org/downloads/).

State's Annual GHG Emissions (mton/yr)				
YEAR	CO2	CH4	N2O	CO2e
2024	227,404,647	552,428	58,049	228,015,124
2025 [SS Year]	0	0	0	0

U.S. Annual GHG Emissions (mton/yr)				
YEAR	CO2	CH4	N2O	CO2e
2024	5,136,454,179	25,626,912	1,500,708	5,163,581,798
2025 [SS Year]	0	0	0	0

GHG Relative Significance Assessment:

A Relative Significance Assessment uses the rule of reason and the concept of proportionality along with the consideration of the affected area (yGba.e., global, national, and regional) and the degree (intensity) of the proposed action's effects. The Relative Significance Assessment provides real-world context and allows for a reasoned choice against alternatives through a relative comparison analysis. The analysis weighs each alternative's annual net change in GHG emissions proportionally against (or relative to) global, national, and regional emissions.

AIR CONFORMITY APPLICABILITY MODEL REPORT
GREENHOUSE GAS (GHG) EMISSIONS

The action's surroundings, circumstances, environment, and background (context associated with an action) provide the setting for evaluating the GHG intensity (impact significance). From an air quality perspective, context of an action is the local area's ambient air quality relative to meeting the NAAQSs, expressed as attainment, nonattainment, or maintenance areas (this designation is considered the attainment status). GHGs are non-hazardous to health at normal ambient concentrations and, at a cumulative global scale, action-related GHG emissions can only potentially cause warming of the climatic system. Therefore, the action-related GHGs generally have an insignificant impact to local air quality.

However, the affected area (context) of GHG/climate change is global. Therefore, the intensity or degree of the proposed action's GHG/climate change effects are gauged through the quantity of GHG associated with the action as compared to a baseline of the state, U.S., and global GHG inventories. Each action (or alternative) has significance, based on their annual net change in GHG emissions, in relation to or proportionally to the global, national, and regional annual GHG emissions.

To provide real-world context to the GHG and climate change effects on a global scale, an action's net change in GHG emissions is compared relative to the state (where action will occur) and U.S. annual emissions. The following table provides a relative comparison of an action's net change in GHG emissions vs. state and U.S. projected GHG emissions for the same time period.

Total GHG Relative Significance (mton)					
		CO2	**CH4**	**N2O**	**CO2e**
2024-2035	State Total	227,404,647	552,428	58,049	228,015,124
2024-2035	U.S. Total	5,136,454,179	25,626,912	1,500,708	5,163,581,798
2024-2035	Action	218	0.008501	0.003511	219
Percent of State Totals		0.00009581%	0.00000154%	0.00000605%	0.00009610%
Percent of U.S. Totals		0.00000424%	0.00000003%	0.00000023%	0.00000424%

From a global context, the action's total GHG percentage of total global GHG for the same time period is: 0.00000057%.*

* Global value based on the U.S. emits 13.4% of all global GHG annual emissions (2018 Emissions Data, Center for Climate and Energy Solutions, accessed 7-6-2023, https://www.c2es.org/content/international-emissions).

Climate Change Assessment (as SC GHG):

On a global scale, the potential climate change effects of an action are indirectly addressed and put into context through providing the theoretical SC GHG associated with an action. The SC GHG is an administrative and theoretical tool intended to provide additional context to a GHG's potential impacts through approximating the long-term monetary damage that may result from GHG emissions affect on climate change. It is important to note that the SC GHG is a monetary quantification, in 2020 U.S. dollars, of the theoretical economic damages that could result from emitting GHGs into the atmosphere.

The SC GHG estimates are derived using the methodology and discount factors in the "Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990," released by the Interagency Working Group on Social Cost of Greenhouse Gases (IWG SC GHGs) in February 2021.

The speciated IWG Annual SC GHG Emission associated with an action (or alternative) are first estimated as annual unit cost (cost per metric ton, $/mton). Results of the annual IWG Annual SC GHG Emission Assessments are tabulated in the IWG Annual SC GHG Cost per Metric Ton Table below:

IWG SC GHG Discount Factor: 2.5%

AIR CONFORMITY APPLICABILITY MODEL REPORT
GREENHOUSE GAS (GHG) EMISSIONS

IWG Annual SC GHG Cost per Metric Ton ($/mton [In 2020 $])			
YEAR	CO2	CH4	N2O
2024	$82.00	$2,200.00	$29,000.00
2025 [SS Year]	$83.00	$2,200.00	$30,000.00

Action-related SC GHG were estimated by calendar-year for the projected action's lifecycle. Annual estimates were found by multiplying the annual emission for a given year by the corresponding IWG Annual SC GHG Emission value (see table above).

Action-Related Annual SC GHG ($K/yr [In 2020 $])				
YEAR	CO2	CH4	N2O	GHG
2024	$17.87	$0.02	$0.10	$17.99
2025 [SS Year]	$0.00	$0.00	$0.00	$0.00

The following two tables summarize the U.S. and State's Annual SC GHG by calendar-year. The U.S. and State's Annual SC GHG are in 2020 dollars and were estimated by each year for the projected action lifecycle. Annual SC GHG estimates were found by multiplying the U.S. and State's annual five-year average GHG emissions for a given year by the corresponding IWG Annual SC GHG Cost per Metric Ton value.

State's Annual SC GHG ($K/yr [In 2020 $])				
YEAR	CO2	CH4	N2O	GHG
2024	$18,647,181.06	$1,215,340.97	$1,683,417.08	$21,545,939.11
2025 [SS Year]	$0.00	$0.00	$0.00	$0.00

U.S. Annual SC GHG ($K/yr [In 2020 $])				
YEAR	CO2	CH4	N2O	GHG
2024	$421,189,242.68	$56,379,205.70	$43,520,521.44	$521,088,969.82
2025 [SS Year]	$0.00	$0.00	$0.00	$0.00

Relative Comparison of SC GHG:

To provide additional real-world context to the potential climate change impact associate with an action, a Relative Comparison of SC GHG Assessment is also performed. While the SC GHG estimates capture an indirect approximation of global climate damages, the Relative Comparison of SC GHG Assessment provides a better perspective from a regional and global scale.

The Relative Comparison of SC GHG Assessment uses the rule of reason and the concept of proportionality along with the consideration of the affected area (yGba.e., global, national, and regional) and the SC GHG as the degree (intensity) of the proposed action's effects. The Relative Comparison Assessment provides real-world context and allows for a reasoned choice among alternatives through a relative contrast analysis which weighs each alternative's SC GHG proportionally against (or relative to) existing global, national, and regional SC GHG. The below table provides a relative comparison between an action's SC GHG vs. state and U.S. projected SC GHG for the same time period:

Total SC-GHG ($K [In 2020 $])					
		CO2	CH4	N2O	GHG
2024-2035	State Total	$18,647,181.06	$1,215,340.97	$1,683,417.08	$21,545,939.11
2024-2035	U.S. Total	$421,189,242.68	$56,379,205.70	$43,520,521.44	$521,088,969.82
2024-2035	Action	$17.87	$0.02	$0.10	$17.99
Percent of State Totals		0.00009581%	0.00000154%	0.00000605%	0.00008348%
Percent of U.S. Totals		0.00000424%	0.00000003%	0.00000023%	0.00000345%

AIR CONFORMITY APPLICABILITY MODEL REPORT
GREENHOUSE GAS (GHG) EMISSIONS

From a global context, the action’s total SC GHG percentage of total global SC GHG for the same time period is: 0.00000046%.*

* Global value based on the U.S. emits 13.4% of all global GHG annual emissions (2018 Emissions Data, Center for Climate and Energy Solutions, accessed 7-6-2023, https://www.c2es.org/content/international-emissions).

Adam Poll, Civilian	Jul 08 2024
Name, Title	**Date**

Emissions Summary

Baseline Emissions							
Source Category	**VOC**	**NO_x**	**CO**	**SO_x**	**PM_{10}**	**$PM_{2.5}$**	**CO_2e**
	(ton/yr)						**MT/yr**
Marine Recovery Operations	4.21	71.58	32.20	1.86	1.53	1.41	6,035.58
Falcon Launches and Landings	0.00	8.48	0.00	0.00	0.00	0.00	19,131.25
Launch Facility Operations*	0.00	0.00	0.00	0.00	0.00	0.00	6,903.73
Total	**4.21**	**80.06**	**32.20**	**1.86**	**1.53**	**1.41**	**32,070.56**

Notes:

*launch facility operational emissions are from 2023 utility data provided by SpaceX

Falcon Launches and Landings baseline scenario is calculated using current methodology used to calculate project emissions rather than the numbers reported in the 2020 CCSFS EA, as we could not verify the calculations in that report

Emissions values for marine recovery operations and falcon launches/landings are from 2020 EA

Project Emissions							
Source Category	**VOC**	**NO_x**	**CO**	**SO_x**	**PM_{10}**	**$PM_{2.5}$**	**CO_2e**
	(ton/yr)						**MT/yr**
Marine Recovery Operations	7.00	129.69	38.60	3.94	2.78	2.53	9,432.23
Launch Facility Operations	0.00	0.00	0.00	0.00	0.00	0.00	14,793.71
Falcon Launches and Landings	0.00	18.68	0.00	0.00	0.00	0.00	47,527.68
Total	7.00	148.36	38.60	3.94	2.78	2.53	71,753.62
Net Increase	**2.80**	**68.30**	**6.40**	**2.08**	**1.25**	**1.12**	**39,683.06**
DAF Thresholds of Insignificance	250	250	250	250	250	250	68,039
Threshold Exceeded?	**No**	**No**	**No**	**No**	**No**	**No**	**No**

Notes:

DAF Thresholds are from USAAF "Level II, Air Quality Quantitative Assessment, Insignificance Indicators"

SpaceX Cape Canaveral Recovery Operations - Marine Recovery Vessels (Dragon capsule)

Baseline

(Calculated - based on information from 2020 CCSFS EA)

Marine Emission Estimates - Havila Harmony

Boat Classification	Phase	Engine	Engine Tier	Fuel	# Engines	Engine Rating (hp)	Engine Rating (kW)	Load Factor	Operation (hr/day)	Operation (days/yr)	Emission Factors (g/kW-hr) VOC	NOx	CO	SOx	PM10	PM2.5	CO2	CH4	N20
Recovery Vessel	Transit	Propulsion	3	0.1%S	4	2,500	1,864	0.50	24.00	54	0.39	5.21	5.00	0.07	0.11	0.11	715.76	0.01	0.03
Recovery Vessel	Transit	Auxiliary	3	0.1%S	1	650	485	0.31	24.00	54	0.38	5.02	5.00	0.07	0.12	0.12	656.00	0.01	0.03

Boat Classification	Engine	Maximum Daily Emissions (lb/day) VOC	NOx	CO	SOx	PM10	PM2.5	CO2	CH4	N20
Recovery Vessel	Propulsion	77.32	1,027.27	986.24	13.41	21.70	21.70	141,182.71	5.72	1.97
Recovery Vessel	Auxiliary	3.01	39.95	39.78	0.54	0.95	0.95	5,218.50	0.23	0.08
Emission Subtotals		**80.33**	**1,067.22**	**1,026.02**	**13.95**	**22.65**	**22.65**	**146,401.21**	**5.95**	**2.05**

Boat Classification	Engine	Annual Emissions (ton/yr) VOC	NOx	CO	SOx	PM10	PM2.5	(MT/yr) CO2	CH4	N20	CO2E
Recovery Vessel	Propulsion	2.09	27.70	26.60	0.36	0.59	0.59	3,454.13	0.14	0.05	3,472.00
Recovery Vessel	Auxiliary	0.08	1.08	1.07	0.01	0.03	0.03	127.67	0.01	0.00	128.39
Emission Subtotals		**2.17**	**28.78**	**27.67**	**0.38**	**0.61**	**0.61**	**3,581.80**	**0.15**	**0.05**	**3,600.40**

Notes:

Source: 2020 EA for SpaceX Falcon Launches at Kennedy Space Center and Cape Canaveral Air Force Station

2020 EA assumed a ship similar to MV Havila Harmony. Engines are 4 x 1900 KW Cummins: Type QSK60 (main), 1 x 485 KW Cummins: Type KTA 19 (auxiliary) https://www.cummins.com/engines/qsk60?v=1236&title_2=&page=3

Assuming 10 dragon capsule recovery operations per year, traveling at most 1000 nm over 5 days based on 2020 EA assumption

Assumed maximum speed of vessel is 15.45 knots, based on technical specifications of Havila Harmony. Assumed 50% ship speed to travel 1000 nm, which was max recovery time and distance in 2020 EA.

Proposed Action

Marine Emission Estimates - Havila Harmony

Boat Classification	Phase	Engine	Engine Tier	Fuel	# Engines	Engine Rating (hp)	Engine Rating (kW)	Load Factor	Operation (hr/day)	Operation (days/yr)	Emission Factors (g/kW-hr) VOC	NOx	CO	SOx	PM10	PM2.5	CO2	CH4	N20
Recovery Vessel	Transit	Propulsion	3	0.1%S	4	2,500	1,864	0.50	24.00	54	0.39	5.21	5.00	0.07	0.11	0.11	715.76	0.01	0.03
Recovery Vessel	Transit	Auxiliary	3	0.1%S	1	650	485	0.31	24.00	54	0.38	5.02	5.00	0.07	0.12	0.12	656.00	0.01	0.03

Boat Classification	Engine	Maximum Daily Emissions (lb/day) VOC	NOx	CO	SOx	PM10	PM2.5	CO2	CH4	N20
Recovery Vessel	Propulsion	77.32	1,027.27	986.24	13.41	21.70	21.70	141,182.71	5.72	1.97
Recovery Vessel	Auxiliary	3.01	39.95	39.78	0.54	0.95	0.95	5,218.50	0.23	0.08
Emission Subtotals		**80.33**	**1,067.22**	**1,026.02**	**13.95**	**22.65**	**22.65**	**146,401.21**	**5.95**	**2.05**

Boat Classification	Engine	Annual Emissions (ton/yr) VOC	NOx	CO	SOx	PM10	PM2.5	(MT/yr) CO2	CH4	N20	CO2E
Recovery Vessel	Propulsion	2.09	27.70	26.60	0.36	0.59	0.59	3,454.13	0.14	0.05	3,472.00
Recovery Vessel	Auxiliary	0.08	1.08	1.07	0.01	0.03	0.03	127.67	0.01	0.00	128.39
Emission Subtotals		**2.17**	**28.78**	**27.67**	**0.38**	**0.61**	**0.61**	**3,581.80**	**0.15**	**0.05**	**3,600.40**

Notes:

*2020 EA assumed a ship similar to MV Havila Harmony. Engines are 4 x 1900 KW Cummins: Type QSK60 (main), 1 x 485 KW Cummins: Type KTA 19 (auxiliary) https://www.cummins.com/engines/qsk60?v=1236&title_2=&page=3

*Assuming 10 Dragon capsule recovery operations per year, traveling at most 1000 nm based on doubling of 2020 EA assumption

*maximum speed of ship is 15.45 knots. Assumed 90% ship speed to travel 1000 nm in 5 days, which was stated recovery time and distance in 2020 EA.

Marine Propulsion

Engine Type	Engine Family	Model	Tier	Fuel	VOC (g/kW-hr)	NOx	CO	SOx	PM10	PM2.5	CO2	CH4	N2O
Slow Speed Diesel		<=1999	Tier 0	0.1%S	0.600	17.01	1.4	0.39	0.26	0.24	589	0.012	0.029
Medium Speed Diesel		<=1999	Tier 0	0.1%S	0.500	13.16	1.1	0.43	0.26	0.24	649	0.010	0.029
Slow Speed Diesel		2000-2010	Tier 1	0.1%S	0.600	15.98	1.4	0.39	0.26	0.24	589	0.012	0.029
Medium Speed Diesel		2000-2010	Tier 1	0.1%S	0.500	12.22	1.1	0.43	0.26	0.24	649	0.010	0.029
Slow Speed Diesel		2011-2015	Tier 2	0.1%S	0.600	14.38	1.4	0.39	0.26	0.24	589	0.012	0.029
Medium Speed Diesel		2011-2015	Tier 2	0.1%S	0.500	10.53	1.1	0.43	0.26	0.24	649	0.010	0.029
Slow Speed Diesel		2016+	Tier 3	0.1%S	0.600	3.38	1.4	0.39	0.26	0.24	589	0.012	0.029
Medium Speed Diesel		2016+	Tier 3	0.1%S	0.500	2.63	1.1	0.43	0.26	0.24	649	0.010	0.029
EPA Certification	HCEXN19.0AAA		Tier 3	0.1%S	0.392	5.21	5.0	0.07	0.11	0.11	716		
Notes:						5.21	5.00	0.07	0.11	0.11	715.76	0.01	0.03

Emission factors from Table 2.3 and 2.4 of the 2019 Port of Los Angeles Emission Inventory Methodology Report

Load factors for propulsion engines based on Table 3.1 of the of the 2019 Port of Los Angeles Emission Inventory Methodology Report

EPA certification based on Tier 3 rating for the engine family from Table 1 to CFR §1042.101.

Marine Auxiliary

Engine Type	Model	Tier	Fuel	VOC (g/kW-hr)	NOx	CO	SOx	PM10	PM2.5	CO2	CH4	N2O
Aux High Speed Diesel	<=1999	Tier 0	0.1%S	0.600	10.9	1.1	0.455	0.26	0.24	656	0.010	0.029
Aux Med Speed Diesel	<=1999	Tier 0	0.1%S	0.600	13.82	1.4	0.455	0.26	0.24	686	0.012	0.029
Aux High Speed Diesel	2000-2010	Tier 1	0.1%S	0.600	9.78	1.1	0.455	0.26	0.24	656	0.010	0.029
Aux Med Speed Diesel	2000-2010	Tier 1	0.1%S	0.600	12.22	1.4	0.455	0.26	0.24	686	0.012	0.029
Aux High Speed Diesel	2011-2015	Tier 2	0.1%S	0.600	7.71	1.1	0.455	0.26	0.24	656	0.010	0.029
Aux Med Speed Diesel	2011-2015	Tier 2	0.1%S	0.600	10.53	1.4	0.455	0.26	0.24	686	0.012	0.029
Aux High Speed Diesel	2011-2015	Tier 3	0.1%S	0.600	1.97	1.1	0.455	0.26	0.24	656	0.010	0.029
Aux Med Speed Diesel	2011-2015	Tier 3	0.1%S	0.600	2.63	1.4	0.455	0.26	0.24	686	0.012	0.029
Aux Med Speed Diesel Tier 3 Standard	2011-2015	Tier 3	0.1%S	0.378	5.022	5	0.068	0.12	0.12			

Notes:

Emission factors from Table 2.9 and 2.10 of the 2019 Port of Los Angeles Emission Inventory Methodology Report

Load factors for propulsion engines based on Table 3.1 of the of the 2019 Port of Los Angeles Emission Inventory Methodology Report

EPA certification based on Tier 3 rating for the engine family from Table 5 to CFR §1042.101.

Marine exhaust emissions were calculated using the following equation:

$$Emissions_{diesel} = \Sigma\, EF_i \times Eng_i \times AvgHP \times Load_i \times Activity_i$$

Where:

EF	=	*Emission factor in grams per horse-power hour*
Eng	=	*Number of engines*
AvgHP	=	*Maximum rated average horsepower*
Load	=	*Load factor*
Activity	=	*Hours of operation*
i	=	*Equipment type*

SpaceX Cape Canaveral Recovery Operations - Helicopters (Dragon capsule)

Baseline

(Calculated - based on information from 2020 CCSFS EA)

							Emission Factors (lb/hr)*				Emissions (lbs/day)				Emissions (tons/year)			
Helicopter	Mode	Average #LTO/day		Hours/Day	Days/year	Horsepower	ROC	NOx	CO	PM10	ROC	NOx	CO	PM10	ROC	NOx	CO	PM10
CH-47 Chinook	LTO	1		1.00	10	9,000	0.70	5.25	0.85	0.11	0.70	5.25	0.85	0.11	0.00	0.03	0.00	0.00
CH-47 Chinook	Operation	N/A		2.27	10	9,000	1.83	53.42	2.16	1.04	4.15	121.09	4.90	2.35	0.05	1.37	0.06	0.03
CH-47 Chinook	Total										**4.85**	**126.34**	**5.75**	**2.47**	**0.05**	**1.40**	**0.06**	**0.03**

Notes:

Source: 2020 EA for SpaceX Falcon Launches at Kennedy Space Center and Cape Canaveral Air Force Station

Emission factors from Federal Office of Civil Aviation (FOCA). n.d. Guidance on Determination of Helicopter Emissions.

Erickson S-64E has a top speed of 115 knots. Assuming helicopter would travel at 50% speed for the maximum range cited in the 2020 EA (150 miles) 10 times per year

Helicopter	Mode	Average #LTO/day	Hours/day	Days/year	Horsepowe	Fuel per day (kg)	Gallons Per day	CO2 MT	CH4 MT	N20	CO2E
CH-47 Chinook	LTO	1	N/A	10.00	9,000.00	153.80	766.64	75.51	0.00	0.00	75.77
CH-47 Chinook	Operation	N/A	2.27	10.00	9,000.00	2,773.77					
CH-47 Chinook	Total					2,927.57					

Notes:

Federal Office of Civil Aviation (FOCA). n.d. Guidance on Determination of Helicopter Emissions.

Erickson S-64E has a top speed of 115 knots. Assuming helicopter would travel at 50% speed for the maximum range cited in the 2020 EA (150 miles) 10 times per year

Proposed Action

							Emission Factors (lb/hr)*				Emissions (lbs/day)				Emissions (tons/year)			
Helicopter	Mode	Average #LTO/day		Hours/Day	Days/year	Horsepower	ROC	NOx	CO	PM10	ROC	NOx	CO	PM10	ROC	NOx	CO	PM10
CH-47 Chinook	LTO	1		1.00	10	9,000	0.70	5.25	0.85	0.11	0.70	5.25	0.85	0.11	0.00	0.03	0.00	0.00
CH-47 Chinook	Operation	N/A		2.27	10	9,000	1.83	53.42	2.16	1.04	4.15	121.09	4.90	2.35	0.05	1.37	0.06	0.03
CH-47 Chinook	Total										**4.85**	**126.34**	**5.75**	**2.47**	**0.05**	**1.40**	**0.06**	**0.03**

Notes:

Emission factors from Federal Office of Civil Aviation (FOCA). n.d. Guidance on Determination of Helicopter Emissions.

Erickson S-64E has a top speed of 115 knots. Assuming helicopter would travel at 50% speed for the maximum range cited in the 2020 EA (150 miles) 10 times per year

Helicopter	Mode	Average #LTO/day	Hours/day	Days/year	Horsepowe	Fuel per day (kg)	Gallons Per day	CO2 MT	CH4 MT	N20	CO2E
CH-47 Chinook	LTO	1	N/A	20	9,000	153.80	767.63	151.22	0.01	0.00	151.74
CH-47 Chinook	Operation	N/A	2.27	20	9,000	2,777.57					
CH-47 Chinook	Total					2,931.37					

Notes

Jet Fuel Density 840 Kg/m3	
Kg to pounds	2.20462
grams to pounds	0.00220462
miles to nautical m	0.868976

Launch, Landing, and Static Fire

Baseline

						Emission Factors						Emissions							Emissions						
			<3,000ft			Pounds per burn second						Tons emitted per launch						Metric tons per Activity	Tons per year						Metric tons per year
Type	Stage	Fuel	Burn time (seconds)	Number of Engines	Annual Activities	VOC	NOx	CO	SOx	PM10	PM2.5	VOC	NOx	CO	SOx	PM10	PM2.5	CO2e	VOC	NOx	CO	SOx	PM10	PM2.5	CO2e
Launch Falcon 9	1	RP1/LOX	23	9	50	0.00	9.42	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	273.96	0.00	5.42	0.00	0.00	0.00	0.00	13,697.79
Landing (Offshore) Falcon 9	1	RP1/LOX	18	3	25	0.00	3.14	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	90.41	0.00	0.71	0.00	0.00	0.00	0.00	2,260.14
Landing (CCSFS) Falcon 9	1	RP1/LOX	18	3	25	0.00	3.14	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	90.41	0.00	0.71	0.00	0.00	0.00	0.00	2,260.14
Static Fire Falcon 9	1	RP1/LOX	7	9	50	0.00	9.42	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	18.26	0.00	1.65	0.00	0.00	0.00	0.00	913.19
Notes:																		Total	0.00	8.48	0.00	0.00	0.00	0.00	19,131.25

Baseline scenario is calculated using our methodology and emission factors from 2019 Merlin test, launch frequencies are from 2020 CCSFS EA, keeping landing frequencies and static fire tests consistent with our current methodology

Proposed Action

						Emission Factors						Emissions							Emissions						
			<3,000ft			Pounds per burn second						Tons emitted per launch						Metric tons per Activity	Tons per year						Metric tons per year
Type	Stage	Fuel	Burn time (seconds)	Number of Engines	Annual Activities	VOC	NOx	CO	SOx	PM10	PM2.5	VOC	NOx	CO	SOx	PM10	PM2.5	CO2e	VOC	NOx	CO	SOx	PM10	PM2.5	CO2e
Launch Falcon 9	1	RP1/LOX	23	9	120	0.00	9.42	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	273.96	0.00	13.00	0.00	0.00	0.00	0.00	32,874.69
Landing (Offshore) Falcon 9	1	RP1/LOX	18	3	120	0.00	3.14	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	90.41	0.00	3.39	0.00	0.00	0.00	0.00	10,848.65
Landing (CCSFS) Falcon 9	1	RP1/LOX	18	3	34	0.00	3.14	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	90.41	0.00	0.96	0.00	0.00	0.00	0.00	3,073.78
Static Fire Falcon 9	1	RP1/LOX	7	9	40	0.00	9.42	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	18.26	0.00	1.32	0.00	0.00	0.00	0.00	730.55
Notes:																		Total	0.00	18.68	0.00	0.00	0.00	0.00	47,527.68

Annual launch activities are taken from 2024 CCSFS Falcon Operations DOPAA or scaled from 2020 CCSFS EA when no information in the 2024 DOPAA was availablle

Emission Factors Per Engine

	Emission Factors (pounds per second per engine)						
Propellant	VOC	NOx	CO	SOx	PM10	PM2.5	CO2
RP-1/LOX	0.00	1.05	0.00	0.00	0.00	0.00	639.12

Source: Exhaust Plume Calculations for SpaceX Merlin5 Booster Engine, Sierra Engineering & Software, Inc. (June 14, 2019)

Notes:

Launch emissions include fuel spent up to 3,000 ft AGL.

Landing emissions include all intermittent burns below 3,000 ft AGL.

Static fire assumes all engines with a 7 second burn time.

Landing emissions assumed to be 33% of nominal power (only 3 engines used).

Launch GHG emissions include fuel spent up to 100,000ft MSL (approximately 105 seconds).

Landing GHG emissions include all intermittent burns below 100,000 ft MSL.

Fairing Recovery Operations

Baseline

																		Emissions										
Vessel	Operations Per Year	Total Ship time on Range	Number of Vessels	Engines and Generators		Horsepower	Engine Rating	Emission Factors (g/kWh)										Tons							Metric Tons			
		Hours		No.	Load		kW	VOCs	NOx	CO	SOx	PM10	PM2.5	Pb	CO2	CH4	N2O	VOCs	NOx	CO	SOx	PM10	PM2.5	Pb	CO2	CH4	N2O	CO2e
Support Vessel Main Engine	50	2	2	2	0.5	3,299	2,460	0.50	10.53	1.10	0.43	0.26	0.24	0.00	649.00	0.01	0.03	0.27	2.86	0.30	0.12	0.07	0.03	0.00	319.32	0.00	0.01	323.69
Auxiliary Engines/Thruster	50	2	2	3	0.31	1,220	910	0.60	10.53	1.40	0.46	0.26	0.24	0.00	686.00	0.01	0.03	0.11	0.98	0.13	0.04	0.02	0.01	0.00	116.08	0.00	0.00	117.59
																	Total	0.38	3.84	0.43	0.16	0.09	0.05	0.00	435.40	0.01	0.02	441.29

Proposed Action

Vessel	Operations Per Year	Total Ship time on Range	Number of Vessels	Engines and Generators		Horsepower	Engine Rating	Emission Factors (g/kWh)										Tons							Metric Tons			
		Hours		No.	Load		kW	VOCs	NOx	CO	SOx	PM10	PM2.5	Pb	CO2	CH4	N2O	VOCs	NOx	CO	SOx	PM10	PM2.5	Pb	CO2	CH4	N2O	CO2e
Support Vessel Main Engine	120	2	2	2	0.5	3,299	2,460	0.50	10.53	1.10	0.43	0.26	0.24	0.00	649.00	0.01	0.03	0.65	6.85	0.72	0.28	0.17	0.08	0.00	766.36	0.01	0.03	776.86
Auxiliary Engines/Thruster	120	2	2	3	0.31	1,220	910	0.60	10.53	1.40	0.46	0.26	0.24	0.00	686.00	0.01	0.03	0.27	2.36	0.31	0.10	0.06	0.03	0.00	278.59	0.00	0.01	282.23
Notes:																	Total	0.92	9.21	1.03	0.38	0.22	0.11	0.00	1044.95	0.02	0.05	1059.09

Source: 2020 EA for SpaceX Falcon Launches at Kennedy Space Center and Cape Canaveral Air Force Station

2020 EA assumed two vessels operating three times per month (36 per year) in 2020-2025, and would operate for no more than two hours in Florida's Coastal Zone (one hour outbound, one hour inbound)

Support vessel information from SpaceX (Bob/Doug are the east coast vessels).

$C6*$E6*$F6*$H6*L6*$B6

Lead emission factor from SBCAPCD: https://www.ourair.org/wp-content/uploads/SBCAPCD-Approved-TAC-Emission-Factors.xlsx

Total ship time, engine specifics, and emission factors consistent with the 2023 SEA.

SpaceX Cape Canaveral Recovery Operations

Baseline

Booster Recovery Operations

Vessel	Operations Per Year	Total Ship time on Range	Engines and Generators		Horsepower	Engine Rating	Engine Tier	Emission Factors (g/kWh)										Emissions (<3 nm) Tons							Metric Tons			
		Hours	No.	Load		kW		VOCs	NOx	CO	SOx	PM10	PM2.5	Pb	CO2	CH4	N2O	VOCs	NOx	CO	SOx	PM10	PM2.5	Pb	CO2	CH4	N2O	CO2e
Tugboat	50	8	2	0.5	5,000	3,729	0	0.50	13.16	1.10	0.43	0.26	0.24	0.00	649.00	0.01	0.03	0.82	21.63	1.81	0.70	0.42	0.39	0.00	967.92	0.01	0.04	981.18
	50	8	2	0.31	575	429	3	0.38	5.02	5.00	0.07	0.12	0.12	0.00	686.00	0.01	0.03	0.04	0.59	0.59	0.01	0.01	0.01	0.00	72.95	0.00	0.00	73.90
Support Vessel	50	8	2	0.5	3,299	2,460	2	0.50	10.53	1.10	0.43	0.26	0.24	0.00	649.00	0.01	0.03	0.54	11.42	1.19	0.46	0.28	0.26	0.00	638.63	0.01	0.03	647.38
	50	8	2	0.31	1,220	910	2	0.60	10.53	1.40	0.46	0.26	0.24	0.00	686.00	0.01	0.03	0.15	2.62	0.35	0.11	0.06	0.06	0.00	154.77	0.00	0.01	156.79
Drone Ship	50	1	2	0.6	2,000	1,491	0	0.50	13.16	1.10	0.43	0.26	0.24	0.00	649.00	0.01	0.03	0.05	1.30	0.11	0.04	0.03	0.02	0.00	58.08	0.00	0.00	58.87
	50	1	1	0.6	0	0	3	0.39	5.21	5.00	0.07	0.11	0.11	0.00	686.00	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	50	1	1	0.6	0	0	3	0.39	0.00	0.00	0.00	0.00	0.00	0.00	686.00	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
																	Total	**1.61**	**37.56**	**4.04**	**1.33**	**0.80**	**0.75**	**0.00**	**1,892.35**	**0.03**	**0.08**	**1,918.12**

Proposed Action

Booster Recovery Operations

Vessel	Operations Per Year	Total Ship time on Range	Engines and Generators		Horsepower	Engine Rating	Engine Tier	Emission Factors (g/kWh)										Emissions (<3 nm) Tons							Metric Tons			
		Hours	No.	Load		kW		VOCs	NOx	CO	SOx	PM10	PM2.5	Pb	CO2	CH4	N2O	VOCs	NOx	CO	SOx	PM10	PM2.5	Pb	CO2	CH4	N2O	CO2e
Tugboat	120	8	2	0.5	5,000	3,729	0	0.50	13.16	1.10	0.43	0.26	0.24	0.00	649.00	0.01	0.03	1.97	51.92	4.34	1.68	1.01	0.95	0.00	2323.01	0.04	0.10	2354.83
	120	8	2	0.31	575	429	3	0.38	5.02	5.00	0.07	0.12	0.12	0.00	686.00	0.01	0.03	0.11	1.41	1.41	0.02	0.03	0.03	0.00	175.07	0.00	0.01	177.36
Support Vessel	120	8	2	0.5	3,299	2,460	2	0.50	10.53	1.10	0.43	0.26	0.24	0.00	649.00	0.01	0.03	1.30	27.41	2.86	1.11	0.66	0.62	0.00	1532.72	0.02	0.07	1553.72
	120	8	2	0.31	1,220	910	2	0.60	10.53	1.40	0.46	0.26	0.24	0.00	686.00	0.01	0.03	0.36	6.29	0.84	0.27	0.15	0.14	0.00	371.46	0.01	0.02	376.30
Drone Ship	120	1	2	0.6	2,000	1,491	0	0.50	13.16	1.10	0.43	0.26	0.24	0.00	649.00	0.01	0.03	0.12	3.12	0.26	0.10	0.06	0.06	0.00	139.38	0.00	0.01	141.29
	120	1	1	0.6	469	350	3	0.39	5.21	5.00	0.07	0.11	0.11	0.00	686.00	0.01	0.03	0.01	0.14	0.14	0.00	0.00	0.00	0.00	17.29	0.00	0.00	17.51
	120	1	1	0.6	255	190	3	0.39	5.21	5.00	0.07	0.11	0.11	0.00	686.00	0.01	0.03	0.01	0.08	0.08	0.00	0.00	0.00	0.00	9.38	0.00	0.00	9.51
																	Total	**3.87**	**90.29**	**9.85**	**3.18**	**1.92**	**1.81**	**0.01**	**4,558.93**	**0.07**	**0.20**	**4,621.01**

Notes:

Assumptions scaled from 2020 CCSFS EA, which states that vessels will be operating within Florida's Coastal Zone for 8 hours total (4 hours outbound, 4 hours inbound) and that the tug tows the drone ship into position.

Lead emission factor from SBCAPCD: https://www.ourair.org/wp-content/uploads/SBCAPCD-Approved-TAC-Emission-Factors.xlsx

Conversions

kw/hp 1.341

Marine Propulsion

Engine Type	Engine Family	Model	Tier	Fuel	VOC (g/kW-hr)	NOx	CO	SOx	PM10	PM2.5	CO2	CH4	N2O
Slow Speed Diesel		<=1999	Tier 0	0.1%S	0.600	17.01	1.4	0.39	0.26	0.24	589	0.012	0.029
Medium Speed Diesel		<=1999	Tier 0	0.1%S	0.500	13.16	1.1	0.43	0.26	0.24	649	0.010	0.029
Slow Speed Diesel		2000-2010	Tier 1	0.1%S	0.600	15.98	1.4	0.39	0.26	0.24	589	0.012	0.029
Medium Speed Diesel		2000-2010	Tier 1	0.1%S	0.500	12.22	1.1	0.43	0.26	0.24	649	0.010	0.029
Slow Speed Diesel		2011-2015	Tier 2	0.1%S	0.600	14.38	1.4	0.39	0.26	0.24	589	0.012	0.029
Medium Speed Diesel		2011-2015	Tier 2	0.1%S	0.500	10.53	1.1	0.43	0.26	0.24	649	0.010	0.029
Slow Speed Diesel		2016+	Tier 3	0.1%S	0.600	3.38	1.4	0.39	0.26	0.24	589	0.012	0.029
Medium Speed Diesel		2016+	Tier 3	0.1%S	0.500	2.63	1.1	0.43	0.26	0.24	649	0.010	0.029
EPA Certification	HCEXN19.0AAA		Tier 3	0.1%S	0.392	5.21	5.0	0.07	0.11	0.11	716		

Notes:

Emission factors from Table 2.3 and 2.4 of the 2019 Port of Los Angeles Emission Inventory Methodology Report 5.21 5.00 0.07 0.11 0.11 715.76 0.01 0.03

Load factors for propulsion engines based on Table 3.1 of the of the 2019 Port of Los Angeles Emission Inventory Methodology Report

EPA certification based on Tier 3 rating for the engine family from Table 1 to CFR §1042.101.

Marine Auxiliary

Engine Type		Model	Tier	Fuel	VOC (g/kW-hr)		NOx	CO	SOx	PM10	PM2.5	CO2	CH4	N2O
Aux High Speed Diesel		<=1999	Tier 0	0.1%S	0.600		10.9	1.1	0.455	0.26	0.24	656	0.010	0.029
Aux Med Speed Diesel		<=1999	Tier 0	0.1%S	0.600		13.82	1.4	0.455	0.26	0.24	686	0.012	0.029
Aux High Speed Diesel		2000-2010	Tier 1	0.1%S	0.600		9.78	1.1	0.455	0.26	0.24	656	0.010	0.029
Aux Med Speed Diesel		2000-2010	Tier 1	0.1%S	0.600		12.22	1.4	0.455	0.26	0.24	686	0.012	0.029
Aux High Speed Diesel		2011-2015	Tier 2	0.1%S	0.600		7.71	1.1	0.455	0.26	0.24	656	0.010	0.029
Aux Med Speed Diesel		2011-2015	Tier 2	0.1%S	0.600		10.53	1.4	0.455	0.26	0.24	686	0.012	0.029
Aux High Speed Diesel		2011-2015	Tier 3	0.1%S	0.600		1.97	1.1	0.455	0.26	0.24	656	0.010	0.029
Aux Med Speed Diesel		2011-2015	Tier 3	0.1%S	0.600		2.63	1.4	0.455	0.26	0.24	686	0.012	0.029
Aux Med Speed Diesel	Tier 3 Standard	2011-2015	Tier 3	0.1%S	0.378		5.022	5	0.068	0.12	0.12			

Notes:

Emission factors from Table 2.9 and 2.10 of the 2019 Port of Los Angeles Emission Inventory Methodology Report

Load factors for propulsion engines based on Table 3.1 of the of the 2019 Port of Los Angeles Emission Inventory Methodology Report

EPA certification based on Tier 3 rating for the engine family from Table 5 to CFR §1042.101.

Launch Facility Operation Emissions

	Electric	Water	Sewage	Launches
	kWh	kgal	kgal	
Baseline	18,165,063	25808	17676	56
Project	38,925,135	55,303	37,878	120

Emissions					
Category	Scenario	unit	value	lbs CO2/MWh	MT CO2
Electric	Baseline	kWh	18,165,063	832.9	6,862.65
	Project	kWh	38,925,135	832.9	14,705.69
Water	Baseline	kgal	25808	832.9	30.91
	Project	kgal	55,303	832.9	66.24
Sewage	Baseline	kgal	17676	832.9	10.16
	Project	kgal	37,878	832.9	21.78
			Total	Baseline	6,903.73
				Project	14,793.71

Notes:
Electricity emission factor is from EPA eGRID.
Average water energy intensity factors are from Next10's 2021 Report.
Baseline year is 2023.

lbs to MT	2204.64
water MWh/million gallons	3.1703
wastewater MWh/million gallons	1.522111111

Appendix B

Exhaust Plume Calculations for SpaceX Merlin 5 Booster Engine

ANALYSIS REPORT	NUMBER: 2019-002 DATE: 14 June 2019
SUBJECT: Exhaust Plume Calculations for SpaceX Merlin5 Booster Engine	PAGE 1 OF 11 NO. OF APPEN. 0
PREPARED FOR: Matthew Thompson, SpaceX	(W.O. 6012)
DISTRIBUTION: Katy Smith, SpaceX	

1.0 SUMMARY

Calculations were performed to estimate the far-field exhaust constituents of the SpaceX Merlin 5 LOX-kerosene booster rocket engine firing under sea-level conditions. Although the exit-plane exhaust is fuel-rich and contains high concentrations of carbon monoxide (CO), subsequent entrainment of ambient air results in complete conversion of the CO into carbon dioxide (CO_2) and oxidation of the soot from the gas generator exhaust. A small amount of thermal nitrous oxides (NOx) is formed, all as NO. The NO emission is predicted to be 1.047 lb_m/s under nominal power (100%) operation.

2.0 ENGINE DESCRIPTION

The subject engine is the baseline booster engine for the SpaceX Falcon 9 launch vehicle family. This analysis address the latest version of the engine, the Merlin 5. The propellants are liquid oxygen (LOX) and the RP-1 grade of kerosene. The subject engine consists of a 16.27:1 regeneratively-cooled thrust chamber nozzle exhaust plus a fuel-rich gas exhaust from the turbopump drive system. As a simplification needed to address the problem with the existing axisymmetric analysis tools, the computational nozzle exit plane includes an outer annulus of low mixture ratio turbine exhaust gas generator surrounding the physical thrust chamber exhaust plume. Characteristic dimensions of the thrust chamber nozzle are included in Table 1.

The nominal operating condition for the Merlin 5 engine is an injector face stagnation pressure (Pc) of 1859 psia and an engine O/F mixture ratio (MR) of 2.356. The associated thrust chamber MR is 2.576 and the gas generator (GG) MR is 0.423. The GG mass fraction is about 4.28% of the total engine flow. The current analysis was performed for the 100% nominal engine operating pressure (Pc=1859 psia) and an engine MR of 2.58.

Table 1: Merlin 5 Nozzle Characteristics

Throat Radius (in)	4.429
Downstream radius of curvature (in)	1.250
Tangency angle (deg)	35.33
Nozzle lip exit angle (deg)	8.973
Nozzle exit diameter (in) [excluding GG exhaust duct]	35.733
Nozzle throat to exit length (in)	39.617

3.0 ANALYSIS APPROACH

A series of simulations were required to estimate the emissions from the Merlin 5 engine. The PERCORP analysis model[1] was used to estimate the O/F mixture ratio variations that exist within the Merlin 5 thrust chamber. The fuel-rich combustion model in PERCORP was also used to estimate the gas generate exhaust constituents. The VIPER parabolized Navier-Stokes model[2] was used to kinetically expand the thrust chamber exhaust to the nozzle exit plane. The VIPER results were used to assess the validity of the PERCORP solution, correlating engine thrust, mass flow rate and specific impulse (ISP) to test results. PERCORP input parameters were adjusted until there was good agreement between the VIPER performance predictions and the test results. The SPF code[3] was used to predict the flow structure of the free exhaust plume and the entrainment of ambient air. VIPER solution was used as the starting condition for the SPF. Though the SPF code can handle detailed chemical kinetics within the plume evolving flow field, the strong barrel shock downstream of the nozzle exit produces numerical convergence problems with the version of SPF used. The present SPF simulations were performed without chemical kinetics. The results were air entrainment and gas temperature profiles. The SPF and VIPER results were used as inputs for one-dimensional kinetic modelling of the plume flow field. The kinetic model in the TDK code[4] was used to model chemical reactions within the evolving plume flow field.

TDK modelling of the plume flow field included chemical mechanism that address a) the oxidation of CO to CO_2, b) the complex oxidation of hydrocarbons to H_2O and CO_2, c) the oxidation of soot to CO_2, and d) the thermal generation of NOx in a mixture of air and combustion products. Table 2 includes the chemical reactions and rates used in the TDK simulation.

Table 2: Kinetic Reactions Included in One Dimensional Chemistry Simulations*

	A	N	B
H + H + m = H2 + m†	6.4E17	1.0	0.0
H + OH + m = H2O + m	8.4E21	2.0	0.0
O + O + m = O2 + m	1.9E13	0.0	-1.79
CO + O + m = CO2 + m	1.0E14	0.0	0.0
O + H + m = OH + m	3.62E18	1.0	0.0
CH4 + m = CH3 + H + m	1.259E17	0	88.4
HCO + m = CO + H + m	5.012E14	0	19.0
C2H3 + m = C2H2 + H + m	7.943E14	0	31.5
N+NO = N2+O	2.700E13	0	0.355
N+O2 = NO+O	9.000E9	-1.0	6.5
N+OH = NO+H	3.360E13	0	0.385
HO2+NO = NO2+OH	2.110E12	0	-0.480
NO2+O = NO+O2	3.900E12	0	-0.240
NO2+H = NO+OH	1.320E14	0	0.360
O2 + H = O + OH	2.2E14	0.0	16.8
H2 + O = H + OH	1.8E10	-1.	8.9
H2 + OH = H2O + H	2.2E13	0.0	5.15
OH + OH = H2O + O	6.3E12	0.0	1.09
CO + OH = CO2 + H	1.5E7	-1.3	-.765
CO + O = CO2	2.5E6	0.0	3.18
CO2 + O = CO + O2	1.7E13	0.0	52.7
CH4+ OH = CH3 + H2O	3.162E13	0	6.0
H + CH4 = CH3 + H2	6.310E14	0	15.1
O + CH4 = CH3 + OH	3.981E14	0	14.0
CH3 + O = CH2O + H	1.259E14	0	2.0
CH3 + OH = CH2O + H2	3.981E12	0	0
C2H2 + OH = C2H + H2O	6.310E12	0	7.0
H + CH2O = HCO + H2	3.162E14	0	10.5
O + CH2O = HCO + OH	1.995E13	0	3.1

* TDK reaction format is k=AT**(-N)*EXP(-1000B/RT) [cc-Kcal-K-mole-s]

† m is any molecule for a third body reaction

Table 2: Kinetic Reactions Included in One Dimensional Chemistry Simulations (ctd)

	A	N	B
OH + CH2O = HCO + H2O	7.943E12	0	0.2
H + HCO = CO + H2	1.995E14	0	0
OH + HCO = CO + H2O	1.000E14	0	0
H + C2H2 = C2H + H2	1.995E14	0	19.0
O + C2H2 = CH2 + CO	5.012E13	0	3.7
C2H + O2 = HCO + CO	1.000E13	0	7.0
CH2 + O2 = HCO + OH	1.000E14	0	3.7
H + C2H4 = C2H3 + H2	1.000E14	0	8.5
C2H2 + H = C2H3	5.500E12	0	2.39
H + C3H6 = C2H4 + CH3	3.981E12	0	0
C(GR)‡ + OH = CO + H	6.02E8	-0.5	0

4.0 ANALYSIS RESULTS

The PERCORP modelling of the Merlin 5 thrust chamber included 11.1% fuel film cooling injected at two locations down the chamber wall. The SpaceX supplied chamber wall temperature profile agreed well with the PERCORP results. The PERCORP solution for the nominal 319.36 lbf-s/lb_m thrust chamber specific impulse includes a 2.0% core mixing loss, yielding a characteristic velocity (C*) efficiency of 96.4%. The C* efficiency agrees well with SpaceX test data. The fuel-rich combustion model was used to predict the GG exhaust species mass fractions (Table 3). The PERCORP results included initial boundary conditions for the VIPER nozzle flow field simulation. The predicted thrust chamber nozzle exit species mass fractions from VIPER are listed in Table 4.

The GG exhaust species from PERCORP and the nozzle exhaust species, temperature and velocity fields from VIPER were used as initial conditions for the SPF exhaust plume flow field modelling. Three heavy hydrocarbon species ($C_{12}H_{23}$, C_7H_{14} and C_3H_6) predicted to exist in the GG exhaust were thermally cracked into smaller constituents (C_2H_2, C_2H_4, CH_4, H_2) using relationships suggested by Reference 5.

The SPF modelling stepped to 100 nozzle exit radii (Rexit = 18.3214 inches, 1.527 ft). Predicted plume contours for temperature and mass fractions of N_2, CO and soot are presented in Figure 1 through Figure 4. Since there plume entrainment and mixing field is simulated for chemically frozen flow, the N_2 contours are representative of the air entrainment, while the CO and soot contours indicate key products of incomplete combustion.

‡ C(GR) is the carbon representative of soot

Table 3: Gas Generator Exhaust Species Mass Fraction from PERCORP

Species	Mass Fraction
CO	0.3035
CO2	0.0625
H2	0.0030
H2O	0.0918
CH4	0.0476
C2H2	0.0114
C2H4	0.2098
C(GR)	0.0030
C2H6	0.0471
C3H6	0.0662
C7H14	0.0397
C12H23	0.1144

Table 4: Thrust Chamber Nozzle Exit Species Mass Fraction from VIPER Simulation

Species	Mass Fraction
CO2	0.4230
H2O	0.2538
CO	0.2536
O2	0.0367
H2	0.0086
C(GR)	0.0066
OH	0.0064
C2H2	0.0062
CH4	0.0027
O	0.0013
C2H4	7.79E-04
H	1.31E-04
HCO	1.49E-05

Figure 1: Plume Temperature Contours (degrees K)
R is radius normalized by Rexit, X is axial distance from nozzle exit normailzied by Rexit

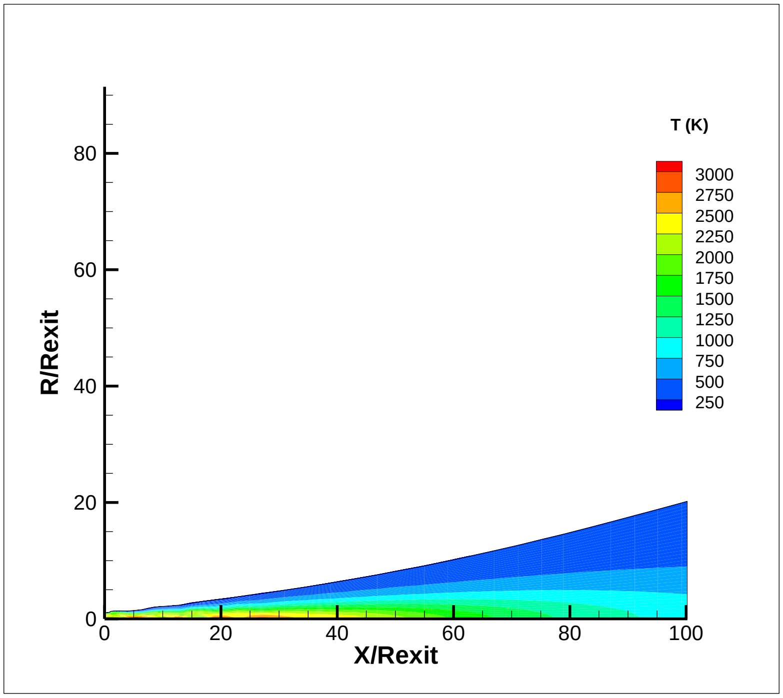


Figure 2: Plume N_2 Mass Fraction Contours (degrees K)
R is radius normalized by Rexit, X is axial distance from nozzle exit normailzied by Rexit

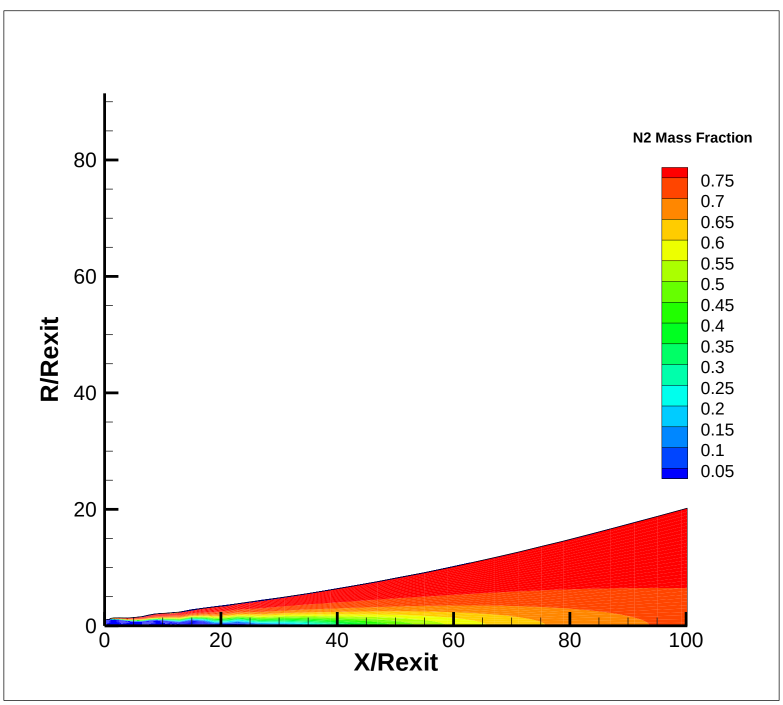


Figure 3: Plume CO Mass Fraction
R is radius normalized by Rexit, X is axial distance from nozzle exit normailzied by Rexit

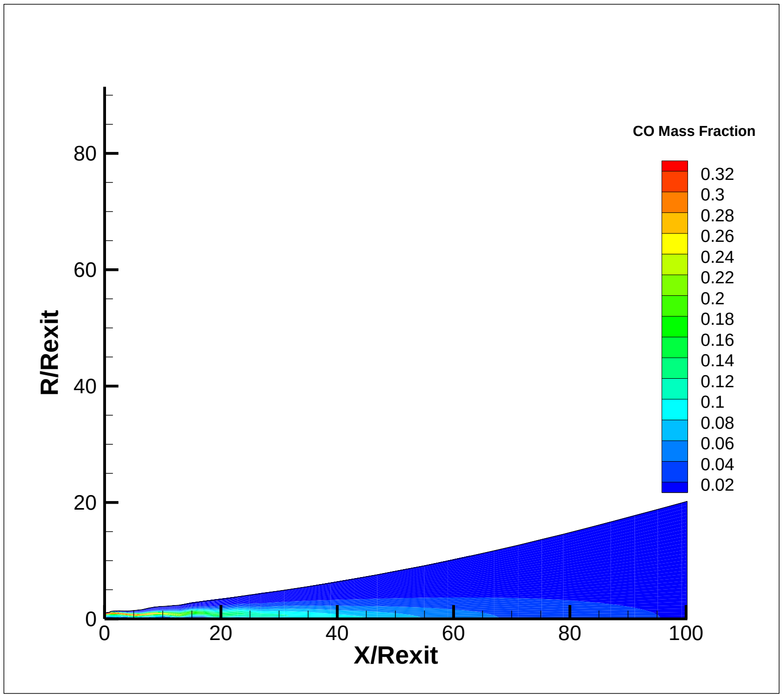
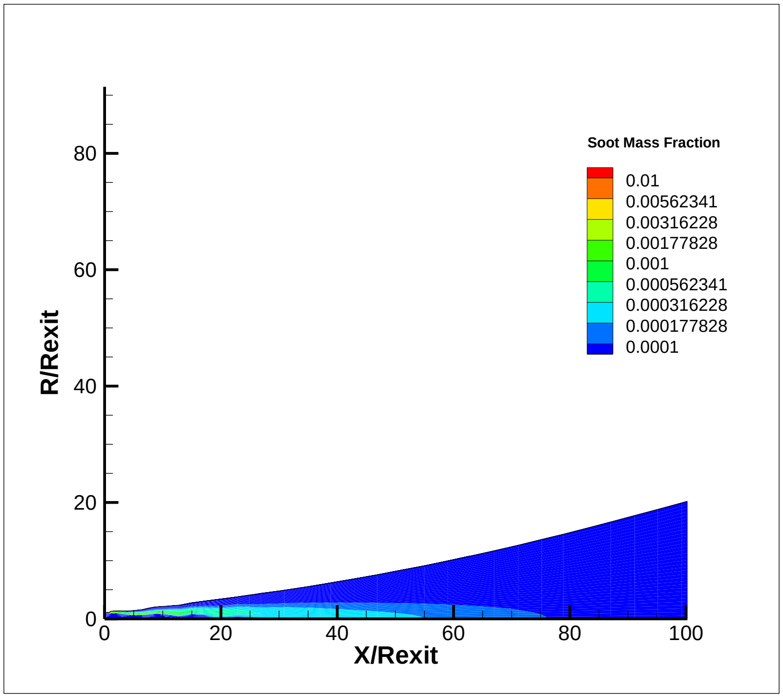


Figure 4: Plume Soot Mass Fraction Contours
R is radius normalized by Rexit, X is axial distance from nozzle exit normailzied by Rexit



The reactive plume was defined to include all flow that had a CO concentration greater than 1,000 ppm. Integration of the SPF data indicates that 18,390 lb/s air is entrained by the end of the simulation (Figure 5). It is estimated that the 153 meter entrainment end point is reached 294 msec after the plume flow exits the nozzle.

Figure 5: Axial Air Entrainment Estimates from SPF.

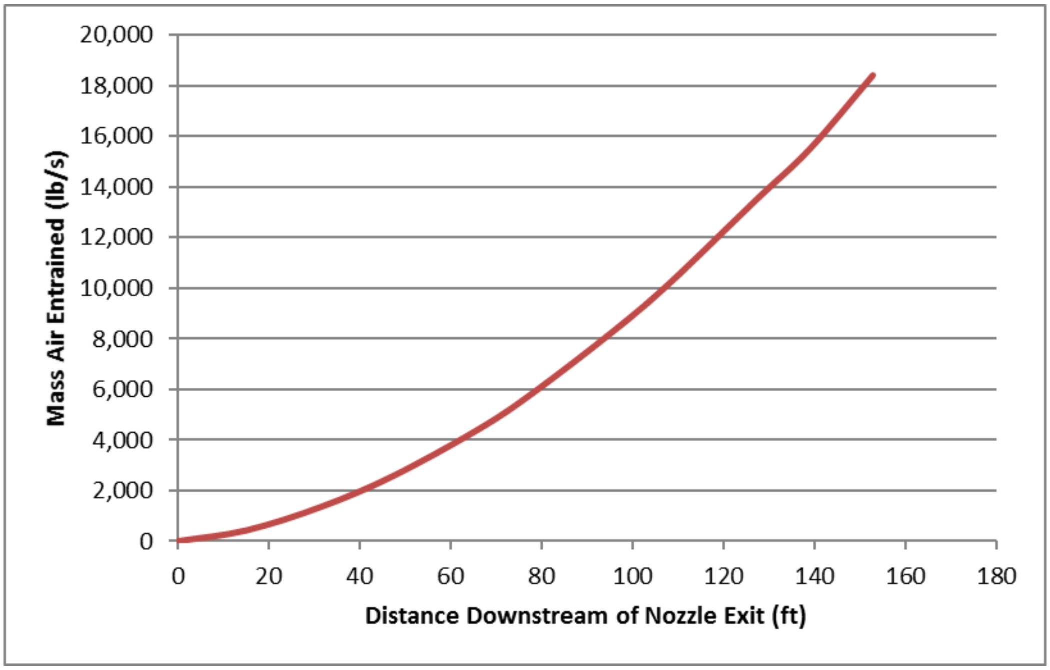
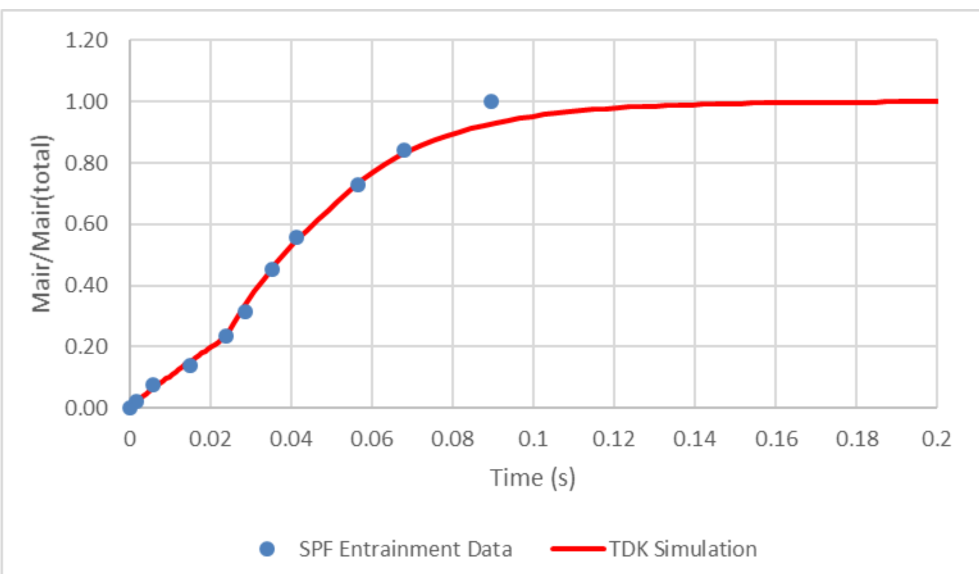


Figure 6: Approximate Air Entrainment Profile used in TDK Simulations



The subsequent TDK simulation of the plume chemistry required an approximate fit of the air entrainment rate. The SPF air entrainment profile was fit to an "availability profile" for the TDK simulations, whereby ambient air is mixed into the plume flow. Figure 6 shows that the approximate TDK air addition agrees well with the entrainment rate predicted by SPF.

The one-dimensional kinetics modeling of the after-burning characteristics of the exhaust plume was performed assuming a piecemeal constant pressure (13.6-14.7 psia) and entrainment of ambient temperature air. The model predicted that all the soot quickly (<5 msec) burns out (i.e. converts to CO). Complete CO oxidation occurs within 35 msec, with concentrations reduced to 2 ppm. The small concentration of unburnt hydrocarbons (CH_4, C_2H_2, C_2H_4, CH_3) are rapidly oxidized, surviving less than 1 msec. The limited thermal NO formation occurs during the early part of the entrainment process, with NO mass fraction constant after about 10 msec. The NO mass fraction at the end of the 157 ft long plume entrainment is 0.000055. Given the total mixed plume mass flow rate of 19041 lb/s, this corresponds to a NO mass flow of 1.047 lb/s. Figure 7 and Figure 8 show the predicted temperature and pollutant species mass fraction profiles. The pollutant flow rates were calculated in terms of lb_m generated per second of steady engine operation.

Figure 7: Predicted Profile of Bulk Plume Temperature and Species Concentration

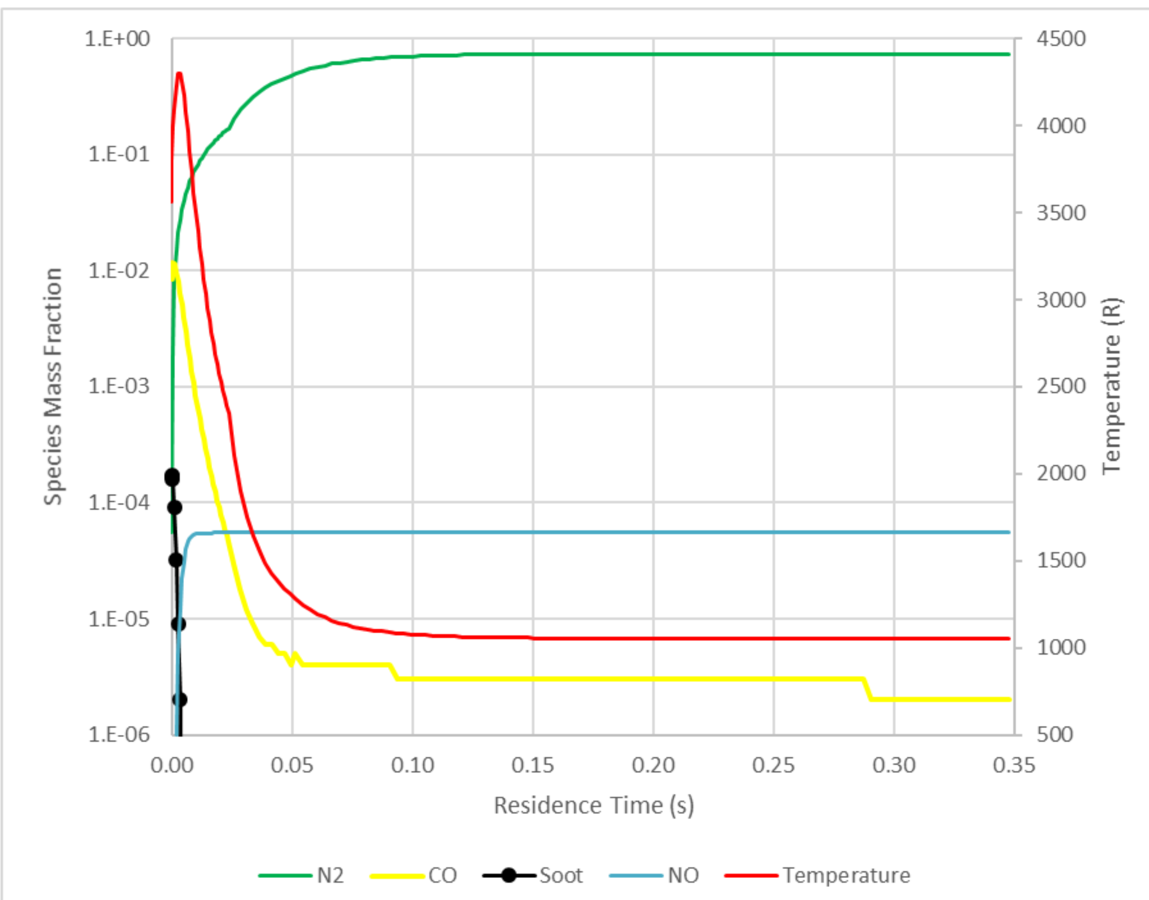
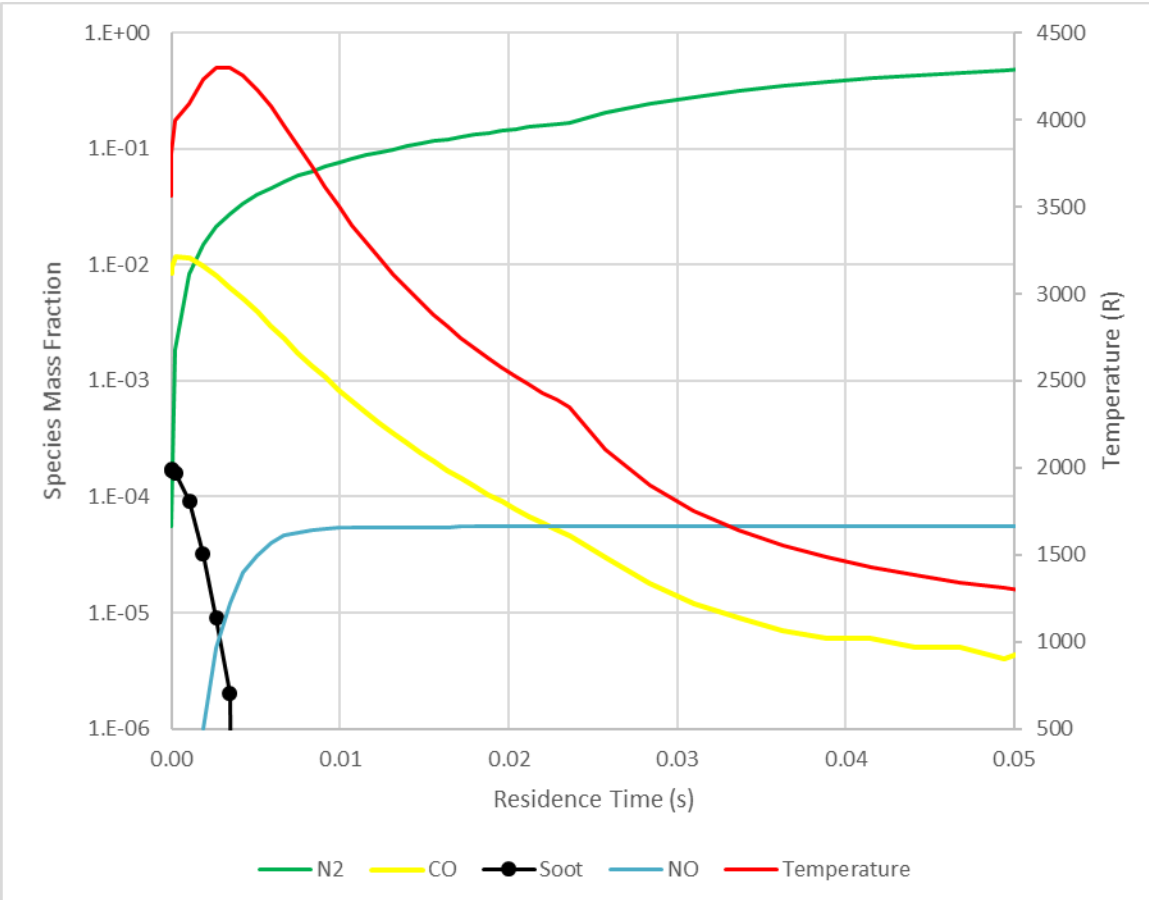


Figure 8: Predicted Profile of Bulk Plume Temperature and Species Concentration for Initial Residence Times



5.0 REFERENCES

[1] *Performance Correlation Program (PERCORP 2006) Reference and User's Manual, Version 2.0*, Sierra Engineering Inc., Carson City, NV, June 2009

[2] *Viscous Interaction Performance Evaluation Routine For Two-Phase Nozzle Flows With Finite Rate Chemistry, VIPER 4.5*, Software and Engineering Associates, Carson City, NV, 2018

[3] Taylor, M.W. and Pergament, H.S.; *Standardized Plume Flowfield Model SPF-III, Version 4.2 Program User's Manual*, PST TR-51, Propulsion Science and Technology, Inc. East Windsor, NJ, June 2000

[4] Nickerson, G. R., Dunn, S.S., Coats, D.E. and Berker, D.R.; *Two-Dimensional Kinetics (TDK) Nozzle Performance Computer Program User's Manual*, Software and Engineering Associates, Carson City, NV, Jan 1999

[5] Nickerson, G.R. and Johnson, C.W.; "A Sooting Model for Fuel Rich LOX/Hydrocarbon Combustion", 28th JANNAF Combustion Meetings, San Antonio, TX, 28 Oct-1 Nov, 1991