Federal Aviation Administration

Tiered Environmental Assessment for SpaceX Starship Indian Ocean Landings

March 2024

Environmental Assessment for SpaceX Starship Indian Ocean Landings

AGENCIES: Federal Aviation Administration (FAA), lead federal agency; the National Aeronautics and Space Administration, and U.S. Coast Guard cooperating agencies.

This Environmental Assessment (EA) is submitted for review pursuant to section 102(2)(C) of the National Environmental Policy Act of 1969 (NEPA), as amended (42 United States Code 4321, et seq.), Council on Environmental Quality NEPA-implementing regulations (40 Code of Federal Regulations Parts 1500 to 1508), and FAA Order 1050.1F, *Environmental Impacts: Policies and Procedures*.

DEPARTMENT OF TRANSPORTATION, FEDERAL AVIATION ADMINISTRATION: The FAA is evaluating SpaceX's proposal to land the Starship vehicle in the Indian Ocean. SpaceX must obtain a license modification from the FAA to land the Starship vehicle in the Indian Ocean. Modification of a license is considered a major federal action subject to environmental review under NEPA. The FAA's federal action is to modify SpaceX's vehicle operator license that would allow SpaceX to land its Starship vehicle in the Indian Ocean, along with potential renewals and modifications to licenses within the scope of operations analyzed in the Final Tiered EA. SpaceX's proposed action is to conduct up to a total of ten nominal operations, including up to a maximum of five overpressure events from Starship intact impact and up to a total of five reentry debris or soft water landings in the Indian Ocean, within a year of issuance of a concurrence letter from National Marine Fisheries Service (NMFS) (Proposed Action). A Starship intact impact is the impact of a fully intact Starship with the Indian Ocean surface causing an overpressure event from the ignition of remaining fuel causing the deflagration of the vehicle. A soft water landing occurs when the vehicle descends to just above the surface of the water and then tips over.

This EA tiers from the 2022 Final Programmatic Environmental Assessment (PEA) for the SpaceX Starship/Super Heavy Launch Vehicle Program at the SpaceX Boca Chica Launch Site in Cameron County, Texas, which analyzed the construction and operations (including launches and landings) of the Starship/Super Heavy launch vehicle program in Boca Chica, Texas. This EA considers the potential environmental impacts from the Proposed Action and No Action Alternative on biological resources. All other resource categories analyzed within the 2022 PEA remain substantially valid, and the Proposed Action would not result in significant impacts.

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This EA becomes a federal document when evaluated, signed, and dated by the Responsible FAA Official.

Responsible FAA Official:

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Acronyms & Abbreviations

BO	Biological Opinion
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
DOT	U.S. Department of Transportation
EA	Environmental Assessment
EEZ	U.S. Exclusive Economic Zone
EFH	Essential Fish Habitat
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FAA	Federal Aviation Administration
FONSI	Finding of No Significant Impact
Kg	Kilograms
LOC	Letter of Concurrence
LOX	Liquid Oxygen
MDP	Marine Debris Program
MMPA	Marine Mammal Protection Act
MT	Metric tons
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act of 1969, as amended
Nm	Nautical miles
NMFS	National Oceanic and Atmospheric Administration National Marine Fisheries Service
RES	Relative Environmental Suitability
ROD	Record of Decision
U.S.C.	United States Code
USFWS	U.S. Fish and Wildlife Service
VLA	Vertical Launch Area

Chapter 1
Introduction

The Federal Aviation Administration (FAA) is evaluating SpaceX's proposal to land its Starship vehicle in the Indian Ocean. SpaceX's Vehicle Operator License No. VOL 23-129 and modifications allows SpaceX to land the Starship vehicle at the Vertical Launch Area (VLA), on a floating platform in the Gulf of Mexico or the Pacific Ocean or expend the vehicle in the Gulf of Mexico or Pacific Ocean. SpaceX must obtain a license modification from the FAA to land its Starship vehicle in the Indian Ocean. Modifying a license is considered a major federal action under the National Environmental Policy Act of 1969, as amended (NEPA; 42 United States Code [U.S.C.] 4321, et seq.), and the Council on Environmental Quality (CEQ) NEPA-implementing regulations (40 Code of Federal Regulations [CFR] parts 1500–1508) and requires an environmental review.

The FAA is the lead federal agency for this Environmental Assessment (EA). This EA evaluates the potential environmental impacts of activities associated with the federal action of modifying SpaceX's license for landings in the Indian Ocean (see Section 2.2 for a more detailed description). The completion of the environmental review process does not guarantee that the FAA will issue a license modification to SpaceX for Starship landing in the Indian Ocean. SpaceX's license application must also meet FAA safety, risk, and financial responsibility requirements per 14 CFR Chapter III.

1.1 Background

The FAA prepared the 2022 Final Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program at the SpaceX Boca Chica Launch Site in Cameron County, Texas (2022 PEA; FAA 2022) to analyze the potential environmental impacts of constructing launch-related infrastructure and operating the Starship/Super Heavy launch vehicle at the Boca Chica Launch Site. The FAA issued a Mitigated Finding of No Significant Impact (FONSI)/Record of Decision (ROD) based on the 2022 PEA on June 13, 2022. Following issuance of the 2022 PEA and FONSI/ROD, SpaceX applied to the FAA for a license for the first orbital launch of the Starship/Super Heavy launch vehicle. SpaceX provided the FAA with additional details regarding Starship and Super Heavy planned descents during the first launch, including potential ocean landing locations. The FAA evaluated new information raised in connection with the first proposed launch and determined that the preparation of a supplemental or new NEPA document was not necessary to support the Proposed Action. The FAA issued a Written Re-evaluation (WR) documenting its conclusion in April 2023 (FAA 2023a). Following the April 20, 2023, launch, SpaceX: (1) reinforced its launch pad foundation with thicker concrete and additional piles; and (2) installed steel plates over the foundation. The November 2023 WR of the 2022 PEA evaluated the deluge system operation, addition of a forward heat shield interstage, and expansion of the Area of Potential Effects for cultural resources. The reinforced launch pad foundation and steel plate improvements were designed to protect against the potential of a pad breakup or a large dust cloud. The steel plates included a water-cooling element (i.e., deluge system) that would be activated to protect the steel plates during an engine ignition event and allow reusability of the steel plates. SpaceX also added a forward heat shield interstage to the

Starship/Super Heavy vehicle to provide thermal protection against heat produced by Starship engines during the stage separation event. The FAA evaluated the information associated with these improvements and determined that the preparation of a supplemental or new NEPA document was not necessary to support the Proposed Action. The FAA issued a WR documenting its conclusion in November 2023 (FAA 2023b).

This EA analyzes the impacts of the activities associated with SpaceX's Starship vehicle reentry operations landing in the Indian Ocean. This EA tiers from the 2022 Final PEA, which analyzed the construction and operations (including launches and landings) of the Starship/Super Heavy launch vehicle program at Boca Chica, Texas. Since publication of the 2022 PEA, SpaceX provided the FAA with additional information regarding Starship downrange ocean landings. The 2022 PEA analyzed the environmental impacts associated with the Starship/Super Heavy program including launches at the VLA in Boca Chica, TX and landings of the Super Heavy at the VLA or downrange in the Gulf of Mexico as well as landings of the Starship at the VLA or on a floating platform in the Gulf of Mexico or the Pacific Ocean, or expended in the Gulf of Mexico or Pacific Ocean. This EA provides a "tiered" environmental review which incorporates the impacts and analysis regarding the vehicle and its operation, while focusing on the operations and associated impacts for the Starship vehicle landing in a location not previously analyzed in the 2022 PEA (Indian Ocean).

1.2 Federal Agency Roles

1.2.1 Federal Aviation Administration

As the lead federal agency, the FAA is responsible for analyzing the potential environmental impacts of the Proposed Action. The Commercial Space Launch Act of 1984, as amended and codified at 51 U.S.C. 50901–50923, authorizes the Secretary of Transportation to oversee, license, and regulate commercial launch and reentry activities, and the operation of launch and reentry sites within the United States or as carried out by U.S. citizens. Section 50905 directs the Secretary to exercise this responsibility consistent with public health and safety, safety of property, and the national security and foreign policy interests of the United States. In addition, Section 50903 requires the Secretary to encourage, facilitate, and promote commercial space launches and reentries by the private sector. As codified at 49 CFR § 1.83(b), the Secretary has delegated authority to carry out these functions to the FAA Administrator.

The regulatory requirements pertaining to commercial launches and individual launch operators are described in 14 CFR Chapter III, Parts 400–460. SpaceX is the exclusive user of the Boca Chica Launch Site. Therefore, SpaceX is not required to apply for and obtain a launch site operator license for that site.

The FAA is also responsible for creating airspace closure areas in accordance with FAA Order 7400.2M, *Procedures for Handling Airspace Matters*, to ensure public safety.

1.3 Purpose and Need

CEQ's NEPA-implementing regulations state that the purpose and need statement shall briefly specify the underlying purpose and need to which the agency is responding in proposing the alternatives including the Proposed Action (40 CFR §1502.13). The FAA's authority with respect to SpaceX's license application is stated above in Section 1.2.1.

The purpose of SpaceX's proposal is to enhance operational capabilities of Starship/Super Heavy launches by extending the operational area to include the Indian Ocean. The need for expanding into the Indian Ocean stems from the increasing complexity and requirements of the Starship mission objectives. The current operational constraints limit optimization of launch trajectories and decrease the probability of success for early mission objectives. Landing operations in the Indian Ocean would give SpaceX the flexibility to design and execute launch trajectories that meet additional mission objectives.

1.4 Documents Incorporated by Reference

As 40 CFR §1501.12 indicates, agencies shall incorporate relevant material into environmental documents by reference when the effect is to cut down on bulk without impeding agency and public review of the action. The following documents are incorporated by reference:

- FAA. 2014a. Final Environmental Impact Statement SpaceX Texas Launch Site. Volume I, May 2014.
- FAA. 2014b. Final Environmental Impact Statement SpaceX Texas Launch Site. Volume II-Appendices, May 2014.
- FAA. 2022. Final Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program at the SpaceX Boca Chica Launch Site in Cameron County, Texas. June.
- FAA. 2023a. Written Re-evaluation of the 2022 Final Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program at the Boca Chica Launch Site in Cameron County Texas. Starship/Super Heavy Vehicle Ocean Landings and Launch Pad Detonation Suppression System. April.

- FAA. 2023b. Written Re-evaluation of the 2022 Final Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program at the Boca Chica Launch Site in Cameron County Texas. Starship/Super Heavy Deluge System Operation, Addition of a Forward Heat Shield Interstage, and Expansion of the Area of Potential Effects for Cultural Resources. November.
- NMFS (National Marine Fisheries Service). 2022. Programmatic Concurrence Letter for Launch and Reentry Vehicle Operations in the Marine Environment and Starship/Super Heavy Launch Vehicle Operations at SpaceX's Boca Chica Launch Site, Cameron County, TX. January.
- NMFS. 2023a. Concurrence Letter for the Endangered Species Act Section 7 Consultation for FAA's Proposed Licensing of SpaceX Starship/Super Heavy Early Developmental Phase Launch and Reentry Operations for First Three Flights in the Gulf of Mexico and North Pacific Ocean. April.

1.5 Other Licenses, Permits and Approvals

To proceed with all of its proposed operations and associated construction identified in Chapter 2 below, SpaceX would require environmental and regulatory approvals in addition to the FAA's license. The FAA has identified the following additional environmental approvals for SpaceX proposal, but others may be required.

- **Endangered Species Act (ESA).** In accordance with ESA Section 7, the FAA conducted consultation with the United States Fish & Wildlife Service (USFWS) and NMFS. NMFS concurred with the FAA's determination that the Proposed Action may affect, but would not likely adversely affect, ESA-listed species and critical habitat under NMFS jurisdiction. The FAA determined the Proposed Action may affect and is likely to adversely affect ESA-listed species and critical habitat under USFWS jurisdiction and conducted formal consultation with the USFWS. The USFWS issued a Biological Opinion (BO), which concluded the Proposed Action is not likely to jeopardize the continued existence of any federally listed species or adversely modify designated critical habitat. The BO contains Reasonable and Prudent Measures and associated Terms and Conditions to avoid, minimize, and mitigate the effects on listed species and critical habitat. SpaceX must implement the Terms and Conditions. Refer to PEA Appendix D for a copy of the BO.
- **Magnuson-Stevens Fishery Conservation and Management Act.** The FAA determined there may be temporary adverse effects to Essential Fish Habitat (EFH), particularly in the event of launch failure involving the spread of debris and release of hazardous material (e.g., liquid propellant). The FAA consulted NMFS regarding potential adverse effects to EFH, and NMFS provided two Conservation Recommendations pursuant to 50 CFR § 600.920, which SpaceX and the FAA have agreed to implement. Refer to Section 3.10 of the PEA.
- **Marine Mammal Protection Act (MMPA).** The FAA evaluated the number of marine species protected under the MMPA and found that the number expected to be harassed by the Proposed Action is less than one. Therefore, the Proposed Action would not subject marine mammals to a

"take" as defined by the MMPA, and authorization is not required (16 U.S.C. 1361 et seq.). Refer to Section 3.10 of the PEA.

Chapter 2
Description of Proposed Action and Alternatives

NEPA requires that the FAA consider the purpose and need for the Proposed Action[1] and from that, "study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources."[2] As discussed in Chapter 3, the FAA has not identified any unresolved conflicts concerning alternative uses of available resources associated with SpaceX's proposal. Therefore, in accordance with NEPA, CEQ's NEPA-implementing regulations, and FAA Order 1050.1F, Paragraph 6-2.1(d), this EA considers the no action alternative and SpaceX's Proposed Action.

2.1 No Action Alternative

Under the No Action Alternative, the FAA would not modify a license to SpaceX for landing the Starship vehicles in the Indian Ocean. In this situation, as permitted under existing licenses, SpaceX could land the Starship vehicle at the VLA or downrange in the Gulf of Mexico, or Pacific Ocean (on a floating platform or expended in the Pacific Ocean). This alternative provides the basis for comparing the environmental consequences of the Proposed Action.

2.2 Proposed Action

The FAA's federal action is to modify SpaceX's vehicle operator license, along with potential renewals and modifications to the license within the scope of operations in this EA, that would allow SpaceX to land its Starship vehicle in the Indian Ocean. The Proposed Action includes expanding the Starship second stage landing area into the Indian Ocean to accommodate new trajectories proposed by SpaceX. In addition, the FAA must also approve related airspace closures for Starship reentry operations.

SpaceX's Proposed Action is to conduct up to a total of ten nominal operations, including up to a maximum of five overpressure events from Starship intact impact and up to a total of five reentry debris or soft water landings in the Indian Ocean, within a year of issuance of a NMFS concurrence letter. The following subsections provide a description of the project's location and proposed reentry operations.

2.2.1 Location

As stated in the 2022 PEA, the Boca Chica Launch Site is located on SpaceX-owned land in Cameron County, Texas, near the cities of Brownsville and South Padre Island. The larger area around the Boca Chica Launch Site includes several private and public industries, including the SpaceX production and

[1] 40 CFR § 1501.5(c)(2).

[2] 42 U.S.C. § 4332(2)(E).

manufacturing facility, the Port of Brownsville, the City of Port Isabel, San Roman Wind Farm, and development on South Padre Island. Boca Chica Village now includes support infrastructure, such as housing, restaurants, and offices used in connection with SpaceX's production and manufacturing facility near Boca Chica Village. The Boca Chica Launch Site location details provided in the 2022 PEA remain substantially the same for this Proposed Action.

Starship Indian Ocean Landing Location

Based on Starship's hardware configuration, SpaceX plans to conduct a passive descent that would result in Starship's impact with the Indian Ocean's surface up to a total of ten nominal operations, including up to a maximum of five overpressure events from Starship intact impact and up to a total of five reentry debris or soft water landings in the Indian Ocean, within a year of issuance of a NMFS concurrence letter. In general, the action area includes a portion of the Indian Ocean where Starship landing activities are proposed to occur, hereafter referred to as the Indian Ocean Landing Area. This area is generally between S 15 and S 30 degrees latitude in the southern Indian Ocean, in waters greater than 200 nautical miles (nm) (370 kilometers [km]) from land. The western portion of the Indian Ocean Landing Area is east of Madagascar and south of Mauritius and Réunion. The second stage landing area continues east and is south of Cocos (Keeling) Islands and Christmas Island off the coast of Indonesia. The proposed Starship Indian Ocean landing area is shown in Figure 1 below.

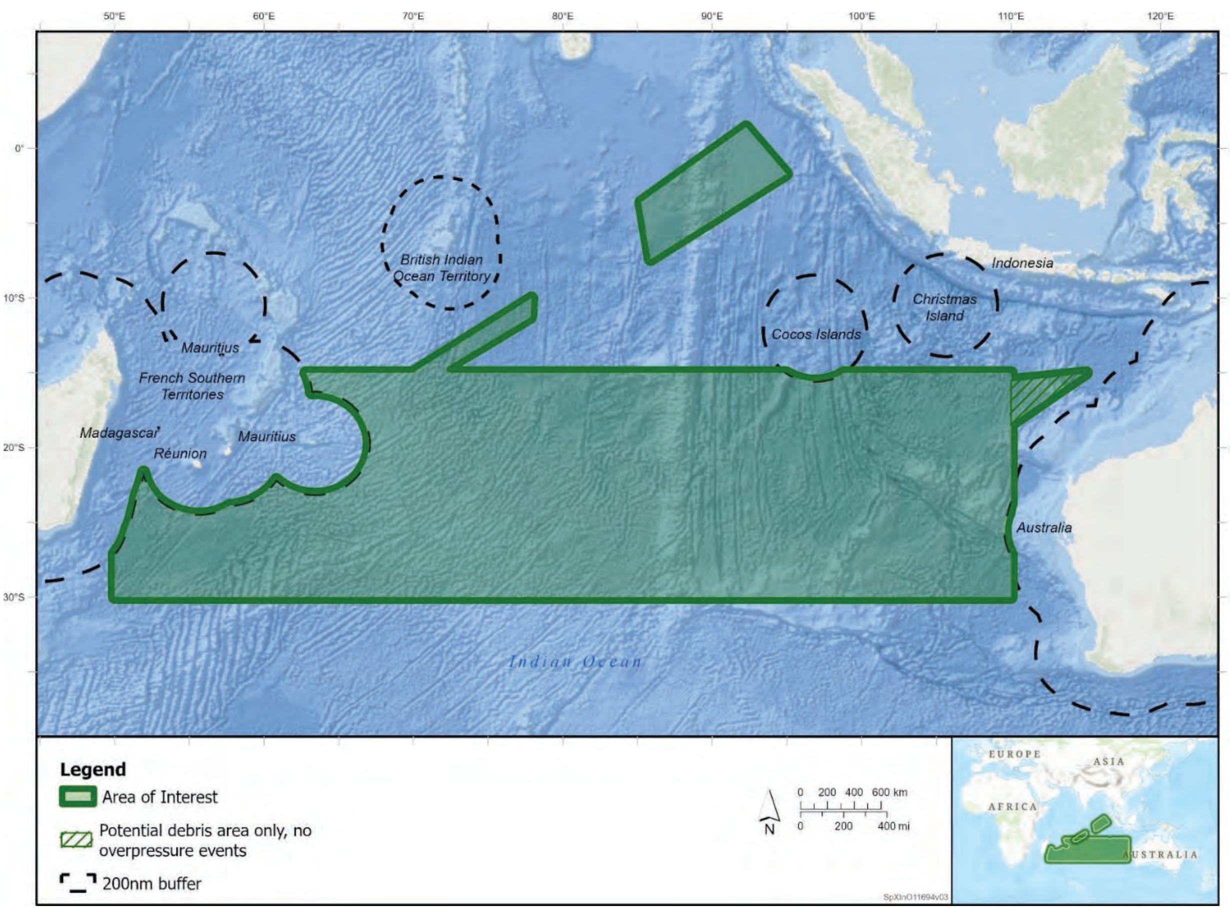

Figure 1. Proposed Starship Indian Ocean Landing Area

2.2.2 Launch/Reentry Vehicle

The reentry vehicle described in this Proposed Action is the same vehicle that was analyzed in the 2022 PEA, therefore, the vehicle's description remains substantially the same. As described in the 2022 PEA, the fully integrated launch vehicle is comprised of two stages: Super Heavy is the first stage (or booster), and Starship is the second stage. The fully integrated Starship/Super Heavy launch vehicle is expected to be approximately 400 feet tall and 30 feet in diameter. As designed, both stages are reusable, with any potential refurbishment actions taking place at SpaceX facilities. Both stages are expected to have minimal post-flight refurbishment requirements; however, they might require periodic maintenance and upgrades. Unlike the SpaceX Falcon launch vehicle, Starship/Super Heavy would not have separable fairings or parachutes. The 2022 PEA states that the Super Heavy is expected to hold up to 3,700 metric tons (MT) of propellant and Starship will hold up to 1,500 MT of propellant, which remains valid for the reentry vehicle in this Proposed Action. During coasting and reentry phases of the mission, Starship may complete demonstration objectives, including venting propellant and engine relight demonstrations.

2.2.3 Reentry Operations

The following paragraphs provide additional detail that more clearly defines the launch profile for Starship's planned landings for future launches. The launches would be low degree inclinations, within the range of what was analyzed in the 2022 PEA, and airspace closures will be coordinated with the FAA in order to meet the requirements of 14 CFR Part 450 and include selection of launch and reentry windows for any given mission. If Starship completes the descent phases as nominally planned, SpaceX expects Starship would explode and break up upon impact with the Indian Ocean's surface, where most debris would be expected to sink. Any vehicle breakups prior to Starship intact impact would be considered an anomaly. As stated in the 2022 PEA, SpaceX would sink or, to the greatest possible extent, recover any large floating debris. Additional details on events regarding Starship that would occur during descent are provided below.

During descent, Starship would vent a majority of the main tank propellant during the in-space coast phase of the launch at or above 120 kilometers above ground level; however approximately 70,000 kilograms (kgs) of propellant would remain in the main tanks and approximately 30,650 kgs of propellant would remain in the header tanks. Starship would impact the Indian Ocean intact, horizontally, and at terminal velocity (i.e., the steady speed achieved by a freely falling object). The impact would disperse settled remaining propellants and drive structural failure of the vehicle. The structural failure would immediately lead to failure of the transfer tube, which would allow the remaining liquid oxygen (LOX) and methane to mix, resulting in an explosive event. While Starship is primarily intended to be a fully reusable vehicle, there are several instances that could lead to expending rather than attempting to land a Starship vehicle during early missions. Some examples include: (1) cases where a specific vehicle has been determined to not be able to survive entry however other mission objectives warrant forgoing entry objectives and flying the mission; (2) higher-energy missions where additional performance is needed could result in removal of recovery hardware in order to increase available payload by decreasing vehicle dry mass; and (3) Starships configured for long-duration in-space missions, such as for propellant storage, do not use an Earth entry heatshield and are instead optimized for in-space operations. As such vehicles reach end of life, a controlled deorbit and disposal would be performed in order to avoid being stranded on-orbit or randomly reentering. During those instances, Starship would tumble as it descends through the atmosphere and break-apart greater than 50 kilometers above ground level.

As described in the programmatic Letter of Concurrence (LOC) (NMFS 2022), the vehicle is not expected to survive re-entry and any debris is expected to have sufficient mass to sink to the seafloor. Debris field characteristics are estimated based on modeled Starship breakup and currently available observational data; limited information is available from the first two test flights due to the occurrence of anomalies and personnel/equipment limitations. The primary debris fragment groups are made up of stainless steel. Other fragmentation groups include silica, aluminum, wiring, battery packs, and plastic. The debris would be of various sizes and masses. The largest debris would come from the Starship structure (barrel section) and would measure approximately 1.83 meters wide and 3.66 meters long and weigh approximately 550 kg. The smallest fragment would be approximately 3 centimeters by 3 centimeters (approximately the size of a quarter) and weigh 0.25 grams. All of the debris would eventually sink, but the rate would depend on the object's size, density and shape and the drag coefficient of water. Most of these materials would sink rapidly (due to the weight and composition of the steel) through the water column, while some items may stay buoyant on the surface or suspended in the water column before sinking towards the seafloor.

Due to the remote location of the landing, distance offshore, and potential safety concerns, SpaceX would not have assets (boat or aircraft) staged offshore prior to launch. Satellite imagery and telemetry-based evidence provided to SpaceX by on-board equipment on Starship would inform the fate of the stage and if a debris generating event could have been an outcome. If debris recovery was needed, an initial survey area would be determined based on last known data location point received from the telemetry on the vehicle upon splashdown. Weather and ocean current data would be used to further characterize the debris field as the operation is conducted. Though not expected and unlikely, if there is floating debris were located, SpaceX would sink or recover any floating debris by physically removing the item or puncturing the item to cause it to sink to the greatest extent practicable.

2.3 Alternatives Considered but Eliminated from Further Consideration

SpaceX considered other potential landing areas in the Atlantic and Pacific Ocean; however, no areas were able to meet all of the combined elements including optimization of launch trajectories, specific vehicle flight testing objectives, mission timelines and planning flexibility.

Chapter 3
Affected Environment and Environmental Consequences

3.1 Introduction

This chapter provides a description of the affected environment and potential environmental consequences for the environmental impact categories that have the potential to be affected by the Proposed Action and No Action Alternative. The environmental impact category assessed in this EA is Biological Resources.

This EA does not analyze potential impacts on the following environmental impact categories in detail because the Proposed Action would not affect the resources included in the category or the resources remain substantially valid as analyzed in the 2022 PEA (see FAA Order 1050.1F, Paragraph 4-2.c):

- **Air Quality and Climate** – Air quality and climate impacts caused from the Proposed Action are expected to be similar to the ones discussed in the 2022 PEA. Impacts to air quality and climate would result from launch operations, and mobile sources during launch activity and any offshore recovery operations of Starship. It was concluded in the 2022 PEA that these effects on a local and regional scale are expected to be minimal.
- **Noise and Noise-Compatible Land Use –** Noise impacts derive from the Proposed Action are expected to be similar to the ones discussed in the 2022 PEA. These individual noise events are not expected to cause general annoyance or pose health concerns due to the sound levels and expected frequency of events, though noise complaints may occur. As such, noise will be intermittent, of short duration, and temporary, and therefore the Proposed Action would not result in significant impacts to these noise sensitive areas.
- **Visual Effects** – Visual effects from the proposed action are expected to be similar to the ones described in the 2022 PEA. Potential visual impacts to the landscape in the study area include glare from the proposed infrastructure and Starship/Super Heavy launch vehicles at the Boca Chica Launch Site and light emissions during nighttime launch and testing operations. The Proposed Action is not expected to result in significant visual impacts so long as the mitigation measures identified in the 2022 PEA are implemented.
- **Cultural Resources** – Effects on cultural resources from the Proposed Action are expected to be similar to the ones discussed in the 2022 PEA. It was concluded that with the resolution of adverse effects on historic properties through Section 106 PA, the Proposed Action would not result in significant impacts on historical, architectural, archeological, or cultural resources.
- **Department of Transportation Act Section 4(f)** – Department of Transportation Act Section 4(f) impacts derived from the proposed action are expected to be similar to the ones discussed in the 2022 PEA. The FAA has determined the Proposed Acton would not result in more than a minimal

(i.e., de minimis) physical use of a Section 4(f) resource and would not constitute a constructive use.

- **Water Resources** – The Proposed Action does not authorize or involve any ground-disturbing activities and would therefore not encroach upon areas designated as navigable waters, wetlands, or floodplains. The proposed operations would not result in any changes to existing discharges to water bodies, create a new discharge that would result in impacts to surface waters, or modify a water body. The proposed operations would not involve activities that would withdraw groundwater from underground aquifers or reduce infiltration or recharge to ground water resources through the introduction of new impervious surfaces. None of SpaceX's existing infrastructure intersects a wild and scenic river protected by the Wild and Scenic Rivers Act. The Proposed Action does not have the potential to disrupt the free-flowing character of any designated wild and scenic river. Therefore, the Proposed Action would not affect wetlands, floodplains, surface waters, groundwater, or wild and scenic rivers.
- **Coastal Resources** – Coastal resource impacts from the Proposed Action are expected to be similar to the ones analyzed in the 2022 PEA. The Proposed Action is not expected to result in significant land use impacts as it is consistent with existing uses of land, would not change land use, and would occur according to existing plans and procedures in place.
- **Land Use** – Land use impacts resulting from the Proposed Action are expected to be similar to the ones discussed in the 2022 PEA. The Proposed Action does not involve the development or disturbance of any land regardless of use. It does not include activities that would change the existing use of land. Therefore, the proposed action would not affect land use.
- **Hazardous Materials, Solid Waste, and Pollution Prevention** – Hazardous materials, solid waste, and pollution prevention impacts resulting from the Proposed Action are expected to be similar to the ones from the 2022 PEA. It was concluded that the Proposed Action would not result in significant impacts regarding hazardous materials, solid waste, and pollution prevention because it would not 1) violate laws or regulations regarding hazardous materials and/or solid waste management; 2) involve a contaminated site; 3) produce an appreciably different quantity or type of hazardous waste; 4) generate an appreciably different quantity or type of solid waste or use a different method of collection or disposal; 5) exceed local capacity; or 6) adversely affect human health and the environment.
- **Natural Resources and Energy Supply** – Impacts to natural resources and energy supply are expected to be similar to the ones discussed in the 2022 PEA. It was concluded that the Proposed Action would not require the need for unusual natural resources and materials or those in short supply.
- **Socioeconomics, Environmental Justice, and Children's Environmental Health and Safety Risks**- Socioeconomics, environmental justice, and children's environmental health and safety risks impacts derived from the Proposed Action are expected to be similar to the ones analyzed in the 2022 PEA. The Proposed Action does not involve activities anticipated to adversely affect existing

economic activity, income, employment, population, housing, sustenance, public services, and social conditions.

3.2 No Action Alternative

Under the No Action Alternative, the FAA would not modify a license to SpaceX for its Starship/Super Heavy launch vehicle at its existing Boca Chica Launch Site. In this situation, as permitted under existing licenses, SpaceX could land the Starship vehicle at the VLA or downrange in the Gulf of Mexico, or Pacific Ocean (on a floating platform or expended in the Pacific Ocean). Under the No Action Alternative, there would be no new impacts on the environmental impact categories analyzed in this EA.

3.3 Biological Resources

3.3.1 Definition of Resource and Regulatory Setting

Biological resources are valued for their intrinsic, aesthetic, economic, and recreational qualities, and they include fish, wildlife, plants, and their respective habitats. Typical categories of biological resources include terrestrial and aquatic plant and animal species, game and non-game species, special status species (state or federally listed threatened or endangered species, marine mammals, or species of concern, such as species proposed for listing or migratory birds), and environmentally sensitive or critical habitats.

Section 7(a)(2) of the ESA requires that each federal agency—in consultation with the USFWS or NMFS—ensures that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of a listed species or result in the destruction or adverse modification of designated critical habitat. The FAA is required to consult the USFWS or NMFS if an action may affect a federally listed species or critical habitat.

The MMPA prohibits, with certain exceptions, the *take* of marine mammals in U.S. waters and by U.S. citizens on the high seas. SpaceX is required to obtain authorization from the USFWS (for sea and marine otters, walruses, polar bears, three species of manatee, and the dugongs) and/or NMFS (for all other marine mammals) if its project would *take* a marine mammal. Often the marine mammals present in a project area are also listed under the ESA.

The Magnuson-Stevens Fishery Conservation and Management Act requires federal agencies to consult with NMFS regarding any activity or proposed activity that is authorized, funded, or undertaken by the agency that may adversely affect EFH. EFH is defined as those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity, and is described and identified by NMFS and regional fishery councils for all federally managed species.

The Migratory Bird Treaty Act protects migratory birds by prohibiting the taking, killing, or possessing of migratory birds (including their eggs, nests, and feathers). SpaceX is responsible for complying with the Migratory Bird Treaty Act.

More information about biological resources can be found in Chapter 2 of the FAA Order 1050.1F Desk Reference (FAA 2020a).

3.3.2 Study Area

The study area consists of a portion of the Indian Ocean where Starship second stage landing activities are proposed to occur. This area is generally between S 15 and S 30 degrees latitude in the southern Indian Ocean in waters greater than 200 nm (370 km) from land. This western portion of the Indian Ocean Landing Area is east of Madagascar and south of Mauritius and Réunion. The second stage landing area continues east and is south of Cocos (Keeling) Islands and Christmas Island off the coast of Indonesia. Figure 1 depicts a map of the Indian Ocean Landing Area.

3.3.3 Existing Conditions

This section describes the habitats and wildlife within the Indian Ocean study area. The 2022 PEA analyzed the affected environment and environmental consequences of the Proposed Action to terrestrial habitat and wildlife, marine habitat and wildlife, and protected species and critical habitat. The existing conditions for biological resources in the 2022 PEA study area were described in the 2014 EIS (FAA 2014a) and have not substantially changed. Therefore, the 2022 PEA information is incorporated by reference, and the sections below focus on the new affected environment of the Proposed Action of landing of the Starship vehicle in the Indian Ocean which was not previously analyzed in the 2022 PEA or 2014 EIS.

3.3.3.1 Marine Habitats and Wildlife

Starship operations would occur in the Indian Ocean. In the event of an anomaly of early unmanned missions, Starship may be expended in the ocean no closer than 200 nm offshore. SpaceX will, to the maximum extent practicable, avoid areas determined to be sensitive to disturbance or highly productive and presumed to have an increased probability of supporting higher densities of marine life. These areas include seamounts, upwellings, coastal areas, coral reefs, and other predominant oceanic habitat areas; these habitats are not described in detail due to their exclusion from the Proposed Action.

The study area consists entirely of pelagic (open ocean) marine habitat. Pelagic ecosystems vary considerably with the depth of the ocean. Surface and near-surface environments are classified as the euphotic zone, due to the abundance of light and dissolved oxygen. These waters are relatively warm and support the majority of wildlife commonly associated with marine ecosystems, including marine mammals, fish, reptiles, birds, and invertebrates (e.g., shrimp, mollusks, squids, jellyfish, etc.).

Deeper water environments have limited to no availability of surface light, lower concentrations of dissolved oxygen, and higher pressure. The taxa of these environments are not well documented but are primarily composed of specialist species with necessary adaptations to thrive under the given conditions.

3.3.3.2 Listed Marine Species

At the request of the FAA, SpaceX conducted a literature review of ESA-listed endangered and threatened species with known or presumed distributions in the study area that may be affected by the proposed activities. Information sources included data obtained from NMFS endangered species web sites; experts in the occurrence and distribution of marine mammals, sea turtles, and fishes; and a review of available literature through established academic journals (ex., Public Library of Science (PLOS), Endangered Species Research, Marine Mammal Science, etc.), and review of monthly new literature summaries provided by the Navy's Marine Applied Research and Library Information Network (MARLIN). Focused distribution and conservation information for each species is included below. Table 1 summarizes ESA-listed species within the study area as well as their requisite habitat.

The MMPA requires that an incidental take authorization be obtained for the unintentional "take" of marine mammals (e.g., by harassment) incidental to otherwise lawful activities. As stated in the 2022 LOC, the action agencies and/or their commercial space partners are required to apply for an MMPA authorization from NMFS if their activities could subject marine mammals to "take" as defined by the MMPA. Calculating the potentially affected area within which marine mammal species could be harassed is one of the required inputs for conducting a quantitative analysis of potential impacts on listed species. Data on the abundance and distribution of the species in the potentially affected area is also required to conduct a quantitative analysis of potential impacts.

The Indian Ocean has not been surveyed in a manner that allows for empirical density estimation of marine mammals, where density estimates would be derived directly from survey sighting data in conjunction with distance sampling theory. However, the U.S. Navy has prepared uniform density estimates for each marine mammal species in the action area using Relative Environmental Suitability (RES) models (U.S. Navy, 2019). RES models estimate local abundance based on the values of the environmental covariates, providing a means to estimate density for areas that have not been surveyed (Kaschner et al. 2006; Kaschner et al. 2012). However, the uncertainty associated with the RES model estimates is very high, and results can substantially diverge from adjacent predicted results (or don't correspond to densities measured from surveyed areas). This method of density estimation is therefore the least preferred type of data source; however, as stated earlier, is the best available science because of the lack of empirical survey data for the Indian Ocean. Table 2 summarizes all marine mammals within the study area and their best available population density estimate.

Table 1 ESA-Listed Species Present in the Starship Landing Area

Common Name	***Scientific Name***	***Distinct Population Segment or Evolutionarily Significant Units***	***ESA Status****	***Presence in Action Area***	***Critical Habitat Designation***
Fishes					
Oceanic whitetip shark	*Carcharhinus longimanus*	-	FT	Pelagic distribution, may occur year-round	No critical habitat designation
Scalloped hammerhead shark	*Sphyrna lewini*	Indo-West Pacific DPS	FT	Mostly coastal and semi-oceanic in temperate and tropical waters	No critical habitat designation
Sea Turtles					
Green sea turtle	*Chelonia mydas*	East Indian-West Pacific DPS	FT-Foreign	Associated with nesting beaches in Australia and Indonesia, may have rare pelagic occurrence in the eastern portion of the Action Area	Critical habitat designated under 63 FR 46693. Critical habitat proposed rule 88 FR 46572. Per 63 FR 46693 and 88 FR 46572, no critical habitat within the Action Area.
		North Indian DPS		Associated with nesting beaches along the coasts of India and Pakistan, may have rare pelagic occurrence in the eastern portion of the Action Area	
		Southwest Indian Ocean DPS		Associated with nesting beaches along the coasts of Kenya, Seychelles, Comoros, Mayotte, Europa Island, South Africa, and Madagascar. May have rare pelagic occurrence in the eastern portion of the Action Area	
Hawksbill sea turtle	*Eretmochelys imbricate*	-	FE	Associated with nesting beaches in Western Australia, may have rare pelagic occurrence in the eastern portion of the Action Area	Critical habitat designated under 63 FR 46693. Per 63 FR 46693, no critical habitat within the Action Area.

Leatherback sea turtle	*Dermochelys coriacea*	-	FE	Pelagic and relatively more tolerant of cooler water temperatures, may occur throughout the Action Area	Critical habitat designated under 77 FR 4170. Per 77 FR 4170, no critical habitat within the Action Area.
Loggerhead sea turtle	*Caretta caretta*	Southwest Indian Ocean DPS	FT-Foreign	Most nesting sites along coast of South Africa and Mozambique. May have rare pelagic occurrence in the western portion of the Action Area	Critical habitat designated under 79 FR 39855. Per 79 FR 39855, no critical habitat within the Action Area.
		Southeast Indo-Pacific DPS	FT-Foreign	Most nesting in Western Australia. May have rare pelagic occurrence in the western portion of the Action Area	
		North Indian Ocean DPS	FE-Foreign	Most nesting occurs in Oman, particularly Masirah Island. May have rare pelagic occurrence in the western portion of the Action Area	
Olive ridley sea turtle	*Lepidochelys olivacea*	-	FT	Most nesting sites along the coast of India, Pakistan, and Bangladesh. Likely occurs in low numbers throughout the northern portion of the Action Area	No critical habitat designation
Marine Mammals					
Blue whale	*Balaenoptera musculus*	-	FE	High densities during the summer and fall with single individuals in the winter and spring	No critical habitat designation
Fin whale	*Balaenoptera physalus*	-	FE	Higher densities in the summer and fall although present year-round	No critical habitat designation
Sei whale	*Balaenoptera borealis*	-	FE	Present year round with more likely presence in the winter and spring	No critical habitat designation
Sperm whale	*Physeter macrocephalus*	-	FE	Present year round with a preference for deep waters and the continental shelf break and slope	No critical habitat designation

*Notes: The FAA conducted a literature review of several species recovery plans and status reviews. The species list was developed during consultation between NMFS and FAA, pursuant to Section 7(a)(2) of the ESA. ESU = Evolutionarily Significant Unit, FE = federally listed endangered, FT = federally listed threatened, FR = Federal Register

Table 2 Marine mammals and estimated densities potentially occurring within the Indian Ocean Landing Area

Common name	Taxonomic name	Family	Estimate Type	Density
Common minke whale	*Balaenoptera acutorostrata*	Balaenopteridae	Seasonal Average	0.01276[1]
Blue Whale	*Balaenoptera musculus*	Balaenopteridae	Annual Average	.00003
Fin Whale	*Balaenoptera physalus*	Balaenopteridae	Seasonal Average	.00087
Sei Whale	*Balaenoptera borealis*	Balaenopteridae	N/A	Unavailable
Sperm Whale	*Macrocephalus*	Balaenopteridae	Annual Average	.00093
Antarctic minke whale	*Balaenoptera bonaerensis*	Balaenopteridae	N/A	Unavailable[1]
Bryde's whale	*Balaenoptera edeni*	Balaenopteridae	Annual Average	0.00032[1]
Omura's whale	*Balaenoptera omurai*	Balaenopteridae	Annual Average	0.00032[1]
Humpback whale	*Megaptera novaeangliae*	Balaenopteridae	Seasonal Average	0.00007[1]
Pygmy sperm whale	*Kogia breviceps*	Kogiidae	Used *K. sima* est.	0.00004[1]
Dwarf sperm whale	*Kogia sima*	Kogiidae	Annual Average	0.00004[1]
Pygmy killer whale	*Feresa attenuata*	Delphinidae	Annual Average	0.00101[1]
Short-finned pilot whale	*Globicephala macrorhynchus*	Delphinidae	Annual Average	0.02716[1]
Risso's dolphin	*Grampus griseus*	Delphinidae	Annual Average	0.07121[1]
Fraser's dolphin	*Lagenodelphis hosei*	Delphinidae	Annual Average	0.00147[1]
Killer whale	*Orcinus orca*	Delphinidae	Annual estimate	0.00100[3]
Melon-headed whale	*Peponocephala electra*	Delphinidae	Annual Average	0.00677[1]
False killer whale	*Pseudorca crassidens*	Delphinidae	Annual Average	0.00020[1]
Pantropical spotted dolphin	*Stenella attenuata*	Delphinidae	Annual Average	0.00729[1]
Striped dolphin	*Stenella coeruleoalba*	Delphinidae	Annual Average	0.11867[1]
Spinner dolphin	*Stenella longirostris*	Delphinidae	Annual Average	0.00560[1]
Rough-toothed dolphin	*Steno bredanensis*	Delphinidae	Annual Average	0.00059[1]
Common bottlenose dolphin	*Tursiops truncatus truncatus*	Delphinidae	Annual Average	0.03617[1]
Southern bottlenose whale	*Hyperoodon planifrons*	Ziphiidae	Annual Average	0.00083[1]
Longman's beaked whale	*Indopacetus pacificus*	Ziphiidae	Annual Average	0.00400[1]
Blainville's beaked whale	*Mesoplodon densirostris*	Ziphiidae	Annual Average	0.0008275[1]
Spade-toothed beaked whale	*Mesoplodon traversii*	Ziphiidae	Annual Average	0.00083[1]

Common name	Taxonomic name	Family	Estimate Type	Density
Cuvier's beaked whale	*Ziphius cavirostris*	Ziphiidae	Annual Average	0.00403[1]

Notes: [1] Source: RES model densities from U.S. Navy 2019, *Supplemental Environmental Impact Statement Surveillance Towed Array Sensor System (SURTASS) Low Frequency Active (LFA) Sonar*; [2] Source: theta-logistic population model from Whitehead & Shin 2022; [3] Source: synthesis of available information on worldwide killer whale abundance and distribution from Forney & Wade 2006.

3.3.3.3 Essential Fish Habitat

Essential Fish Habitat (EFH) refers to those areas formally designated by NMFS and RMFS for protection under the Magnuson-Stevens Fishery Conservation and Management Act EFH provisions. EFH cannot be identified in areas beyond the outer limits of the U.S. Exclusive Economic Zone (EEZ) and Federal agencies need not consult with NMFS regarding the effects of actions on habitats beyond the EEZ (62 Fed. Reg. 66535, (January 17, 2002)). All components of the study area are outside the EEZ; therefore, EFH is not considered further in this tiered EA.

3.3.4 Environmental Consequences

A significant impact on biological resources would occur if the USFWS or NMFS determines that the action would likely jeopardize the continued existence of a federally listed, threatened, or endangered species or would result in the destruction or adverse modification of federally designated critical habitat. The FAA has not established a significance threshold for unlisted species. Factors to consider when assessing the significance of potential impacts on unlisted species include whether the action would have the potential for:

- a long-term or permanent loss of unlisted plant or wildlife species (e.g., extirpation of the species from a large project area, such as from a new commercial service airport);
- adverse impacts on special status species or their habitats;
- substantial loss, reduction, degradation, disturbance, or fragmentation of native species' habitats or their populations; or
- adverse impacts on a species' reproductive success rates, natural mortality rates, non-natural mortality (e.g., road kills and hunting), or ability to sustain the minimum population levels required for population maintenance.

Overall impacts on biological resources, considering the new information related to the Proposed Action, would be comparable to those discussed in the 2022 PEA. The 2022 PEA determined the Proposed Action would not be expected to result in significant impacts on marine habitats and wildlife.

As described in the 2022 PEA, the FAA completed a programmatic ESA consultation with the NMFS for launch and reentry operations in the marine environment (NMFS 2022). NMFS concurred with the FAA's determination that the space launch and reentry activities presented in the programmatic consultation would not adversely affect ESA-listed species or designated critical habitat and issued a programmatic LOC (NMFS 2022). The same impact mechanisms and effects described and assessed as part of the NMFS consultation are applicable to non-protected species. The prior consultation concluded with NMFS concurring that SpaceX's landing and recovery operations would be unlikely to adversely affect federally listed, threatened, and endangered species. Based on the same reasoning, it is unlikely that non-protected marine wildlife would be adversely affected. As stated in the 2022 PEA, the effects from ocean landing and recovery operations would be negligible. As stated in the 2022 LOC, it has been normal practice for decades for vertical rocket launches to involve expending one or more stages (or boosters) in the ocean with residual propellant resulting in a potential overpressure explosive event (FAA 2016; NASA 2013; NASA 2009; FAA 2020b; USAF 2006).

3.3.4.1 Impact by Fallen Objects

Direct strikes by debris from Starship are extremely unlikely for all species of concern, fish, sea turtles, and marine mammals. This is due to the small size of the components as compared to the vast open ocean. If debris from the vehicle struck an animal near the water's surface, the animal would be injured or killed. As stated in the 2022 PEA, given the low frequency of the Starship/Super Heavy ocean descent and landing operations, and the fact that marine wildlife, marine mammals, and special status species spend the majority of their time submerged as opposed to on the surface, it is extremely unlikely they would be impacted. The relative occurrence of these animals at the ocean surface, spatially and temporally, combined with the low frequency of the Proposed Action, reduce the likelihood of impacts to extremely low. Additionally, there are no known interactions with any of these species after decades of similar rocket launches and reentries. Further, the projected landing areas for both Super Heavy and Starship are well offshore where density of marine species decreases compared to coastal environments and upwelling areas (FAA 2017).

3.3.4.2 Exposure to Hazardous Materials

SpaceX expects residual LOX and methane to remain on Starship during descent and landing. Unlike other launch vehicle propellants and fuels, LOX and methane are not toxic pollutants. Starship is expected to experience an explosive event upon impact with the ocean's surface and subsequent vehicle failure. As all liquid fuel is likely to be consumed during vehicle breakup, only structural debris would remain. When Starship is not configured to survive atmospheric reentry, the vehicle would tumble and break apart as it descends through the atmosphere, and residual fuel would be dispersed and evaporated before reaching the ocean's surface such that only structural debris would remain. Structural debris of both Starship and Super Heavy is made of inert materials, such as steel, carbon composite, silica heat tiles and is not anticipated to affect water quality. For these reasons, after considering the new information, the chance for marine species to be exposed to the residual propellant is still extremely low and therefore discountable, as the 2022 PEA concluded.

3.3.4.3 Exposure to Sonic Booms and Impulse Noise

A sonic boom is the sound associated with the shock waves created by a vehicle traveling through the air faster than the speed of sound. As described in the 2022 PEA, sonic booms that would occur during descent and landing would intercept the ocean's surface. However, exceptionally little energy from in-air noise is transmitted into water (FAA 2017). Due to the limited occurrences of ocean landings, the low magnitude of the sonic booms (no greater than 2 pounds per square foot for Starship), the substantial attenuation of the sonic booms at the air/water interface, and the exponential attenuation with water depth, sonic booms would not result in impacts on marine species beneath the surface, even when the new information regarding the vehicle landings is considered.

3.3.4.4 Indirect Impacts

Water Quality

Water quality would not be impacted by residual fuel remaining after a Starship breakup. Starship is expected to experience an explosive event upon impact with the ocean's surface and subsequent vehicle failure. The explosive event would be expected to consume all remaining fuel. As all liquid fuel is likely to be consumed during vehicle breakup, only structural debris would remain. For events where the vehicle would break up in the atmosphere, residual propellant would be dispersed and evaporated such that only structural debris would remain. Structural debris is made of inert materials, such as steel, carbon composite, silica heat tiles and is not anticipated to affect water quality. In the event of an intact landing, residual propellant would be retained and not released into the ocean but may eventually warm up, turn gaseous, and vent to the atmosphere through open valves. Accordingly, indirect effects on the ESA-listed sharks, ESA-listed sea turtles, and ESA-listed marine mammals within the Action Area resulting from water quality changes attributable to the Proposed Action should be considered insignificant (not measurable) (NMFS 2024).

Bioaccumulation

Bioaccumulation is the net buildup of substances (e.g., chemicals or metals) in an organism from inhabiting a contaminated habitat, ingesting food or prey containing the contaminated substance, or from ingesting the substance directly. Pollutants in the environment bioaccumulate and then biomagnify to high levels in some organisms, including ESA-listed species, due to their high position in the food chain, long life, and large size. Much research has been conducted on the fate and transport of metals associated with munitions expended by military activities, with specific concern for bioaccumulation. Information from investigations at Navy testing and training ranges and sites where munitions were disposed of at sea following the end of World War II indicates that even in a variety of areas having concentrated expended military materials, there has been no significant impact on the immediate vicinity or the wider area as a result of those materials being present. It is unlikely bioaccumulation would measurably impact ESA-listed species for the following reasons: (1) the few landing events included in the Proposed Action would limit the amount of chemicals that could become available for trophic transfer; and (2) the discreet localized areas where fragments would descend to benthic habitats. Accordingly, indirect effects associated with potential bioaccumulation of expended Starship fragments on the ESA-listed sharks, ESA-listed sea turtles, and ESA-listed marine mammals within the Action Area should be considered insignificant (not measurable) (NMFS 2024).

Prey Availability

Prey availability could be further impacted by fallen objects generated by the overpressure event as they strike the surface and descend through the water column. Secondary impacts on fish could occur after the Starship fragments sink to the seafloor. Over time, the fragments may be colonized by marine organisms that attach to hard surfaces, with a greater probability of colonization at shallower depths within the photic zone (down to about 200 m). For fishes that feed on these types of organisms, or whose abundances are limited by available hard structural habitat, the fragments that sink during an overpressure event could provide an incidental beneficial impact. In addition to physical effects of an overpressure event on prey fishes, such as being stunned, prey might have behavioral reactions to underwater sound. For instance, prey fishes might exhibit a strong startle reaction to an impulsive sound generated by an overpressure event that might include scattering away from the source. The sound from an overpressure event might induce startle reactions and temporary dispersal of schooling fishes if they are within close proximity, however, uninjured fish would likely resume normal activities in a short period after the initial stimulus. Invertebrate prey species, including krill, jellyfish, and other planktonic species, in the immediate vicinity of an explosion and overpressure event would be directly affected with the potential for injury or mortality. Farther from the impact site, these species are less likely to be affected by changes in pressure since many are generally the same density as water and few, if any, have air cavities that would function like the fish swim bladder in responding to a pressure change. Invertebrates directly affected by an event would represent only a marginal fraction of the overall abundance of prey available to cetaceans and sea turtles in the Indian Ocean.

Accordingly, indirect effects associated with prey availability to the ESA-listed sharks, ESA-listed sea turtles, and ESA-listed marine mammals within the Action Area should be considered insignificant (not measurable) and discountable (unlikely to occur) (NMFS 2024).

3.3.4.5 Listed Marine Species

In accordance with Section 7 of the ESA, the FAA conducted consultation with the NMFS. The FAA has concluded that the Proposed Action “may affect, but not likely adversely affect” (Appendix B) the ESA-listed oceanic whitetip shark, scalloped hammerhead, green sea turtle (East Indian-West Pacific Distinct Population Segment (DPS), North Indian DPS, and the Southwest Indian Ocean DPS), hawksbill sea turtle; leatherback sea turtle; loggerhead sea turtle (Southwest Indian Ocean DPS, Southeast Indo-Pacific DPS, and North Indian Ocean DPS), olive ridley sea turtle, blue whale, fin whale, sei whale, and sperm whale (Table 1). Because the proposed activities would occur entirely outside of the territorial waters of the U.S., the proposed second stage landings in the Indian Ocean would have no effect on designated or proposed critical habitat for these ESA-listed species.

Using the potentially affected area within which ESA-listed marine species could be harassed, and averaging the seasonal data available for the ESA-listed species that could be present, SpaceX calculated the number of ESA-listed marine mammals, fishes, and sea turtles that could potentially be harassed by a Starship explosive event near the ocean’s surface in the landing area. Propellant would remain in the header tanks and the main tanks, approximately 30,650 kg and 70,000 kg, respectively. An explosion would most likely occur within the transfer tube, simultaneously igniting the headers and main because the fuel system is connected. SpaceX analyzed the combined explosive weight from the transfer tube, headers and main as a single explosion.

For the header tanks, an explosive weight of 3,647.35 kg was used based on a 11.9 percent yield, which is highly conservative value based on a simulation of uncontained mixing between two close coupled masses of propellant and no barriers impeding their mixing. For the main tanks, an explosive weight of 6,300 kg was used based on a 9 percent yield. The total remaining propellant in Starship would amount to approximately 9947.35 kg and the explosion would likely occur 4.5m above the ocean surface. It was further assumed that only half of the explosive energy of the explosive event would enter the water based on the location of the Starship at the time of explosion. Therefore, acoustic effects were calculated using 50 percent of the calculated yield, 4,973.68 kg.

The analysis for 9 percent yield was used in the 2023 NMFS Consultation, and due to the small variation in propellant mass and small change to the propellant mass fill geometry, the assumption that the manner of propellant mixing will remain consistent is still appropriate. This methodology, which includes a highly conservative adjustment to account for uncertainty, produced a conservative yield estimate of 9 percent. SpaceX would be able to initiate a landing burn due to the increased propellant and control the vehicle until the flip to vertical (nose up) descent occurs by adjusting the flap positions. SpaceX has simulated a 6 Degree of Freedom Monte Carlo model of Starship with aerodynamic inputs validated by evidence from the suborbital test flights. These simulations can predict the vehicle orientation at impact given various scenarios involving the fins and show that Starship would belly flop with fins in their normal configuration. These assumptions are validated by over 100 video records from developmental scenarios archived by SpaceX.

As shown in Table 3 below, the number of ESA-listed species expected to be harassed is less than one. Therefore, Starship descent and landing operations may affect, but are not likely to adversely affect, any ESA-listed marine mammals, sea turtles, sharks or fishes.

On March 7, 2024, NMFS provided a letter of concurrence for the FAA's determination of may affect but is not likely to adversely affect ESA-listed species and designated habitat when considering this additional information. Please see the letter in Appendix B.

Table 3 Overpressure Events Modeling Results SPL Peak Unweighted (ESA-Listed Species)

Blast Inputs	
TNT Yield (kg)	
Surface Pressure in Air (kPa)	
Surface Pressure in Water (kPa)	
Peak SPL dB (re 1 µPa)	

Enter 4.5m Incident Pressure from https://unsaferguard.org/un-saferguard/kingery-bulmash

INPUTS	CALCS	RESULTS

ESA SPL for Indian Ocean

SPL Peak (Indian Ocean)			NMFS Thresholds (dB re 1 uPa)		Harassment Area (km^2)		Species Harassment Results	
ESA Species Data (Indian Ocean)	Type	Density (per km^2)	PTS	TTS	PTS	TTS	PTS	TTS
Blue Whale	LF cetacean	0.0000030	219	213	0.23182	0.92288	0.00000070	0.00000277
Fin Whale	LF cetacean	0.0008700	219	213	0.23182	0.92288	0.00020168	0.00080291
Sei Whale	LF cetacean	Unavailable	219	213	0.23182	0.92288	Unavailable	Unavailable
Sperm Whale	MF cetacean	0.00093	230	224	0.01841	0.07331	0.00001712	0.00006818
Green Turtle	Turtle	Unavailable	232	226	0.01162	0.04625	Unavailable	Unavailable
Hawksbill Turtle	Turtle	Unavailable	232	226	0.01162	0.04625	Unavailable	Unavailable
Leatherback Turtle	Turtle	Unavailable	232	226	0.01162	0.04625	Unavailable	Unavailable
Loggerhead Turtle	Turtle	Unavailable	232	226	0.01162	0.04625	Unavailable	Unavailable
Olive Ridley Turtle	Turtle	Unavailable	232	226	0.01162	0.04625	Unavailable	Unavailable
Species	Type	Density (per km^2)	Onset of Physical Injury (dB re 1 uPa)		Injury Area (km^2)		Species Injury Results	
Oceanic Whitetip Shark	Fish	Unavailable	206		4.63		Unavailable	Unavailable
Scalloped Hammerhead Shark	FIsh	Unavailable	206		4.63		Unavailable	Unavailable

Table 4 Overpressure Events Modeling for SPL (MMPA-Listed Species)

Blast Inputs	
TNT Yield (kg)	
Surface Pressure in air (kPa)	
Water Peak Source Sound Level	
Surface Pressure in Water (kPa)	
Peak SPL dB (re 1 uPa)	

INPUTS	CALCS	RESULTS

MMPA SPL for Indian Ocean

Species Data (Indian Ocean)			NMFS Thresholds (dB re 1 uPa)		Harassment Area (km^2)		Species Harassment Results	
Species	**Type**	**Density (per km^2)**	**PTS**	**TTS**	**PTS**	**TTS**	**PTS**	**TTS**
Antarctic Minke Whale	LF cetacean	0.00001	219	213	0.23	0.92	0.000002	0.000009
Bryde's Whale	LF cetacean	0.00032	219	213	0.23	0.92	0.000074	0.000295
Dwarf Sperm Whale	MF cetacean	0.00005	230	224	0.02	0.07	0.000001	0.000003
False Killer Whale	MF cetacean	0.00020	230	224	0.02	0.07	0.000004	0.000015
Fraser's Dolphin	MF cetacean	0.00147	230	224	0.02	0.07	0.000027	0.000108
Humback Whale	LF cetacean	0.00007	219	213	0.23	0.92	0.000016	0.000065
Killer Whale	MF cetacean	0.00100	230	224	0.02	0.07	0.000018	0.000073
Melon-Headed Whale	MF cetacean	0.00677	230	224	0.02	0.07	0.000125	0.000496
Minke Whale	LF cetacean	0.01276	219	213	0.23	0.92	0.002958	0.011776
Pantropical Spotted Dolphin	MF cetacean	0.00729	230	224	0.02	0.07	0.000134	0.000534
Pygmy Killer Whale	MF cetacean	0.00101	230	224	0.02	0.07	0.000019	0.000074
Pygmy Sperm Whale	MF cetacean	0.00004	230	224	0.02	0.07	0.000001	0.000003
Omura's Whale	LF cetacean	0.00032	219	213	0.23	0.92	0.000074	0.000295
Risso's Dolphin	MF cetacean	0.07121	230	224	0.02	0.07	0.001311	0.005220
Sei Whale	LF cetacean	Unavailable	219	213	0.23	0.92	Unavailable	Unavailable
Short-Finned Pilot Whale	MF cetacean	0.02716	230	224	0.02	0.07	0.000500	0.001991
Striped Dolphin	MF cetacean	0.11867	230	224	0.02	0.07	0.002185	0.008699
Spinner Dolphin	MF cetacean	0.00560	230	224	0.02	0.07	0.000103	0.000411
Rough-Toothed Dolphin	MF cetacean	0.00059	230	224	0.02	0.07	0.000011	0.000043
Common Bottlenose Dolphin	MF cetacean	0.03617	230	224	0.02	0.07	0.000666	0.002652
Southern Bottlenose Whale	MF cetacean	0.00083	230	224	0.02	0.07	0.000015	0.000061
Longman's Beaked Whale	MF cetacean	0.00464	230	224	0.02	0.07	0.000085	0.000340
Blainville's Beaked Whale	MF cetacean	0.000934	230	224	0.02	0.07	0.000017	0.000068
Cuvier's Beaked Whale	MF cetacean	0.004545	230	224	0.02	0.07	0.000084	0.000333

Using the potentially affected area within which MMPA species could be harassed and the estimates of density data available for the MMPA species that could be present, SpaceX estimated the number of individuals of each species that could potentially be harassed by an explosive event near the ocean's surface (see **Error! Reference source not found.**).

As shown in **Error! Reference source not found.**, the number of individuals estimated to be harassed for all MMPA species potentially present is less than one. As stated above, the uncertainty associated with the RES model density estimates is very high because it relies on correlations between species occurrence with habitat features, rather than empirical survey data, to produce the estimates. In addition, SpaceX would implement conservation measures listed above by prioritizing avoidance of aggregating features and refugia where densities of MMPA species and their prey are expected to be greater. The estimates of densities are therefore conservatively high since the model inputs to estimate densities assume uniform densities for each species across the Action Area and does not exclude these aggregating features.

Based on the modeling results of near-surface explosions described above and in the 2022 PEA, and the implementation of conservation measures that prioritize avoidance of aggregating features (Section 3.3.5), the probability of take of MMPA species is sufficiently low to determine that potential for take is very unlikely.

3.3.5 Conservation Measures

The NMFS concurrence letter includes the following discretionary conservation recommendations:

1. FAA gather acoustic data on the expected explosive event. Sound source verification may help to more accurately determine the impacts of this explosion scenario in the future.
2. The action agency should coordinate with the NMFS ESA Interagency Cooperation Division to foster collaboration with the NOAA Marine Debris Program (MDP), in order to evaluate how activities of the MDP may apply to debris that originates from space launch and reentry operations (e.g., expended vehicle components).

The following conservation measures would be adhered to by SpaceX:

1. SpaceX will perform land landings greater than 200 nm of any land area. Areas within 200 nm are not planned to be used for landings, and are therefore excluded from the Action Area.
2. SpaceX will, to the maximum extent practicable, avoid areas determined to be sensitive to disturbance or highly productive and presumed to have an increased probability of supporting higher densities of marine life, including:
    a. Important Marine Mammal Areas (IMMAs): IMMAs are defined as discrete portions of habitat, important to marine mammal species, that have the potential to be delineated and managed for conservation;
    b. Ecologically or Biologically Significant Area (EBSA). An EBSA is an area of the ocean that has special importance in terms of its ecological and biological characteristics: for example, by providing essential habitats, food sources or breeding grounds for particular species;
3. SpaceX would avoid, if possible, locations that include physiographic features (e.g., plateaus, ridges, spreading zones, known seamounts and ocean vents)

SpaceX contractors and subject matter experts completed a literature review in October 2023 that identified locations within the Action Area that may: (1) aggregate MMPA species and their prey; (2) offer other refugia for MMPA species; or (3) otherwise provide conservation benefit. These areas are shown in Figure 2. Potential Indian Ocean Landing Areas within the Action Area will be prioritized to avoid these locations.

The NMFS concurrence letter also includes the following project design criteria and reporting requirements:

1. After each Starship/Super Heavy flight, FAA will provide information to NMFS detailing the results of launch and landings, based on available telemetry data received from the vehicles, including:

a. Whether Starship and Super Heavy resulted in an anomaly or nominal landing, and where (expressed in the last known GPS location) the anomaly or landing occurred.

b. The debris catalog generation, approximate location, and any other information that can corroborate assumptions about the debris and/or debris field from a launch failure anomaly (of each vehicle).

c. Whether Starship landings occurred in the expected manner (i.e., belly flop or soft-water landing or atmospheric breakup with debris field within the Indian Ocean landing area). For landings resulting in explosion, information reported to NMFS shall include the amount of fuel/propellant remaining in main and header tanks, Starship orientation upon landing, debris catalog generation, and any other data that can corroborate whether the assumptions about the explosion and area of impact (physically and acoustically) were appropriate.

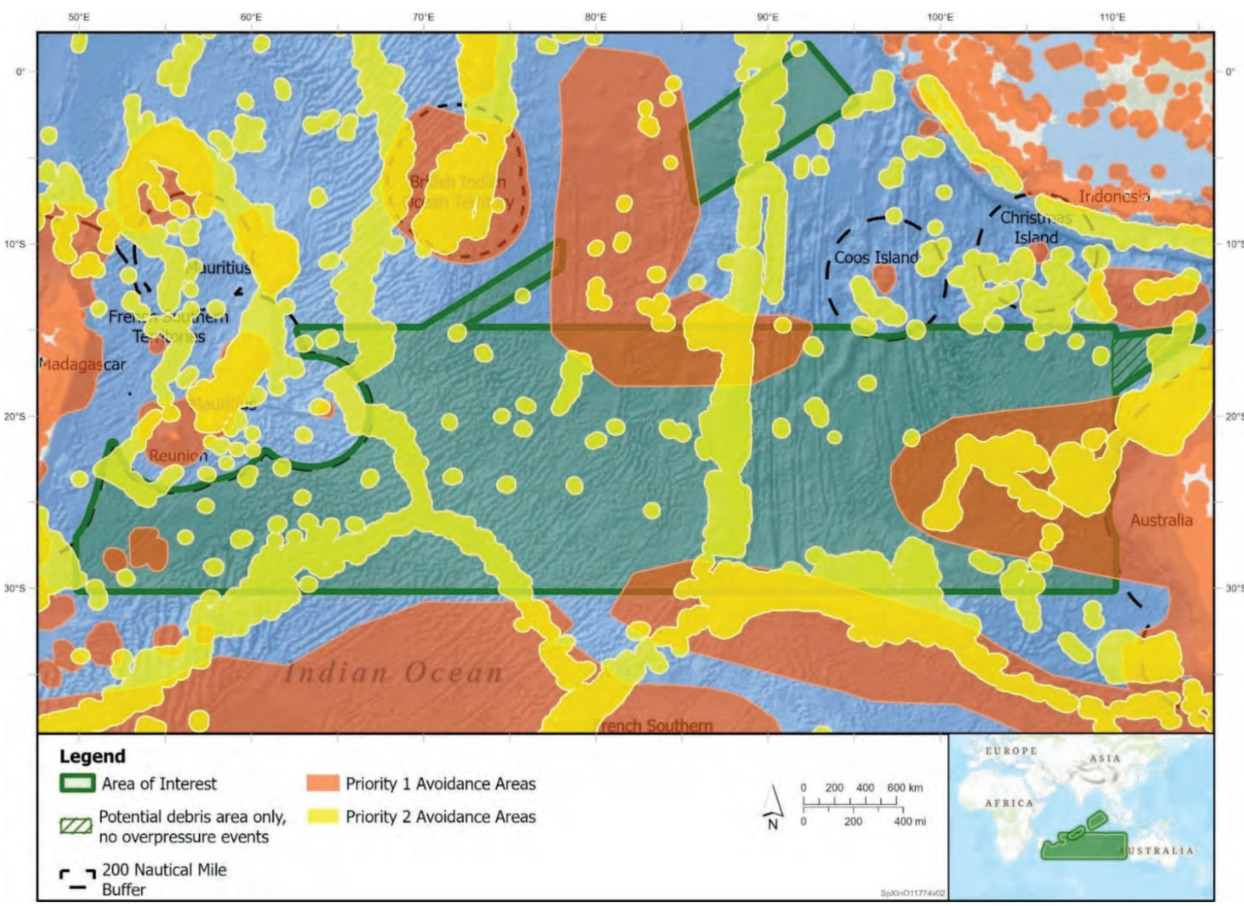

Figure 2 Avoidance Level 1 and 2 Areas within the Action Area

Chapter 4 **Cumulative Effects**

The CEQ NEPA-implementing regulations define cumulative effects as "effects on the environment that result from the incremental effects of the action when added to the effects of other past, present, and reasonably foreseeable actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions" (40 CFR § 1508.1(g)(3)). Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time. Past, present, and reasonably foreseeable actions that: (1) overlap the study areas identified in Chapter 3; (2) result in impacts on a resource; and (3) occur in close proximity to the reentry site would be expected to have more potential for cumulative effects than those actions more geographically separated from the reentry site.

The same environmental impact categories that were dismissed from analysis in Chapter 3 are not included in the cumulative effects analysis because the Proposed Action would not affect them (directly or indirectly); therefore, the Proposed Action would not contribute to cumulative effects on these environmental impact categories. Those environmental impact categories include biological resources.

4.1 Study Area

The study area for the cumulative effects analysis is the same study area as that defined for biological resources in Chapter 3 because it is the largest study area defined for direct and indirect effects.

4.2 Past and Present Actions

The FAA reviewed primary literature, popular press releases, and industry reports for relevant past and ongoing actions within the study area with potential to produce additive or synergistic adverse effects to the marine environment when considered in tandem with the Proposed Action. The following past and ongoing actions have the potential to increase debris, vessel noise, and presence of contaminants within the marine environment:

- Expenditure of launch vehicles in the study area by foreign launch programs in China, India, and Australia (Paget & Maxouris 2022; Clark 2023; Turnbull 2022);
- Maritime shipping of dry bulk goods, commodities, petroleum, and natural gas (Baruah et al. 2023); and
- Commercial fishing pressure, both regulated and unregulated (WWF 2020).

4.3 Reasonably Foreseeable Actions

The FAA reviewed primary literature, popular press releases, and industry reports for relevant reasonably foreseeable actions within the study area with potential to produce additive or synergistic adverse effects to the marine environment when considered in tandem with the Proposed Action. The following past and ongoing actions have the potential to increase debris, vessel noise, and presence of contaminants within the marine environment:

- Launch vehicle stage recovery operations from Indian and Chinese launch programs (Bhattacharjee 2022; Jones 2023);
- Increased launch frequency from foreign launch programs in China, India, and Australia;
- Development of launch programs and expenditure of launch vehicles from Indonesia and South Africa (Nugraha et al. 2022; SANSA 2023); and
- Increased commercial fishing pressure and maritime shipping.

4.4 Cumulative Effects Analysis

4.4.1 Biological Resources

All past, present, and reasonably foreseeable projects have the potential to contribute additive adverse effects to the marine environment when considered cumulatively with the Proposed Action.

Launch vehicles expended in the study area by India, China, and Australia would additively increase noise, debris, presence of contaminants, and injury risk to marine species through the mechanisms discussed under the Proposed Action. As these launch programs mature over time and new launch programs develop in Indonesia and South Africa, the frequency of launch expenditures would commensurately increase, which in turn increases the likelihood of adverse cumulative impacts. The magnitude of impacts resulting from these expenditures would be variable and dependent upon the specific areas in which stages are expended, the manner vehicles are expended (e.g., explosion in air, explosion on surface of water, breakup on water, etc.), and physical specifications of the expended vehicle. However, given the large scale of the study area in relation to the expected area of individual launch vehicle impacts and expected frequency of impact, it is highly unlikely that any individual area within the study area would experience multiple expenditures of launch vehicles. Although it is possible that the Proposed Action could contribute incremental stressors to a small number of individuals of a given species, which would further compound effects on a given individual already experiencing stress from other launch activities, it is not anticipated that the Proposed Action has the potential to have any measurable additional stress on any marine species populations. Effects attributable to individual launch expenditures would be additive, but overall similar to those discussed in Section 3.3.4. As such, cumulative adverse effects of expenditure of other launch vehicles would not be significant when considered in conjunction with the Proposed Action.

Ongoing maritime shipping operations in the study area would contribute additive cumulative effects through anthropogenic vessel noise, increased risk of contaminant exposure, and increased risk of direct strikes with surface-dwelling species. The Indian Ocean region accounts for over one third of global bulk cargo traffic and two thirds of global liquid energy traffic (Baruah et al. 2023). The study area overlaps directly with Cape of Good Hope shipping lanes commonly used for import and export of major commodities by India, China, Australia, and Indonesia. Vessel traffic in these regions would contribute additive noise and disturbance to marine species, increased risk of accidental release of toxic chemicals or petroleum products, and increased risk of direct strike of surface-dwelling marine species. Over time, vessel traffic in the region is expected to increase as markets in Southeast Asia continue to mature and increase maritime liquid energy imports. However, shipping lanes within the study area receive substantially less traffic than other regions of the Indian Ocean due to the comparative inefficiencies of rounding the Cape of Good Hope as opposed to transiting through the Suez Canal or the Strait of Malacca (Baruah et al. 2023). Given the large scale of the study area and the very low density of marine species within the benthic portions of the study area, the effects of ongoing and increased vessel traffic in the study area are not expected to substantially affect marine species or habitats. Although it is possible that the Proposed Action could contribute incremental stressors to a small number of individuals of a given species, which would further compound effects on a given individual already experiencing stress from maritime shipping, it is not anticipated that the Proposed Action has the potential to have any measurable additional stress on any marine species populations. As such, cumulative adverse effects of ongoing and increased maritime shipping in the study area would not be significant when considered in conjunction with the Proposed Action.

Ongoing commercial fishing operations in the study area would contribute additive cumulative effects through the same mechanisms as vessel traffic in addition to direct harvest pressure on targeted species and indirect pressure on other species resulting in bycatch. The Indian Ocean region accounts for approximately 15 percent of accounted global marine capture harvest and the recent fishery assessments indicate that nearly 30 percent of stocks in the region are not fished within biologically sustainable levels (WFF 2020). Fisheries within the study area are primarily managed under the Southern Indian Ocean Fisheries Agreement, which regulates bottom contact-fishing and total allowable catch of toothfish; however, management rules for specific fisheries are limited and enforcement varies by nation (WFF 2020). Commercial fishing activities adversely affect targeted marine species directly through harvest activities as well as indirect effects to non-target species through bycatch. Commercial fishing pressure within the region is expected to increase over time as demand for fish products continues to increase worldwide. However, the study area is primarily comprised of open, benthic habitat and does not have high density of commercially viable fisheries. Those higher quality areas which do exist would be avoided by Proposed Action. Given the large scale of the study area and the very low density of marine species within the benthic portions of the study area, the effects of ongoing and increased commercial fishing in the study area are not expected to substantially affect marine species or habitats. Although it is possible that the Proposed Action could contribute incremental stressors to of individuals of a given species, which would further compound effects on a given individual already experiencing stress from commercial fishing, it is not anticipated that the Proposed Action has the potential to have any measurable additional stress on any marine species populations. As such, cumulative adverse effects of ongoing and increased commercial fishing in the study area would not be significant when considered in conjunction with the Proposed Action.

Overall, the Proposed Action, when combined with other past, present, and reasonably foreseeable actions, is not expected to result in significant cumulative effects on biological resources. Expenditure of launch vehicles by foreign nations, maritime shipping, and commercial fishing pressure would contribute additive adverse effects to marine species through the mechanisms addressed above. However, given the large scale of the study area and relative low density of marine species, the Proposed Action, when combined with other past, present, and reasonably foreseeable actions, is not expected to result in significant cumulative effects on biological resources.

Chapter 5
List of Preparers, Independent Evaluators, and Agencies and Persons Consulted

5.1 List of Preparers

Name	**Title**	**Area of Contribution**
SpaceX		
Kim Tice, M.S., C.S.P, A.S.P M.S. Systems Engineering B.S. Mechanical Engineering Years of Experience: 30	Senior Environmental Engineer	Document Preparation
Katy Groom, P.E. B.S. Environmental Engineering Years of Experience: 12	Manager, Environmental Regulatory Affairs	Quality Control
Kelsey Condell, M.S. M.S. Biology B.S. Wildlife and Fisheries Conservation Biology Years of Experience: 12	Environmental Engineer	Document Preparation

5.2 List of Independent Evaluators

Stacey Zee, Manager, Operations Support Branch
FAA Office of Commercial Space Transportation

Amy Hanson, Environmental Protection Specialist
FAA Office of Commercial Space Transportation

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Appendix A
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Appendix B
NMFS Consultation Materials

U.S. Department of Transportation
Federal Aviation Administration

Office of Commercial Space Transportation

800 Independence Ave., SW.
Washington, DC 20591

2 February 2024

Consulting Biologist
Endangered Species Act Interagency Cooperation Division
Office of Protected Resources
National Marine Fisheries Service
Silver Spring, MD 20910

Subject: 2nd Stage Landing Area in the Indian Ocean to Support Endangered Species Act Section 7 Consultation with the National Marine Fisheries Service as supplemental information for Programmatic Concurrence Letter for Launch and Reentry Vehicle Operations dated 31 January 2022

Dear Consulting Biologist,

The Federal Aviation Administration (FAA) Office of Commercial Space Transportation completed a programmatic Endangered Species Act (ESA) consultation with National Marine Fisheries Service (NMFS) Office of Protected Resources (OPR) for launch and reentry operations in the marine environment on January 31, 2022. NMFS concurred with the FAA's determination that the space launch and reentry activities presented in the programmatic consultation would not adversely affect ESA-listed species or designated critical habitat and issued a Programmatic Letter of Concurrence (LOC)[1].

On 4 April 2023, the FAA transmitted to NMFS a biological assessment for SpaceX landings in the Pacific Ocean,[2] in accordance with the FAA's obligations under Section 7(a)(2) of the Endangered Species Act (ESA). That consultation package described the affected environment and environmental impacts of Starship/Super Heavy operations at the Boca Chica, Texas Launch Site. SpaceX's proposed operations included launches originating from Boca Chica, as well as site-specific analysis for landings in the Gulf of Mexico and in the Pacific Ocean.

The purpose of this letter is to provide your office with information to supplement the previous

[1] See Programmatic Concurrence Letter for Launch and Reentry Vehicle Operations in the Marine Environment and Starship/Super Heavy Launch Vehicle Operations at SpaceX's Boca Chica Launch Site, Cameron County, TX, dated January 2022.

[2] See: Concurrence Letter for the Endangered Species Act Section 7 Consultation for FAA's Proposed Licensing of SpaceX Starship/Super Heavy Early Developmental Phase Launch and Reentry Operations for First Three Flights in the Gulf of Mexico and North Pacific Ocean, dated 14 April 2023 (Consultation number: OPR-2023-00318).

consultation with similar proposed activities in the Indian Ocean, and to request concurrence from your office on conclusions reached from the FAA's literature review of protected resources and the FAA's analysis of effects resulting from second stage landing activities within the new Action Area of the Programmatic LOC.

Based on the information included in this letter, the FAA has concluded that the proposed action "may affect, but not likely adversely affect" the ESA-listed oceanic whitetip shark (*Carcharhinus longimanus*), scalloped hammerhead shark (*Sphyrna lewini*), green sea turtle (*Chelonia mydas*)[3], hawksbill sea turtle (*Eretmochelys imbricata*), leatherback sea turtle (*Dermochelys coriacea*), loggerhead sea turtle (*Caretta caretta*)[3], olive ridley sea turtle (*Lepidochelys olivacea*), blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physalus*), sei whale (*Balaenoptera borealis*) and sperm whale (*Physeter macrocephalus*). Because the proposed activities would occur entirely outside of the territorial waters of the U.S., the proposed second stage landings in the Indian Ocean would have no effect on designated or proposed critical habitat for these ESA-listed species. A summary of the FAA's analysis is included below.

Action Area: Indian Ocean Landing Area

In general, the action area includes a portion of the Indian Ocean where Starship second stage landing activities are proposed to occur, hereafter referred to as the Indian Ocean Landing Area. This area is generally between S 15 and S 30 degrees latitude in the southern Indian Ocean in waters greater than 200 nautical miles (nm) (370 kilometers [km]) from land. This western portion of the Indian Ocean Landing Area is east of Madagascar and south of Mauritius and Réunion. The second stage landing area continues east and is south of Cocos (Keeling) Islands and Christmas Island off the coast of Indonesia. Figure 1 shows a map of the Indian Ocean Landing Area.

SpaceX Proposed Activities requiring FAA Licensing

SpaceX is proposing a Starship second stage landing area in the Indian Ocean to accommodate new trajectories[4] proposed by SpaceX. To support this effort, SpaceX plans on conducting 5 landings per year within the Indian Ocean Landing Area. SpaceX is currently operating under the Operational Phase as specified in the LOC, which consists of up to 5 Super Heavy Launches per year. The proposal to land up to 5 Starships in the Indian Ocean would add an additional geographic location for second stage (Starship) landings, and would not increase the number of operations described in the LOC. The landings in the Indian Ocean would replace landings originally analyzed in the LOC and in the 2022 Programmatic Environmental Assessment. The 5 Super Heavy launches in the Operational Phase could still include the integrated second stage, which would result in a total of 5 Starship landings and 5 Super Heavy landings per year. SpaceX is still iterating towards the goal of full reusability of both stages. Once the vehicles are fully reusable, SpaceX would land up to five Starships and up to 5 Super Heavies annually on a floating platform or back on land. Super Heavy may land on a floating platform in the Gulf of Mexico or back on land. Starship could land on a floating platform in the Gulf of Mexico or in the Pacific Ocean, or back on

[3] The FAA determined that three green sea turtle distinct population segments (DPS) overlap with the Action Area—the East Indian-West Pacific DPS, North Indian DPS, and the Southwest Indian Ocean DPS.
[4] The trajectory is coordinated and submitted to the FAA through a Flight Data Package and approved prior to each launch. SpaceX is required to be within the parameters described in the Flight Data Package. The action area described in this LOC would cover any trajectory SpaceX would submit to the FAA which targets landing in the Indian Ocean.

land as described in the 2022 Programmatic Environmental Assessment.

The proposed action involves a second stage (Starship) descent along planned trajectories[5] that meet operational requirements specified for each launch event. Landing events generally proceed as follows:

- After ascent engine cutoff, Starship would retain residual propellant in the main tanks and in the header tanks. Following the in-space coast phase, Starship would begin its passive descent.
- During descent, when the second stage is supersonic, a sonic boom (overpressure of high-energy impulsive sound) would be generated but would be directed entirely at the ocean surface without impacting any land areas.
- Some residual propellant (approximately 30,650 kg in the headers and approximately 70,000 kg in the mains) would remain in Starship. Starship would impact the Indian Ocean intact, horizontally, and at terminal velocity (i.e., the steady speed achieved by a freely falling object). The SpaceX license application materials include a Starship reentry into the Earth's atmosphere following the second engine cut off (SECO) and would result in a break up upon reentry or an intact landing. Any reentries or breakups prior to the SECO would be considered an anomaly and is not appropriate for consideration under consultation.

An explosion would most likely occur within the transfer tube, simultaneously igniting the headers and main because the fuel system is connected. The transfer tube is used to transfer fuel between the headers and main. The total propellant remaining would include any remaining propellant in the transfer tube. The transfer tube would have different amounts of fuel depending on the timing and quantity of fuel distribution by the flight computer between the headers and main.

SpaceX analyzed the combined explosive weight from the headers and main as a single explosion. The explosion would generate a sound wave which starts within Starship and continues into atmospheric air before impacting the water.

Conservation Measures

SpaceX contractors and subject matter experts, in preparation of this consultation, completed a literature review in August 2023 that identified ESA-listed species with potential occurrence in the Action Area and locations within the Action Area that may (1) aggregate ESA-listed species and prey for ESA-listed species, (2) offer other refugia for ESA-listed species, or (3) otherwise provide conservation benefit. These areas are shown in the maps in Attachment 1 (Conservation Measures). Potential Indian Ocean Landing Areas within the Action Area will be prioritized to avoid these locations, referred to as avoidance areas and further defined in Attachment 1 (Conservation Measures). Conservation measures are incorporated into SpaceX's proposed action for the purposes of avoiding and minimizing potential adverse effects.

[5] The second stage has a flight termination system that will activate and destroy the vehicle if the flight is not on the planned trajectory.

Description of ESA-listed Species within the Indian Ocean Landing Area

At the behest of the FAA, SpaceX conducted a literature review of ESA-listed endangered and threatened species with known or presumed distributions in the Indian Ocean Landing Area that may be affected by the proposed activities. Information sources included data obtained from NMFS endangered species web sites; experts in the occurrence and distribution of marine mammals, sea turtles, and fishes; and a review of available literature through established academic journals (ex., PLOS, Endangered Species Research, Marine Mammal Science, etc.), and review of monthly new literature summaries provided by the Navy's Marine Applied Research and Library Information Network (MARLIN). Focused distribution and conservation information for each species is included below.

Oceanic Whitetip Shark

NMFS completed a comprehensive status review of the oceanic whitetip shark and based on the best scientific and commercial information available, including the status review report[6], listed the species as threatened on 1 March 2018 (83 FR 4153). NMFS determined that oceanic whitetip sharks within the Indian Ocean, for the purposes of assessing regional threats and population viability, are grouped within the Indian Ocean management unit. Because the oceanic whitetip shark's range is largely outside of U.S. jurisdiction, one of the major components of oceanic whitetip shark conservation focuses on strategic international cooperation. As a pelagic species that occurs mostly offshore, oceanic whitetip shark is managed on the high seas across its global range by four major tuna-focused Regional Fisheries Management Organizations. Oceanic whitetip sharks within the Indian Ocean are managed by the Indian Ocean Tuna Commission (IOTC). Oceanic whitetip shark conservation is most threatened by commercial fisheries bycatch combined with demand for its fins. They are frequently caught in pelagic longline, purse seine, and gillnet fisheries worldwide and their fins are highly valued in the international trade for shark products.[6]

While little life history information exists from the Indian Ocean, based on similarities in oceanographic conditions that affect life history characteristics, NMFS considers the life history of oceanic whitetip sharks in the Indian Ocean similar to the life history of those in the Pacific Ocean. This species has a clear preference for open ocean waters, with abundances decreasing with greater proximity to continental shelves. Oceanic whitetip sharks are considered hadopelagic, meaning that they spend their entire lives in the ocean's epipelagic zone, which extends from the surface to about 200 m deep, and far offshore.

Preferring warm waters near or over 20 degrees Centigrade (68 degrees Fahrenheit), and offshore areas, the oceanic whitetip shark is known to undertake seasonal movements to higher latitudes in the summer[7] and may regularly explore deep depths and low temperature environments as a foraging strategy.[8]

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[6] Bonaccorso, E., Ordóñez-Garza, N., Pazmiño, D. A., Hearn, A., Páez-Rosas, D., Cruz, S. & Guayasamin, J. M. (2021). International fisheries threaten globally endangered sharks in the Eastern Tropical Pacific Ocean: the case of the Fu Yuan Yu Leng 999 reefer vessel seized within the Galápagos Marine Reserve. Scientific Reports, 11(1), 14959.
[7] Young, C. N., & Carlson, J. K. (2020). The biology and conservation status of the oceanic whitetip shark (*Carcharhinus longimanus*) and future directions for recovery. *Reviews in Fish Biology and Fisheries, 30*(2), 293- 312.
[8] Young, C. N., Carlson, J., Hutchinson, M., Hutt, C., Kobayashi, D., McCandless, C. T., & Wraith, J. (2016). Status review report: oceanic whitetip shark (*Carcharhinius longimanus*). Final Report to the National Marine Fisheries Service, Office of Protected Resources.

Scalloped Hammerhead Shark—Indo-West Pacific DPS

In 2011, NMFS determined scalloped hammerhead sharks to be overfished based on a stock assessment of scalloped hammerhead sharks in U.S. waters.[9] As a result, NMFS issued moratoriums on take and possession in 2011. In 2014, NMFS listed the Central and Southwest Atlantic and Indo-West Pacific DPSs of the scalloped hammerhead population as threatened and the Eastern Pacific DPS as endangered under the ESA (79 FR 52576). The Central Pacific, Northwest Atlantic, and Gulf of Mexico DPSs of scalloped hammerhead sharks have not been listed under the ESA.

The scalloped hammerhead shark is a coastal and semi-oceanic species distributed in temperate to tropical waters across the globe. Scalloped hammerhead sharks inhabit the surface to depths of 275 meters (900 feet) and prefer coastal waters with temperatures between 23 and 26 degrees Centigrade (73 to 79 degrees Fahrenheit);[10] with animals generally remaining close to shore during the day and moving into deeper waters to feed at night. Daly-Engel et al. (2012) found that females remain close to coastal habitats, while males disperse across larger open ocean areas.[11] Thomas et al. (2021) determined that fisheries bycatch, particularly of juvenile scalloped hammerhead (and other hammerhead shark species) was the greatest threat in waters off the coast of India.[12]

Green Sea Turtle--North Indian Ocean DPS, Southwest Indian Ocean DPS, East Indian-West Pacific DPS

The green turtle was listed under the ESA on July 28, 1978 (43 FR 32800). Breeding populations of the green turtle in Florida and along the Pacific Coast of Mexico were listed as endangered; all other populations were listed as threatened including the three DPSs with distributions overlapping the Action Area. Within the Indian Ocean, nesting beaches are known to occur within the Seychelles Islands, French Island holdings (Comoros Islands, Esparses Islands), locations along the Indian Coast, Pakistani coast, locations on the Arabian Peninsula and countries along the Red Sea (Djibouti, Egypt, Eritrea, Iran, Kuwait, Oman, Saudi Arabia, Somalia, Sudan, and Yemen), and locations along the Malaysian coast and Indonesian outer islands.[13,14] Ameri et al. noted coastal development and erosion, bycatch, pollution, direct exploitations, vessel strikes in nearshore foraging and resting habitats, predation (on eggs and

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[9] Hayes, C. G., Jiao, Y., & Cortés, E. (2009). Stock assessment of scalloped hammerheads in the western North Atlantic Ocean and Gulf of Mexico. *North American Journal of Fisheries Management, 29*(5), 1406-1417.

[10] Huynh, H. H., & Tsai, W. P. (2023). Estimation of the population status of smooth hammerhead shark (Sphyrna zygaena) and scalloped hammerhead shark (Sphyrna lewini) in the Northwest Pacific Ocean: A data-limited approach. *Journal of Sea Research, 195*, 102434.

[11] Daly-Engel, T. S., Seraphin, K. D., Holland, K. N., Coffey, J. P., Nance, H. A., Toonen, R. J., & Bowen, B. W. (2012). Global phylogeography with mixed-marker analysis reveals male-mediated dispersal in the endangered scalloped hammerhead shark (Sphyrna lewini). *PLoS One, 7*(1), e29986.

[12] Thomas, S., Muktha, M., Sen, S., Kizhakudan, S. J., Akhilesh, K. V., Purushottama, G. B., & Nataraja, G. D. (2021). Status of the hammerhead shark (Carcharhiniformes: Sphyrnidae) fishery in Indian waters with observations on the biology of scalloped hammerhead Sphyrna lewini (Griffith & Smith, 1834). *Aquatic Conservation: Marine and Freshwater Ecosystems, 31*(11), 3072-3086.

[13] Sanchez, C., Lucas, C., Odhiambo, O., Beswick, J., & van de Geer, C. (2020). A juvenile green turtle long distance migration in the Western Indian Ocean. *Marine Turtle Newsletter*, (160), 5-7.

[14] Mobaraki, A. S., Ghasemi, M. M., & Kami, H. G. (2019). First record of green sea turtle nesting at Sheedvar Island, Persian Gulf, Iran. *Indian Ocean Turtle Newsl*, 30, 5-7

hatchlings), and climate change as primary threats for green sea turtles within the Action Area.[15]

For open ocean movements, tagging of green sea turtles since the 1970s provides the most complete understanding of distributions within the Indian Ocean. Long-term tagging and recapture records maintained for green turtles in Oman, under the Ministry of Regional Municipalities and Environment/Nature Conservation, has provided information on green turtle movements.[16] Some turtles in the area migrate long distances from distant feeding grounds to nesting beaches, while others are non-migratory.

Loggerhead Turtle—Southwest Indian Ocean DPS, Southeast Indo-Pacific DPS, and North Indian Ocean DPS

On September 22, 2011, NMFS determined that the Southwest Indian Ocean DPS and Southeast Indo-Pacific DPS were threatened and the North Indian Ocean DPS was endangered (76 FR 58868). Loggerhead turtles are found worldwide mainly in subtropical and temperate regions of the Atlantic, Pacific, and Indian Oceans, and in the Mediterranean Sea.[17] Based on satellite telemetry, loggerheads migrate along a north-south trans-equatorial axis in the Indian Ocean. Loggerheads follow the currents of their respective north and south oceanic gyres between feeding, breeding, and developmental habitats. Loggerheads present in the Indian Ocean nest along beaches of Oman (Masirah Isalnd), Mozambique, Madagascar, as well western Australia beaches (from Steep Point in the south to the Muiron Islands in the north). The primary threat to loggerhead sea turtles in the Indian Ocean is commercial fisheries bycatch, followed by impacts associated with climate change, coastal development, predation, and poaching of eggs from nests.[18]

Olive Ridley Sea Turtle

Olive ridley sea turtles that nest along the Pacific coast of Mexico are listed as endangered under the ESA in 1978, while all other populations are listed under the ESA as threatened (43 FR 32800). Most olive ridley turtles lead a primarily open ocean existence.[19] Nesting sites for olive ridley turtles are widely dispersed throughout the Indian Ocean. Nesting occurs along the entire coast of the Indian subcontinent from Pakistan in the Arabian Sea to Bangladesh in the Bay of Bengal. Other nesting

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[15] Al Ameri, H. M., Al Harthi, S., Al Kiyumi, A., Al Sariri, T. S., Al-Zaidan, A. S. Y., Antonopoulou, M. & Godley, B. J. (2022). Biology and conservation of marine turtles in the northwestern Indian Ocean: a review. Endangered Species Research, 48, 67-86.

[16] Mobaraki, A., RastegarPouyani, E., Kami, H. G., & Khorasani, N. (2020). Population study of foraging Green sea turtles (*Chelonia mydas*) in the Northern Persian Gulf and Oman Sea, Iran. *Regional Studies in Marine Science, 39*, 101433.

[17] Conant, T. A., Dutton, P. H., Eguchi, T., Epperly, S. P., Fahy, C. C., Godfrey, M. H., ... & Witherington, B. E. (2009). Loggerhead sea turtle (*Caretta caretta*) 2009 status review under the US Endangered Species Act. Report of the loggerhead biological review Team to the National Marine Fisheries Service, 222, 5-2.

[18] Lohe, A., & Possardt, E. (2021). Loggerhead Sea Turtle (*Caretta caretta*) North Indian Ocean DPS, Southwest Indian Ocean DPS, Southeast Indo-Pacific Ocean DPS, South Pacific Ocean DPS, South Atlantic Ocean DPS, Northeast Atlantic Ocean DPS, and Mediterranean Sea DPS 5-Year Review: Summary and Evaluation.

[19] Cáceres-Farias, L., Reséndiz, E., Espinoza, J., Fernández-Sanz, H., & Alfaro-Núñez, A. (2022). Threats and vulnerabilities for the globally distributed Olive Ridley (*Lepidochelys olivacea*) sea turtle: A historical and current status evaluation. *Animals, 12*(14), 1837.

locations may include Lakshadweep, Andaman and Nicobar Islands,[20] Oman,[21] and Maldives Islands.[22] Natural habitat degradation, coastal development, pollution, bycatch, climate change, predation by humans and animals, infectious diseases and illegal trade are the most notorious threats to explain olive ridley populations rapid declines.[13] Behera and Kaiser (2020) noted tidal inundation of nests and depredation by terrestrial predators (dogs, pigs, jackals, hyenas, and monitor lizards) accounted for a 61 percent nest failure rate at one of the largest olive ridley rookery sites at Gahurmatha, India.[23]

Hawksbill Sea Turtle

The hawksbill sea turtle is listed as endangered under the ESA in 1978 (35 FR 8491). With worldwide numbers likely below 25,000 females nesting annually,[24] hawksbill turtles are critically endangered, and their populations are declining throughout their range.[25] Nesting occurs along the entire coast of the Indian subcontinent from Pakistan in the Arabian Sea to Bangladesh in the Bay of Bengal, as well as Chagos Islands and the Maldives.[26]

Direct harvest of eggs and nesting adult females from beaches, as well as direct hunting of turtles in foraging areas, continues in many countries within the Indian Ocean basin that support nesting beaches.[27] The second-most significant threat to hawksbill sea turtles is loss of nesting habitat caused by rapid coastal development. Coastal pollution as a result of increased development degrades water quality, particularly coral reefs, which are primary foraging areas for hawksbills. Due to their preference for nearshore areas, hawksbills are particularly susceptible to nearshore fisheries gear such as drift nets, entanglement in gill nets, and capture on fishhooks.[28e]

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[20] Malarvizhi, A., Ilaamurughu, M. M., & Mohan, P. M. (2022). The Probable Cause for Nesting Pattern of Olive Ridley (*Lepidochelys olivacea*) at Ramnagar Beach, North East Coast of Andaman Island, India. Open Journal of Marine *Science, 13*(1), 7-27.

[21] Rees A.F., Papathanasopoulou N.A., Al Sariri T.H., Godley B.J. (2021). Diving behaviour of two olive ridley turtles during the inter-nesting period at Masirah Island, Oman. *Indian Ocean Turtle Newsletter 33*:2-6.

[22] Stelfox, M., Burian, A., Shanker, K., Rees, A. F., Jean, C., Willson, M. S. & Sweet, M. (2020). Tracing the origin of olive ridley turtles entangled in ghost nets in the Maldives: A phylogeographic assessment of populations at risk. Biological conservation, 245, 108499.

[23] Behera, S., & Kaiser, H. (2020). Threats to the nests of Olive Ridley Turtles (*Lepidochelys olivacea* Eschschholtz, 1829) in the world's largest sea turtle rookery at Gahirmatha, India: need for a solution. *Herpetology Notes, 13,* 435-442.

[24] Gaos, A. R., Kurpita, L., Bernard, H., Sundquist, L., King, C. S., Browning, J. H. & Martin, S. L. (2021). Hawksbill nesting in Hawai 'i: 30-year dataset reveals recent positive trend for a small, yet vital population. Frontiers in Marine Science, 8, 770424.

[25] Hof, C. A. M., Desbiens, A., Kinch, J., Fitzsimmons, N., Versace, H., Amon, A. & Jensen, M. (2023). From rookeries to foraging grounds: understanding regional connectivity and genetic diversity in hawksbill turtles. Frontiers in Marine Science, 10, 1-12.

[26] National Marine Fisheries Service, and U. S. Fish and Wildlife Service (2007). Hawksbill Sea Turtle (Eretmochelys imbricata) 5-year Review: Summary and Evaluation. Silver Spring, MD: National Marine Fisheries Service.

[27] Van Houtan, K. S., D. L. Francke, S. Alessi, T. T. Jones, S. L. Martin, L. Kurpita, C. S. King, and R. W. Baird (2016). The developmental biogeography of hawksbill sea turtles in the North Pacific. *Ecology and Evolution, 6*(8), 2378– 2389.

[28] Gaos, A. R., Lewison, R. L., Wallace, B. P., Yañez, I. L., Liles, M. J., Nichols, W. J., ... & Seminoff, J. A. (2012). Spatial ecology of critically endangered hawksbill turtles *Eretmochelys imbricata*: implications for management and conservation. *Marine Ecology Progress Series, 450*, 181-194.

Leatherback Sea Turtle

The leatherback sea turtle is listed as a single population and is classified as endangered under the ESA (35 FR 8491). The leatherback sea turtle is the most widely distributed of all sea turtles, found from tropical to subpolar oceans. Because leatherback nest on tropical and occasionally subtropical beaches, it has the most extensive range of any turtle.[29] Leatherbacks are also the most migratory sea turtles, with populations traversing the Pacific, Atlantic, and Indian oceans between nesting and foraging grounds, and migratory routes extending into subpolar regions.[9] Leatherbacks range widely throughout the Indian Ocean, although nesting appears restricted to a few scattered areas. In the northeast Indian Ocean and Southeast Asia, leatherbacks nest on the Indian mainland, Andaman and Nicobar Islands, Sri Lanka, western coast of Thailand, Sumatra, and Java, with recent nesting reports from Myanmar.[30] The only known significant nesting of leatherbacks in the southwest Indian Ocean occurs at the Maputaland rookery in South Africa and Mozambique with a new nesting report from Kenya reported in 2020 and Miramar in 2021.[31]

Like other sea turtles in the Indian Ocean, leatherbacks are threatened by natural habitat degradation, coastal development, pollution, bycatch, climate change, predation by humans and animals, infectious diseases, and illegal trade.

Blue Whale

The blue whale is listed as endangered under the ESA and as depleted under the Marine Mammal Protection Act (MMPA) throughout its range. The subspecific taxonomy has not been fully resolved, but there are five currently recognized subspecies. Two of these subspecies, both considered "pygmy type" subspecies, may occur within the Action Area:

- *B. m. indica*, a subspecies of blue whale that appears to stay year-round between Somalia and Sri Lanka;[32] and
- *B. m. brevicauda*, a subspecies of blue whale associated by Ichihara (1966) with the portion of the Indian Ocean south of Madagascar, and in the eastern Indian Ocean west of Australia and Indonesia.[33]

These two populations are assumed to be the same subspecies based on audio structure of recorded vocalizations.[34]

B. m. indica. Blue whales of subspecies *B. m. indica* are considered to be resident within the

[29] Witzell, W. N. (1999). Distribution and relative abundance of sea turtles caught incidentally by the US pelagic longline fleet in the western North Atlantic Ocean, 1992-1995. *Fishery Bulletin, 97*(1), 200-211.
[30] Platt, S. G., Kingsley, C., Latt, A. Z., Platt, K., & Owens, D. W. (2021). Recent nesting record of the Leatherback in coastal Myanmar. *Indian Ocean Turtle Newsletter, 33*, 5-6.
[31] van de Geer, C. H., Karisa, L., & Kiptum J. (2020). First recorded leatherback turtle (Dermochelys coriacea) nesting event in Kenya. *Indian Ocean Turtle Newsletter, 31*, 16-18.
[32] Alling, A., Dorsey, E., Gordon, J., (1991). Blue Whales (Balaenoptera musculus) off the Northeast Coast of Sri Lanka: Distribution, Feeding and Individual Identification, 257.
[33] Ichihara, T. (1966). The pygmy blue whale, Balaenoptera musculus brevicauda, a new subspecies from the Antarctic. Whales, dolphins, and porpoises, 79-111.
[34] Branch, T. A., Stafford, K. M., Palacios, D. M., Allison, C., Bannister, J. L., Burton, C. L. K.,& Warneke, R. M. (2007). Past and present distribution, densities and movements of blue whales *Balaenoptera musculus* in the Southern Hemisphere and northern Indian Ocean. *Mammal Review, 37*(2), 116-175.

northwestern Indian Ocean, based on sightings and strandings reported year-round, as well as distributional gaps to the south and east. However, blue whales undertake migrations within the region. Blue whale distribution in the Northern Indian Ocean is driven by oceanographic changes associated with the monsoons. Specifically, most blue whales feed in productive upwelling areas off Somalia and southern Arabia during the Southwest Monsoon (approximately May-October), while some feed off the southwest coast of India and the west and south coasts of Sri Lanka. The whales then disperse during the Northeast Monsoon (approximately December-March) to areas such as the east and south coasts of Sri Lanka, west of the Maldives, the Indus Canyon, and parts of the southern Indian Ocean. Acoustic evidence suggests that some of these whales may travel as far south as the sub-Antarctic waters around Crozet Islands in the southern hemisphere in late summer and in the northern hemisphere in early fall, though calling was much less frequent compared with the other blue whale populations simultaneously using the area.[35]

B. m. brevicauda. The subspecies *B. m. brevicauda* undergoes seasonal migrations to breeding and feeding locations, and are generally tied to highly productive areas with dense aggregations of krill. Pygmy blue whales mainly remain north of the Antarctic Circumpolar Current (52-56 degrees S)[28] and are most abundant in waters off Australia, Madagascar, and New Zealand.[36] Australian pygmy blue whales likely spend winter in waters off Indonesia before traveling south along western Australia to feed in summer.[37]

Blue whale annual density in the Action Area is estimated to be 0.00003 whales/km^2 based on data reported in the Navy's SURTASS EIS/OEIS for locations in the northern and eastern Indian Ocean.

Fin Whale

The fin whale is listed under the ESA as endangered throughout its range and depleted under the MMPA. Based on recent acoustic studies,[38] there is a high likelihood that fin whales in the Indian Ocean migrate from south to north at the end of the austral summer after summer feeding off of Antarctica, and then move northward to sub-tropical and tropical latitudes in the winter while remaining in the Southern Hemisphere.[39] Accordingly, fin whales are probably most abundant in the Action Area during austral winter months, and likely absent during the southern hemisphere's warmer months while feeding off the Antarctic coast, with a range from approximately 25 degrees S latitude to higher latitudes towards the Antarctic coast.

Fin whale annual density in the Action Area is estimated to be 0.00087 whales/km^2 (CV = 0.89) based on

[35] Samaran, F., Stafford, K. M., Branch, T. A., Gedamke, J., Royer, J. Y., Dziak, R. P., & Guinet, C. (2013). Seasonal and
[36] Bailey, H., Mate, B. R., Palacios, D. M., Irvine, L., Bograd, S. J., & Costa, D. P. (2009). Behavioural estimation of blue whale movements in the Northeast Pacific from state-space model analysis of satellite tracks. *Endangered Species Research, 10*, 93-106.
[37] Thums, M., Ferreira, L. C., Jenner, C., Jenner, M., Harris, D., Davenport, A. & McCauley, R. (2022). Pygmy blue whale movement, distribution and important areas in the Eastern Indian Ocean. *Global Ecology and Conservation, 35*, e02054.
[38] Leroy, E. C., Samaran, F., Stafford, K. M., Bonnel, J., & Royer, J. Y. (2018). Broad-scale study of the seasonal and geographic occurrence of blue and fin whales in the Southern Indian Ocean. *Endangered Species Research, 37*, 289-300.
[39] Širović, A., Hildebrand, J. A., Wiggins, S. M., & Thiele, D. (2009). Blue and fin whale acoustic presence around Antarctica during 2003 and 2004. Marine Mammal Science, 25(1), 125-136.

the average of seasonally stratified data reported in the Navy's SURTASS EIS/OEIS for locations in the northern and eastern Indian Ocean. The seasonal density estimates, in number of whales/km^2, were 0.00001 in winter, 0.00099 in spring, 0.00128 in summer, and 0.00121 in fall non-austral seasons.

Sei Whale

The sei whale is listed as endangered under the ESA and as depleted under the MMPA throughout its range. There is no designated critical habitat for this species. Sei whales have a worldwide distribution and are found primarily in cold temperate to subpolar latitudes. During winter, sei whales can be found in warmer tropical waters. In the Southern Hemisphere, the population is estimated to range between 9,800 and 12,000 (no CV) individuals.[40,41] The IWC reported an estimate of 9,718 sei whales (no CV) based on results of surveys between 1978 and 198842 (IWC 1996). There are no reliable distribution data for sei whales within the Indian Ocean; however, they likely follow the same seasonal occurrence patterns as fin whales, with an austral summer feeding season along the Antarctic coast, and northern migrations to subtropical waters within the Action Area (generally 20 to 25° S latitude as the northern limit).

Sperm Whale

The sperm whale is listed as endangered under the ESA, but there is no designated critical habitat for this species. In the western Indian Ocean, there is evidence that concentrations of mixed female/immature whale groups exist south of the Seychelles.[43] In the central Indian Ocean, concentrations of sperm whales have been recorded to the north of St. Paul and Amsterdam Islands in the austral summer.[44]

No estimates of density, abundance or trends are available for most cetacean species in the Indian Ocean, given the very limited survey effort in this region.[45] Whitehead (2018) estimated current sperm whale abundance to be approximately 300,000– 450,000 worldwide.[46] Although his estimates are based on extrapolating surveyed areas to unsurveyed areas without a systematic survey design, these are the best available and most current estimates of sperm whale abundance in the Indian Ocean. Using extrapolation from nearby surveyed areas, sperm whale abundance in the Indian Ocean ranges from

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[40] Mizroch, S. A., D. W. Rice, D. Zwiefelhofer, J. M. Waite, and W. L. Perryman. (2009). Distribution and movements of fin whales in the North Pacific Ocean. Mammal Review 39(3): 193–227.
[41] Perry, S. L., D. P. DeMaster and G. K. Silber. 1999. The great whales: History and status of six species listed as endangered under the U.S. Endangered Species Act of 1973. Marine Fisheries Review Vol. 61 Issue 1. Pages 1–74.
[42] International Whaling Commission. (2016). Report of the Scientific Committee. Journal of Cetacean Research and Management 17: 1–92.
[43] Sarano, F., Girardet, J., Sarano, V., Vitry, H., Preud'Homme, A., Heuzey, R.,& Jung, J. L. (2021). Kin relationships in cultural species of the marine realm: case study of a matrilineal social group of sperm whales off Mauritius island, Indian Ocean. *Royal Society Open Science, 8(*2), 201794.
[44] Gosho, M. E., Rice, D. W., & Breiwick, J. M. (1984). The sperm whale, Physeter macrocephalus. Marine Fisheries Review, 46(4), 54-56.
[45] Kaschner K, Quick NJ, Jewell R, Williams R, Harris CM (2012) Global Coverage of Cetacean Line-Transect Surveys: Status Quo, Data Gaps and Future Challenges. PLoS ONE 7(9): e44075.
[46] Whitehead, H. (2018). Sperm whale: Physeter macrocephalus. In Encyclopedia of marine mammals (pp. 919- 925). Academic Press.

62,000 - 92,000 individuals.[37,47] Whitehead also estimated that the global population is at about 32 percent of historical numbers with an annual population increase of about 1.1 percent per year. Sperm whales are highly nomadic, mobile predators with no known concentration areas in the Indian Ocean. Sightings likely represent transiting individuals and pods. Sperm whale density in the Action Area is estimated to be 0.00093 whales/km^2 based on data reported in the Navy's SURTASS EIS/OEIS data for locations in the northern and eastern Indian Ocean. The seasonal density estimates, in number of whales/km^2, were 0.00096 in winter, 0.00087 in spring, 0.00097 in summer, and 0.00092 in fall non-austral seasons.

Effects of the Action

This section evaluates how, and to what degree, the proposed activities potentially impact ESA-listed species known to occur within the Action Area. The associated stressors vary in intensity, frequency, duration, and location within the Action Area. The stressors considered in this analysis include the following:

- Acoustic (in-air overpressure events resulting from sonic booms and explosions).
- Impact by fallen objects.
- Indirect Effects (impacts on habitat, impacts on prey availability, hazardous materials).
- Cumulative Effects.

The potential direct, indirect, and cumulative impacts of the Proposed Action were analyzed based on these potential stressors interacting with the ESA-listed species and using the best scientific and commercial data available to assess potential impacts. Direct impacts are caused by the action and occur at the same time and place. Indirect impacts could result under two scenarios. First, ESA-listed species could be affected by the Proposed Action later in time; or secondly, they could be affected via an indirect pathway as a result of an impact on one resource inducing an impact on another resource.

Sonic Boom Overpressure Events

A sonic boom is the sound associated with the shock waves created by a vehicle traveling through the air faster than the speed of sound. As described OPR-2021-02908, Programmatic Concurrence for Launch Vehicle and Reentry Operations,[48] sonic booms that would occur during descent and landing would intercept the ocean's surface. However, exceptionally little energy from in-air noise is transmitted into water.[49] Due to the limited occurrences of ocean landings, the low magnitude of the sonic booms (no greater than 2 pounds per square foot [psf] for Starship), the substantial attenuation of the sonic booms at the air/water interface, and the exponential attenuation with water depth, sonic booms would not result in impacts on marine species beneath the surface.

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[47] Whitehead, H. (2002). Estimates of the current global population size and historical trajectory for sperm whales. Marine Ecology Progress Series, 242, 295-304.
[48] NMFS (2022). Programmatic Concurrence Letter for Launch and Reentry Vehicle Operations in the Marine Environment and Starship/Super Heavy Launch Vehicle Operations at SpaceX's Boca Chica Launch Site, Cameron County, TX. January.
[49] FAA (2017). Final Environmental Assessment and Finding of No Significant Impact for Issuing a License to LauncherOne, LLC for LauncherOne Launches at the Mojave Air and Space Port, Kern County, California.

Cetaceans and sea turtles spend most of their time (>90 percent for most species) entirely submerged below the surface. When at the surface, their bodies are almost entirely below the water's surface, with only the blowhole or turtle's head exposed briefly to allow breathing. This minimizes in-air noise exposure, both natural and anthropogenic, essentially 100 percent of the time because their ears are nearly always below the water's surface.

In-air noise caused by sonic boom re-entry may affect ESA-listed sharks, sea turtles, and marine mammals within the Action Area. ESA-listed species exposed to noise generated by a sonic boom would likely exhibit brief behavioral changes and resume normal behavior exhibited prior to the overpressure event. Because of the limited time ESA-listed species would be expected to be at or near the water's surface (oceanic whitetip shark is expected to be submerged 100 percent of the time, while ESA-listed marine mammals and sea turtles are expected to be submerged 90 percent of the time), the high altitude where the descending Starship would generate a sonic boom, the known properties of sound deflection at the surface of water, and the rapid attenuation of the reduced sound that could be perceived under water, the FAA concludes that sonic boom noise is discountable (adverse effects are extremely unlikely to occur) and insignificant (adverse effects are unmeasurable or undetectable).

Near-Surface Explosions and Overpressure Events

Overpressure events from Starship explosions generated during impact may affect ESA-listed sharks, sea turtles, and marine mammals within the Action Area. ESA-listed species, if in close proximity to the Starship landing location and subsequent explosion, could be at risk of mortality, physical injury, or behavioral changes that would be considered adverse effects.

The FAA independently evaluated and approved an analysis methodology developed by SpaceX that relies on the robust application of scientific principles; a conservative estimation of the necessary coefficients based on available, existing reference data; and the application of appropriate species harassment thresholds taken directly from NMFS. The approach for this analysis was derived from the assessment developed in the 2023 NMFS Consultation Letter, Consultation response, and Underwater Noise Analysis Methodology for Starship/Super Heavy Attachment 1[50] (2023 NMFS Consultation). This analysis was used to estimate the affected area from the explosive event over which NMFS thresholds could be exceeded for ESA-listed species, if present. Propellant would remain in the header tanks and the main tanks, approximately 30,650 kgs and 70,000 kgs, respectively. An explosion would most likely occur within the transfer tube, simultaneously igniting the headers and main because the fuel system is connected. Through discussion with NMFS, SpaceX determined that assessing the explosion as a single event was the most appropriate analysis, and SpaceX analyzed the combined explosive weight from the transfer tube, headers and main as a single explosion (see Attachment 2).

For the header tanks, an explosive weight of 3,647.35 kilograms (kg) was used based on an 11.9 percent explosive yield, which is highly conservative value based on a simulation of uncontained mixing between two close coupled masses of propellant and no barriers impeding their mixing. This is comparable to a Starship impacting the Indian Ocean intact, horizontally, and at terminal velocity. For the main tanks, an explosive weight of 6,300 kg was used based on a 9 percent explosive yield. The analysis for 9 percent yield was used in the 2023 NMFS Consultation, and due to the small variation in propellant mass and

[50] FAA (2023). 2023 NMFS Consultation Letter, Consultation response, and Underwater Noise Analysis Methodology for Starship/Super Heavy.

small change to the propellant mass fill geometry, the assumption that the manner of propellant mixing will remain consistent is still appropriate. Therefore, the total remaining propellant in the headers and main would be 9,947.35kg (3,647.35 kg in the headers plus 6,300 kg in the main). It was further assumed that only half of the explosive energy of the explosive event would enter the water based on the location of the Starship at the time of explosion. Therefore, acoustic effects were calculated using 50 percent of the calculated yield, 4,973.68 kg (See Attachment 2, Calculations for a detailed explanation of effects methodology).

Calculating the potentially affected area, referenced in Attachment A of the 2023 NMFS Consultation, within which ESA-listed marine species could be harassed is one of the required inputs for conducting a quantitative analysis of potential impacts on listed species. Data on the abundance and distribution of the species in the potentially affected area is also required to conduct a quantitative analysis of potential impacts.

According to previous consultations between the U.S. Navy and NMFS, the most appropriate metric for this type of analysis is density (number of animals present per unit area; U.S. Navy 2018), which was discussed above and included in Table 2.

Using the potentially affected area within which ESA-listed marine species could be harassed and the estimates of annual density data available for the ESA-listed species that could be present, SpaceX estimated the number of individuals of each species that could potentially be harassed by an explosive event near the ocean's surface (see Table 2). As shown in Table 2, the number of individuals estimated to be harassed for each ESA-listed species potentially present is less than one.

Based on the modeling results of near-surface explosions described above and in the 2022 PEA, the occurrence probability of a blue whale, fin whale, or sperm whale is sufficiently low to determine that potential adverse effects are discountable (extremely unlikely to occur). Other ESA-listed species potentially occurring in the Action Area (oceanic whitetip shark, scalloped hammerhead shark, sei whale, and the five sea turtle species) were not included in the explosion effects modeling due to a lack of available density data. Sei whales are known to be a temperate species preferring colder waters than typically occur in the Action Area and therefore are expected to have a lower population density and lower potential for harassment or injury than the modeled cetacean species. Both green and hawksbill sea turtles prefer shallow nearshore habitat located inshore of the Action Area, suggesting that their distribution in the Action Area would be limited and densities would likely be sufficiently low as to not result in effects from the Action. Similarly, leatherback, loggerhead, and olive ridleys have strong associations with coastal and neritic waters and occurrences within the Action Area are expected to be limited to rare transits of individual turtles; no effects from explosions are expected to occur for these species. Although densities for oceanic whitetip shark in the Action Area are unknown, the species is expected to occur deeper in the water column than the cetaceans and sea turtles, which need to surface to breathe. Oceanic whitetip sharks have a preference for the surface mixed layer, however unlike cetaceans and sea turtles, remain fully submerged and therefore the sharks are likely to be farther from a near-surface explosion and overpressure event and less likely to be affected than modeled species. Although densities within the Action Area for scalloped hammerhead sharks are also unknown, these sharks are more associated with coastal shallow water habitats with only very limited pelagic occurrence and effects from exposure to explosions are expected to be lower than modeled species. Based on these qualitative assessments, exposure to overpressure events from Starship explosions are anticipated to be discountable (extremely unlikely to occur) for these species.

Impact by Fallen Objects

Debris created by either a near-surface Starship explosion or from a high-altitude breakup of the Starship on descent would create a debris field comprised of mostly heavy-weight metals and some composite (e.g., carbon fiber) materials. Most of these materials would sink rapidly (due to the weight and composition of the steel) through the water column, while some items may stay buoyant on the surface or suspended in the water column before sinking towards the seafloor.

The primary debris fragment groups are made up stainless steel. Other fragmentation groups include silica, aluminum, wiring, battery packs, and plastic.

The debris would be various sizes and masses. The largest debris would come from the Starship structure (barrel section) and would measure approximately 1.83m wide and 3.66m long and weigh approximately 550kg. The smallest fragment would be approximately 3cm by 3 cm (approximately the size of a quarter) and weigh 0.25g. All of the debris would eventually sink but the rate would depend on the object's size, density and shape as well as the drag coefficient of water. Limited information is available on debris from the first two test flights due to the flights ending in anomalies and personnel and equipment limitations. Debris field characteristics are estimated based on modeled Starship breakup and currently available observational data.

If debris from a Starship near surface explosion or high-altitude disintegration struck an animal near the water's surface, the animal would be injured or killed. Therefore, the expending of debris from an expended Starship may affect ESA-listed sharks, sea turtles, and marine mammals within the Action Area. Direct strikes by debris from Starship are extremely unlikely because of the relatively small size of the components as compared to the open ocean areas. Given the low frequency of a Starship ocean descent and landing over the Indian Ocean, and the fact that marine wildlife spends the majority of their time submerged as opposed to on the surface, it is extremely unlikely ESA-listed species would be impacted. The relative availability of these animals at the ocean surface, spatially and temporally, combined with the low frequency of the Proposed Action, reduce the likelihood of impacts. Additionally, there are no known interactions with any of these species after decades of similar rocket launches and reentries.

Further, the projected landing area for Starship is well offshore where density of marine species decreases compared to coastal environments and upwelling areas.[41] Accordingly, adverse interactions with expended debris are discountable (unlikely to occur).

Indirect Effects

This section analyzes the potential for indirect effects resulting from overpressure events and fallen objects on specific ESA-listed species. These stressors may introduce indirect effects, such as potential impacts on water quality, bioaccumulation, and prey availability.

Water quality. Water quality may be impacted by any residual fuel remaining within Starship fragments, although if any fuel remained after the overpressure event, the fuel would likely off gas at the surface. Unconsumed fuel could be toxic to prey items at or near the surface (the fuel, less dense than water, would remain at or near the surface). Impacts, however, are anticipated to be minimal for the following reasons: (1) over 90% of propellant fuel would be consumed during the launch, ascent, descent phase and subsequent overpressure event; (2) most propellant combustion byproducts are benign, while those of concern would be diluted to below detectable levels within a short time; (3) most fuel byproducts are naturally occurring chemicals; and (4) most of the constituents of concern in the byproducts and residual fuel are biodegradable by various marine organisms or by physical and chemical processes common in marine ecosystems. Accordingly, indirect effects on the ESA-listed sharks, ESA-listed sea turtles, and ESA-listed marine mammals within the Action Area resulting from water quality changes attributable to the Proposed Action should be considered insignificant (not measurable).

Bioaccumulation. Bioaccumulation is the net buildup of substances (e.g., chemicals or metals) in an organism from inhabiting a contaminated habitat, ingesting food or prey containing the contaminated substance,[51] or from ingesting the substance directly.[52] Pollutants in the environment bioaccumulate and then biomagnify to high levels in some organisms, including ESA-listed species, due to their high position in the food chain, long life, and large size.[53] Much research has been conducted on the fate and transport of metals associated with munitions expended by military activities, with specific concern for bioaccumulation. Information from investigations at Navy testing and training ranges and sites where munitions were disposed of at sea following the end of World War II indicates that even in a variety of areas having concentrated expended military materials, there has been no significant impact on the immediate vicinity or the wider area as a result of those materials being present.[54,55,56] It is unlikely bioaccumulation would measurably impact ESA-listed species for the following reasons: (1) the few landing events included in the Proposed Action would limit the amount of chemicals that could become available for trophic transfer; and (2) the discreet localized areas where fragments would descend to benthic habitats. Accordingly, indirect effects associated with potential bioaccumulation of expended Starship fragments on the ESA-listed sharks, ESA-listed sea turtles, and ESA-listed marine mammals within the Action Area should be considered insignificant (not measurable).

Prey availability. Prey availability could be further impacted by fallen objects generated by the overpressure event as they strike the surface and descend through the water column. Secondary impacts on fish could occur after the Starship fragments sink to the seafloor. Over time, the fragments may be colonized by marine organisms that attach to hard surfaces, with a greater probability of colonization at shallower depths within the photic zone (down to about 200 m). For fishes that feed on these types of organisms, or whose abundances are limited by available hard structural habitat, the

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[51] Newman, M. C. (1998). Uptake, biotransformation, detoxification, elimination, and accumulation. Fundamentals of Ecotoxicology (pp. 25). Chelsea, MI: Ann Arbor Press.
[52] Moore, C. J. (2008). Synthetic polymers in the marine environment: A rapidly increasing, long-term threat. Environmental Research, 108(2), 131–13
[53] Defenders of Wildlife (2015). A Petition to List the Oceanic Whitetip Shark (Carcharhinus longimanus) as an Endangered, or Alternatively as a Threatened, Species Pursuant to the Endangered Species Act and for the Concurrent Designation of Critical Habitat. Denver, CO: Defenders of Wildlife
[54] Environmental Sciences Group (2005). Canadian Forces Maritime Experimental and Test Range Environmental Assessment Update 2005. Kingston, Canada: Environmental Sciences Group, Royal Military College.
[55] University of Hawaii (2014). Ordnance Reef (HI-06) Follow-Up Investigation, Final Assessment Report (Contract No. W91ZLK-10-D-005). Johnstown, PA: National Defense Center for Entergy and Environment.
[56] Briggs, C., S. M. Shjegstad, J. A. K. Silva, and M. H. Edwards (2016). Distribution of chemical warfare agent, energetics, and metals in sediments at a deep-water discarded military munitions site. *Deep Sea Research Part II: Topical Studies in Oceanography 128:* 63–69.

fragments that sink during an overpressure event could provide an incidental beneficial impact.[57,58] In addition to physical effects of an overpressure event on prey fishes, such as being stunned, prey might have behavioral reactions to underwater sound. For instance, prey fishes might exhibit a strong startle reaction to an impulsive sound generated by an overpressure event that might include scattering away from the source. The sound from an overpressure event might induce startle reactions and temporary dispersal of schooling fishes if they are within close proximity, however, uninjured fish would likely resume normal activities in a short period after the initial stimulus.[59,60] Invertebrate prey species, including krill, jellyfish, and other planktonic species, in the immediate vicinity of an explosion and overpressure event would be directly affected with the potential for injury or mortality. Farther from the impact site, these species are less likely to be affected by changes in pressure since many are generally the same density as water and few, if any, have air cavities that would function like the fish swim bladder in responding to a pressure change.[61,62] Invertebrates directly affected by an event would represent only a marginal fraction of the overall abundance of prey available to cetaceans and sea turtles in the Indian Ocean.

Accordingly, indirect effects associated with prey availability to the ESA-listed sharks, ESA-listed sea turtles, and ESA-listed marine mammals within the Action Area should be considered insignificant (not measurable) and discountable (unlikely to occur).

Cumulative Effects

Cumulative effects on the ESA-listed species are those effects of future State or private activities, not involving federal activities, that are reasonably certain to occur within the Action Area (50 C.F.R. Part 402.02). For purposes of conducting an analysis for cumulative effects, the FAA identified broad categories of activities that could affect ESA-listed species within the Action Area, including commercial fishing and harvest, maritime traffic, coastal land development, ocean pollution, ocean noise, and offshore energy development. Any impacts that might occur as a result of the Proposed Action could be additive to behavioral disturbance, injury, and mortality associated with other actions within the Action Area. Therefore, this section evaluates risks posed by non-federal activities in the Action Area that could result in cumulative adverse effects on ESA-listed species populations.

Oceanic Whitetip Shark and Scalloped Hammerhead Shark. For the purposes of conducting an analysis for potential cumulative effects on the oceanic whitetip shark and the scalloped hammerhead shark, the FAA identified broad categories of activities including commercial fishing and harvest, ocean pollution,

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[57] Love, M. S., and A. York (2005). A comparison of the fish assemblages associated with an oil/gas pipeline and adjacent seafloor in the Santa Barbara Channel, Southern California Bight. *Bulletin of Marine Science, 77*(1), 101– 117.
[58] Macreadie, P. I., A. M. Fowler, and D. J. Booth (2011). Rigs-to-reefs: Will the deep sea benefit from artificial habitat? *Frontiers in Ecology and the Environment, 9*(8), 455–461.
[59] Popper, A. N., J. A. Gross, T. J. Carlson, J. Skalski, J. V. Young, A. D. Hawkins, and D. G. Zeddies (2016). Effects of exposure to the sound from seismic airguns on pallid sturgeon and paddlefish. *PLoS ONE, 11*(8), e0159486.
[60] Wright, D. G. (1982). A Discussion Paper on the Effects of Explosives on Fish and Marine Mammals in the Waters of the Northwest Territories (Canadian Technical Report of Fisheries and Aquatic Sciences). Winnipeg, Canada: Western Region Department of Fisheries and Oceans.
[61] Budelmann, B. U. (1992). Hearing in nonarthropod invertebrates D. B. Webster, R. R. Fay and A. N. Popper (Eds.), *Evolutionary Biology of Hearing* (pp. 141-155). New York: Springer Verlag.
[62] Popper, A. N., Salmon, M. & Horch, K. W. (2001). Acoustic detection and communication by decapod crustaceans. *Journal of Comparative Physiology A, 187*, 83-89.

ocean noise, and offshore energy development. Any impacts that might occur could be additive to behavioral disturbance, injury and mortality associated with other actions within the Action Area. Therefore, this section evaluates risks posed by non-federal activities in the Action Area that could result in cumulative adverse effects on the oceanic whitetip shark and the scalloped hammerhead shark.

The aggregate impacts of past, present, and other reasonably foreseeable future actions contributing multiple water quality, noise, and physical risks to fishes would likely continue to have significant effects on ESA-listed sharks and their populations. However, the activities proposed under the Proposed Action are generally isolated from other activities in space and time, are not concentrated in any one location for any extended period of time, and are of a short duration. Although it is possible that the Proposed Action could contribute incremental stressors to a small number of individuals sharks, which would further compound effects on a given individual already experiencing stress, it is not anticipated that the Proposed Action has the potential to have any measurable additional stress on oceanic whitetip shark or scalloped hammerhead shark populations. Therefore, it is anticipated that the Proposed Action may affect, but are not likely to adversely affect the oceanic whitetip shark and scalloped hammerhead within the Action Area.

Green Sea Turtle, Hawksbill Sea Turtle, Leatherback Sea Turtle, Loggerhead Sea Turtle, Olive Ridley Sea Turtle. For the purposes of conducting an analysis for potential cumulative effects on sea turtles, the FAA identified broad categories of activities including commercial fishing and harvest, maritime traffic and vessel strikes, coastal land development, ocean pollution, ocean noise, and offshore energy development. Any impacts that might occur could be additive to behavioral disturbance, injury and mortality associated with other actions within the Action Area. Therefore, this section evaluates risks posed by non-federal activities in the Action Area that could result in cumulative adverse effects on sea turtles.

Based on the listing status of the sea turtle species within the Action Area, there is a clear indication that the current aggregate impacts of past human activities are significant for sea turtles. Bycatch, vessel strikes, coastal land development, and ocean pollution are the leading causes of mortality and population decline for sea turtles.

As discussed above, ESA-listed sea turtles could be affected by overpressure events and fallen objects. Some stressors could also result in injury or mortality to a relatively small number of individuals, but the likelihood of these effects is discountable. It is anticipated that the Proposed Action may affect, but is not likely to adversely affect ESA-listed sea turtle species within the Action Area. Effects from the Proposed Action to sea turtle food sources would be insignificant. Likewise, the stressors under the Proposed Action generally would not overlap other stressors in space and time as they occur as dispersed, infrequent, and isolated events that do not last for extended periods.

It is possible that the response of a previously stressed animal to impacts associated with the Proposed Action could be more severe than the response of an unstressed animal or impacts from the Proposed Action could make an individual more susceptible to other stressors. Likewise, the Proposed Action could contribute incremental stressors to individuals, which would both compound effects on a given individual already experiencing stress which may further stress populations in significant decline. Although the aggregate impacts of past, present, and other reasonably foreseeable future actions continue to have significant impacts on all sea turtle species in the Action Area, the Proposed Action is not likely to incrementally contribute to declines in sea turtle populations within the Action Area.

In summary, the aggregate impacts of past, present, and other reasonably foreseeable future actions continue to have significant impacts on all sea turtle species in the Action Area. The Proposed Action could contribute incremental stressors to individuals, which may further stress populations in significant decline. However, the incremental stressors anticipated from the Proposed Action would be insignificant considering the relative contribution from the Proposed Action in comparison to other actions and because the Proposed Action generally will not overlap in space and time with other stressors. Therefore, it is anticipated that the Proposed Action may affect, but are not likely to adversely affect ESA-listed sea turtles within the Action Area.

Blue Whale, Fin Whale, Sei Whale, Sperm Whale. For the purposed conducting a cumulative effects analysis for ESA-listed marine mammals, the FAA identified broad categories of activities, including commercial fishing and harvest (including bycatch, hunting, and entanglement), maritime traffic and vessel strikes, ocean pollution, ocean noise, maritime debris, and ingestions. Any impacts that might occur could be additive to behavioral disturbance, injury and mortality associated with other actions within the Action Area. Therefore, this section evaluates risks posed by non-federal activities in the Action Area that could result in cumulative adverse effects on ESA-listed marine mammals.

If the health of an individual marine mammal were compromised, it is possible this condition could alter the animal's expected response to stressors associated with the Proposed Action. The behavioral and physiological responses of any marine mammal to a potential stressor, such as underwater sound, could be influenced by various factors, including disease, dietary stress, body burden of toxic chemicals, energetic stress, percentage body fat, age, reproductive state, and social position. Synergistic impacts are also possible; for example, animals exposed to some chemicals may be more susceptible to noise-induced loss of hearing.[63] While the response of a previously stressed animal might be different from the response of an unstressed animal, no data are available at this time that accurately predict how stress caused by various ocean pollutants would alter a marine mammal's response to stressors associated with the Proposed Action.

The Proposed Action could contribute incremental stressors to individuals, which would both further compound effects on a given individual already experiencing stress and in turn has the potential to further stress populations in significant decline or those that exhibit positive recovery trends within the Action Area. Although the aggregate impacts of past, present, and other reasonably foreseeable future actions continue to have significant impacts on ESA-listed marine mammals in the Action Area, the Proposed Action would be insignificant and is not likely to incrementally contribute to declines in ESA-listed marine mammal populations, reverse positive trends in some marine mammal populations, or alter distributions of ESA-listed marine mammals.

[63] Fechter, L. D., & Pouyatos, B. (2005). Ototoxicity. Environmental health perspectives, 113(7), A443-A444.

Request for Concurrence

In summary, based on the information included in this letter, the FAA has concluded that the proposed action "may affect, but not likely adversely affect" the ESA-listed oceanic whitetip shark, scalloped hammerhead shark, green sea turtle (East Indian-West Pacific DPS, North Indian DPS, and the Southwest Indian Ocean DPS), hawksbill sea turtle; leatherback sea turtle; loggerhead sea turtle (Southwest Indian Ocean DPS, Southeast Indo- Pacific DPS, North Indian Ocean DPS), olive ridley sea turtle, blue whale, fin whale, sei whale and sperm whale. Because the proposed activities would occur entirely outside of the territorial waters of the U.S., the proposed second stage landings in the Indian Ocean would have no effect on designated or proposed critical habitat for these ESA-listed species.

Sincerely,

STACEY MOLINICH ZEE

Digitally signed by STACEY MOLINICH ZEE
Date: 2024.02.02 14:05:40 -05'00'

Stacey M. Zee

Manager, Operations Support Branch

Attachments:

- Attachment 1: Conservation Measures
- Attachment 2: Comprehensive Analysis of Sound Attenuation during Explosive Scenarios Involving a Fully-Propelled Starship
- Attachment 3: Sound Exposure Levels Cumulative Noise Metric

Table 1 ESA- Listed Species Within the Action Area

Common Name	***Scientific Name***	***Distinct Population Segment or Evolutionarily Significant Units***	***ESA Status****	***Presence in Action Area***	***Critical Habitat Designation***
Fishes					
Oceanic whitetip shark	*Carcharhinus longimanus*	-	FT	Pelagic distribution, may occur year-round	No critical habitat designation
Scalloped hammerhead shark	*Sphyrna lewini*	Indo-West Pacific DPS	FT	Mostly coastal and semi-oceanic in temperate and tropical waters,	No critical habitat designation
Sea Turtles					
Green sea turtle	*Chelonia mydas*	East Indian-West Pacific DPS	FT-Foreign	Associated with nesting beaches in Australia and Indonesia, may have rare pelagic occurrence in the eastern portion of the Action Area	Critical habitat designated under 63 FR 46693. Critical habitat proposed rule 88 FR 46572. Per 63 FR 46693 and 88 FR 46572, no critical habitat within the Action Area.
		North Indian Ocean DPS		Associated with nesting beaches along the coasts of India and Pakistan, may have rare pelagic occurrence in the eastern portion of the Action Area	
		Southwest Indian Ocean DPS		Associated with nesting beaches along the coasts of Kenya, Seychelles, Comoros, Mayotte, Europa Island, South Africa, and Madagascar. May have rare pelagic occurrence in the eastern portion of the Action Area	
Hawksbill sea turtle	*Eretmochelys imbricate*	-	FE	Associated with nesting beaches in Western Australia, may have rare pelagic occurrence in the eastern portion of the Action Area	Critical habitat designated under 63 FR 46693. Per 63 FR 46693, no critical habitat within the Action Area.
Leatherback sea turtle	*Dermochelys coriacea*	-	FE	Pelagic and relatively more tolerant of cooler water temperatures, may occur throughout the Action Area	Critical habitat designated under 77 FR 4170. Per 77 FR 4170, no critical habitat within the Action Area.

Common Name	***Scientific Name***	***Distinct Population Segment or Evolutionarily Significant Units***	***ESA Status****	***Presence in Action Area***	***Critical Habitat Designation***
Sea turtles (continued)					
Loggerhead sea turtle	*Caretta caretta*	Southwest Indian Ocean DPS	FT-Foreign	Most nesting sites along coast of South Africa and Mozambique. May have rare pelagic occurrence in the western portion of the Action Area	Critical habitat designated under 79 FR 39855. Per 79 FR 39855, no critical habitat within the Action Area.
		Southeast Indo-Pacific DPS	FT-Foreign	Most nesting in Western Australia. May have rare pelagic occurrence in the western portion of the Action Area	
		North Indian Ocean DPS	FE-Foreign	Most nesting occurs in Oman, particularly Masirah Island. May have rare pelagic occurrence in the western portion of the Action Area	
Olive ridley sea turtle	*Lepidochelys olivacea*	-	FT	Most nesting sites along the coast of India, Pakistan, and Bangladesh. Likely occurs in low numbers throughout the northern portion of the Action Area	No critical habitat designation
Marine Mammals					
Blue whale	*Balaenoptera musculus*	-	FE	High densities during the summer and fall with single individuals in the winter and spring	No critical habitat designation
Fin whale	*Balaenoptera physalus*	-	FE	Higher densities in the summer and fall although present year-round	No critical habitat designation
Sei whale	*Balaenoptera borealis*	-	FE	Present year round with more likely presence in the winter and spring	No critical habitat designation
Sperm whale	*Physeter macrocephalus*	-	FE	Present year round with a preference for deep waters and the continental shelf break and slope	No critical habitat designation

*Notes: ESU = Evolutionarily Significant Unit, FE = federally listed endangered, FT = federally listed threatened, FR = Federal Register

Table 2 Overpressure Events Modeling Results- Combined Explosion SPL

Blast Inputs	
TNT Yield (kg)	
Surface Pressure in Air (kPa)	
Surface Pressure in Water (kPa)	
Peak SPL dB (re 1 µPa)	

INPUTS	CALCS	RESULTS

ESA SPL for Indian Ocean

SPL Peak (Indian Ocean)			NMFS Thresholds (dB re 1 uPa)		Harassment Area (km²)		Species Harassment Results	
ESA Species Data (Indian Ocean)	**Type**	**Density (per km²)**	**PTS**	**TTS**	**PTS**	**TTS**	**PTS**	**TTS**
Blue Whale	LF cetacean	0.0000030	219	213	0.23182	0.92288	0.00000070	0.00000277
Fin Whale	LF cetacean	0.0008700	219	213	0.23182	0.92288	0.00020168	0.00080291
Sei Whale	LF cetacean	Unavailable	219	213	0.23182	0.92288	Unavailable	Unavailable
Sperm Whale	MF cetacean	0.00093	230	224	0.01841	0.07331	0.00001712	0.00006818
Green Turtle	Turtle	Unavailable	232	226	0.01162	0.04625	Unavailable	Unavailable
Hawksbill Turtle	Turtle	Unavailable	232	226	0.01162	0.04625	Unavailable	Unavailable
Leatherback Turtle	Turtle	Unavailable	232	226	0.01162	0.04625	Unavailable	Unavailable
Loggerhead Turtle	Turtle	Unavailable	232	226	0.01162	0.04625	Unavailable	Unavailable
Olive Ridley Turtle	Turtle	Unavailable	232	226	0.01162	0.04625	Unavailable	Unavailable
Species	**Type**	**Density (per km²)**	**Onset of Physical Injury (dB re 1 uPa)**		**Injury Area (km²)**		**Species Injury Results**	
Oceanic Whitetip Shark	Fish	Unavailable	206		4.63		Unavailable	Unavailable
Scalloped Hammerhead Shark	FIsh	Unavailable	206		4.63		Unavailable	Unavailable

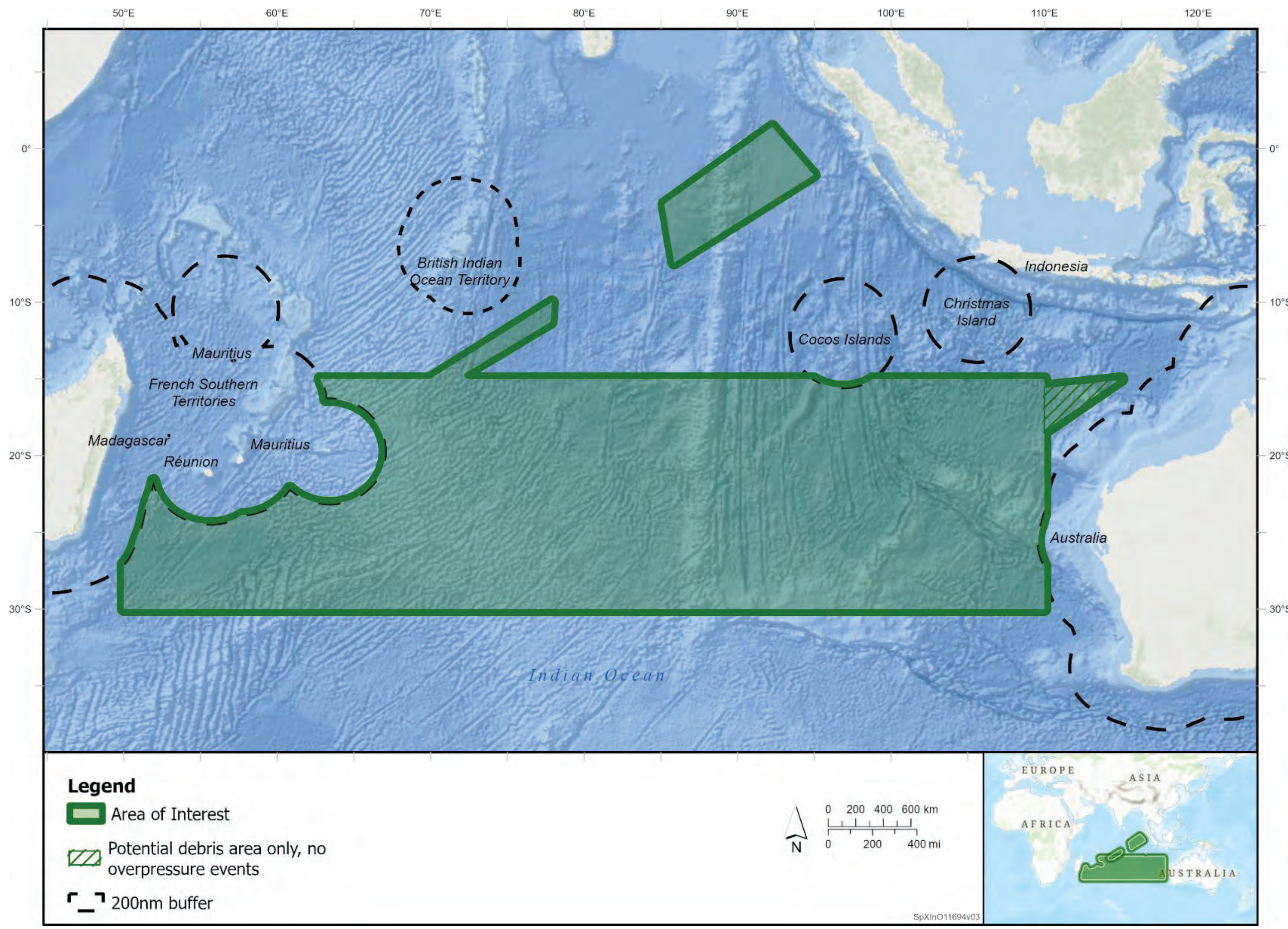


Figure 2: Proposed SpaceX Second Stage Indian Ocean Landing Area: Action Area

ATTACHMENT 1: CONSERVATION MEASURES

SpaceX contractors and subject matter experts, in preparation of this consultation, completed a literature review in August 2023 that identified ESA-listed species with potential occurrence in the Action Area and locations within the Action Area that may (1) aggregate ESA-listed species and prey for ESA-listed species, (2) offer other refugia for ESA-listed species, or (3) otherwise provide conservation benefit. These areas are shown in the maps below. Potential Indian Ocean landing areas within the Action Area will be prioritized to avoid these locations, referred to as avoidance areas and further defined below. Conservation measures are incorporated into SpaceX's proposed action for the purposes of avoiding and minimizing potential adverse effects. These measures include:

- SpaceX has revised the Action Area to restrict any landings within 200 nm of any land area. Areas within 200 nm are not planned to be used for landings, and are therefore excluded from the Action Area.
- SpaceX will, to the maximum extent practicable, avoid areas determined to be sensitive to disturbance or highly productive and presumed to have an increased probability of supporting higher densities of marine life. These areas are categorized as Avoidance Level 1 Areas, and landing sites would be selected to avoid these areas. Other physiographic features with the potential to support sensitive habitat are categorized as Avoidance Level 2 Areas and would also be avoided, if possible, but are not considered as high of a priority to avoid due to a lower expectation of aggregating ESA-listed species (CM-MAP 1):
    - **Avoidance Level 1 Area.** Areas determined to have higher potential for conservation value that are located within the Action Area:
        - **Important Marine Mammal Areas (IMMAs**). IMMAs are defined as discrete portions of habitat, important to marine mammal species, that have the potential to be delineated and managed for conservation. IMMAs consist of areas that may merit place-based protection and/or monitoring. The IMMA concept was developed by the International Union for Conservation of Nature (IUCN) Joint Species Survival Commission (SSC) and World Commission on Protected Area (WCPA) Marine Mammal Protected Areas Task Force (MMPATF). The Action Area overlaps with two Areas of Interest (AOI)—the Exmouth and Wallaby Plateau Offshore Western Australia AOI and the Subtropical Convergence Zone AOI (CM-MAP 2). [1]
        - **Ecologically or Biologically Significant Area (EBSA)**. An EBSA is an area of the ocean that has special importance in terms of its ecological and biological characteristics: for example, by providing essential habitats, food sources or breeding grounds for particular species (CM-MAP 3). [2]

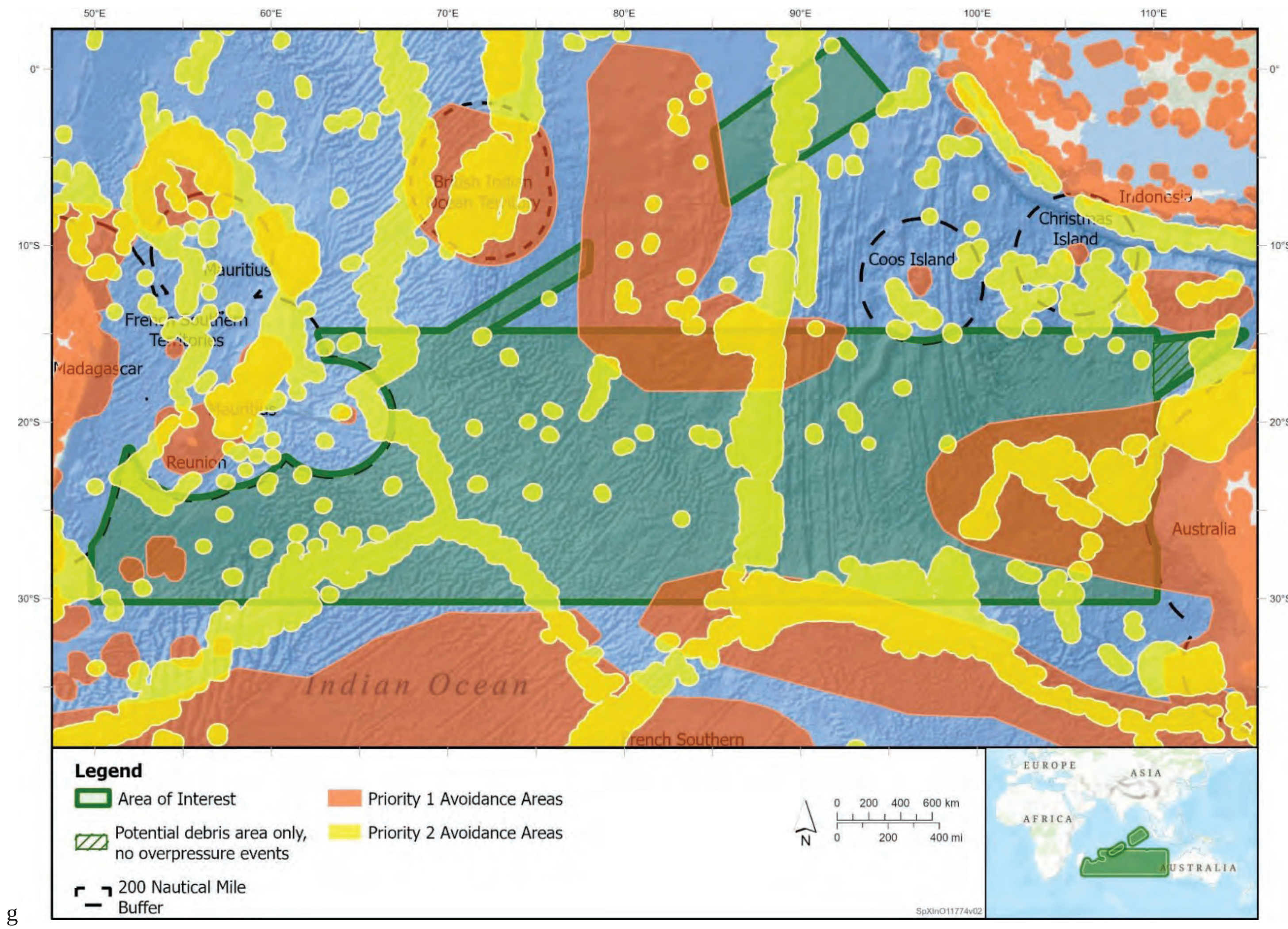
Avoidance Level 2 area. Locations that include physiographic features (e.g., plateaus, ridges, spreading zones, known seamounts and ocean vents) outside of Avoidance Level 1 Areas (CM-MAP 4 and CM-MAP

[1] IUCN-MMPATF (2022). Global Dataset of Important Marine Mammal Areas (IUCN-IMMA). Made available under agreement on terms and conditions of use by the IUCN Joint SSC/WCPA Marine Mammal Protected Areas Task Force and accessible via the IMMA e-Atlas https://www.marinemammalhabitat.org/imma-eatlas

[2] Convention on Biological Diversity Secretariat. (2023). https://www.cbd.int/ebsa/

5).[3,4]

[3] Taneja, R., O'Neill, C., Lackie, M., Rushmer, T., Schmidt, P., & Jourdan, F. (2015). 40Ar/39Ar geochronology and the paleoposition of Christmas Island (Australia), Northeast Indian Ocean. Gondwana Research, 28(1), 391-406
[4] Chan, S., Crosby, M. J., Islam M. Z. and Tordoff, A. W. (2004) Important Bird Areas in Asia: Key Sites for Conservation. BirdLife International. http://datazone.birdlife.org/info/ibasasia



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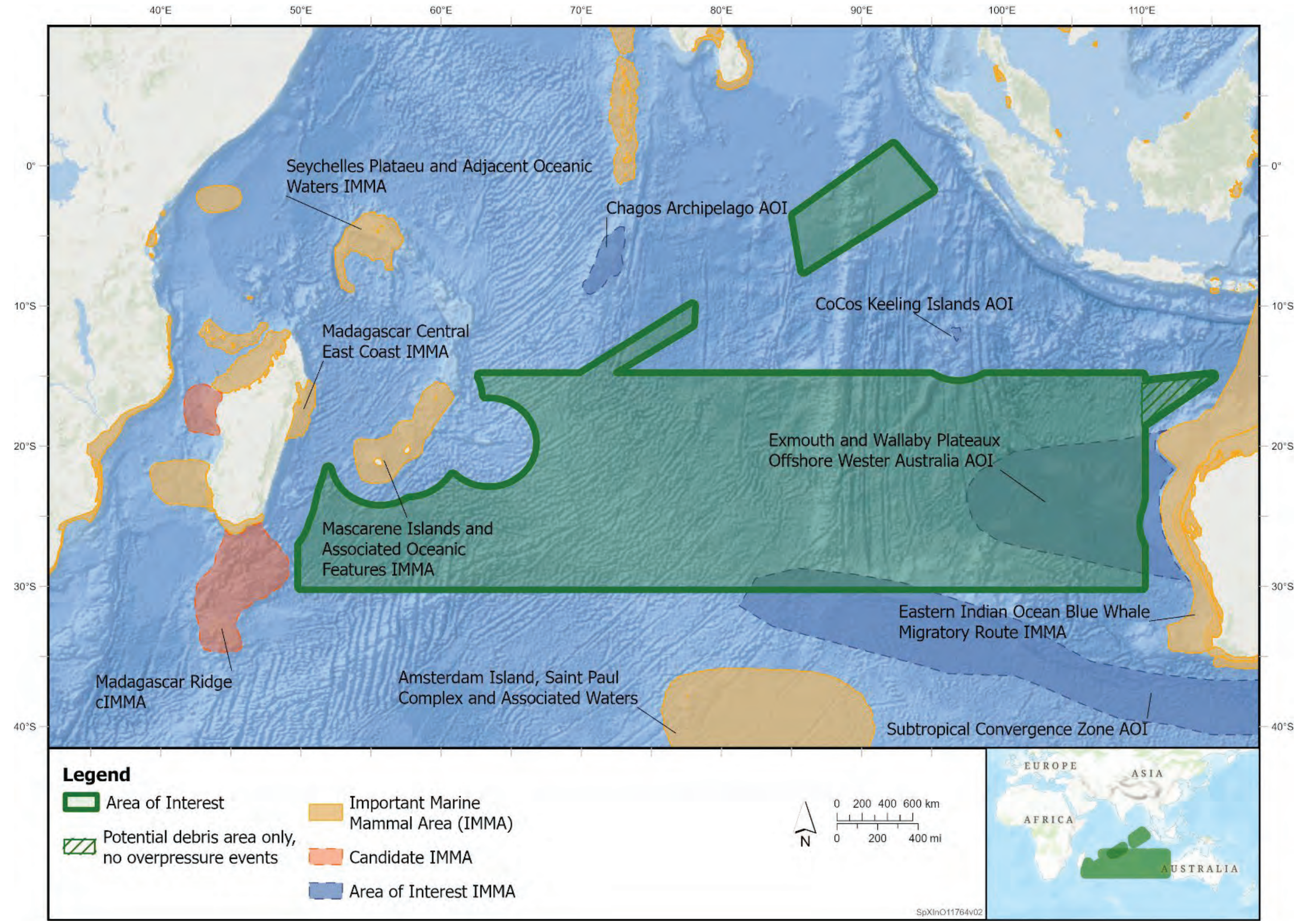
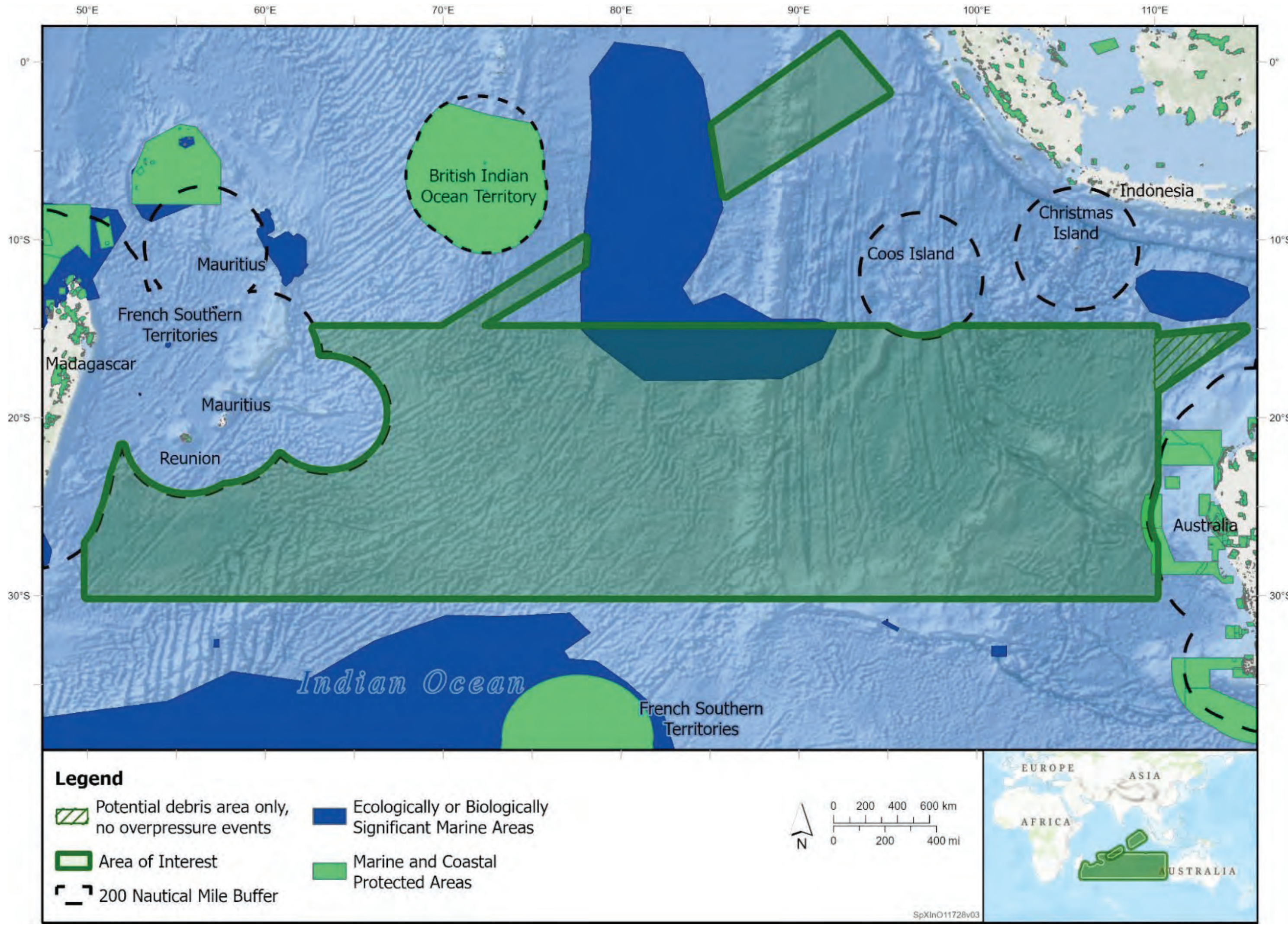
Map CM-1: Avoidance Level 1 and 2 Areas within the Action Area



Source:
IUCN-MMPATF (2022). Global Dataset of Important Marine Mammal Areas (IUCN-IMMA). Made available under agreement on terms and conditions of use by the IUCN Joint SSC/WCPA Marine Mammal Protected Areas Task Force and accessible via the IMMA e-Atlas https://www.marinemammalhabitat.org/imma-eatlas.

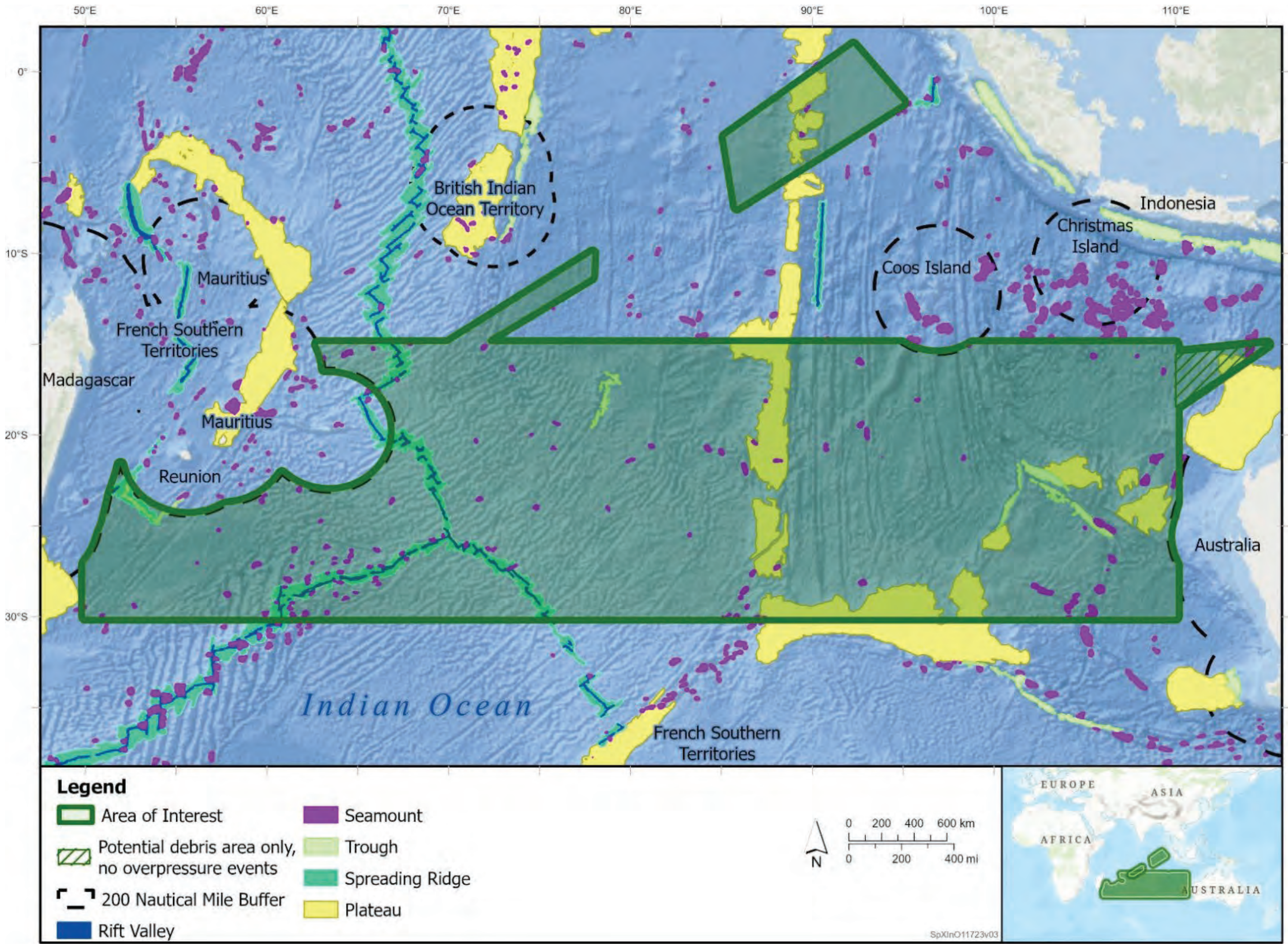
Map CM-2: Important Marine Mammal Areas within the Action Area



Source:

Convention on Biological Diversity Secretariat. (2023). https://www.cbd.int/ebsa/

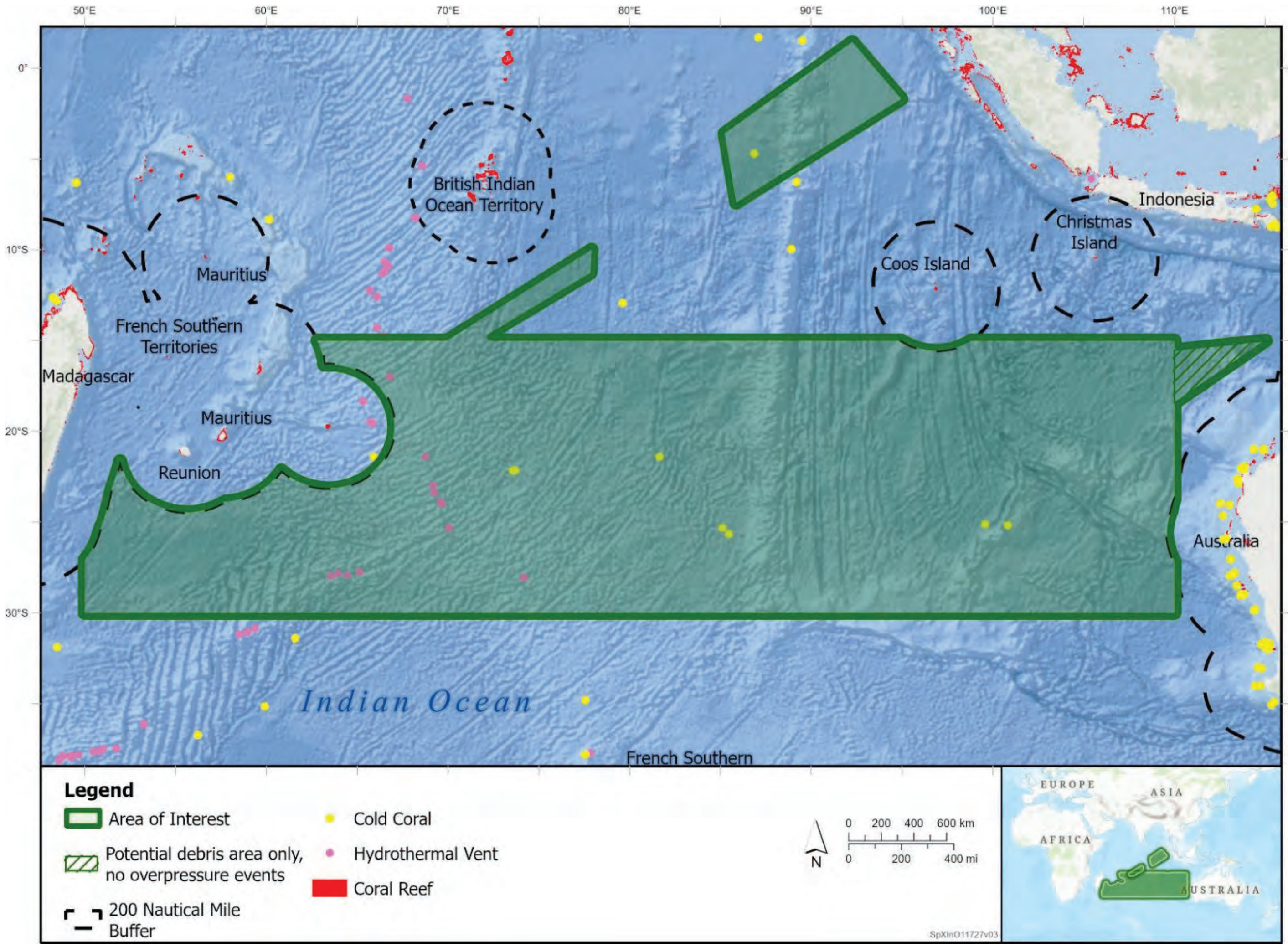
Map CM-3: Marine Protected Areas and Ecologically or Biologically Significant Marine Areas within the Action Area



Source:

Taneja, R., O'Neill, C., Lackie, M., Rushmer, T., Schmidt, P., & Jourdan, F. (2015). 40Ar/39Ar geochronology and the paleoposition of Christmas Island (Australia), Northeast Indian Ocean. Gondwana Research, 28(1), 391-406.

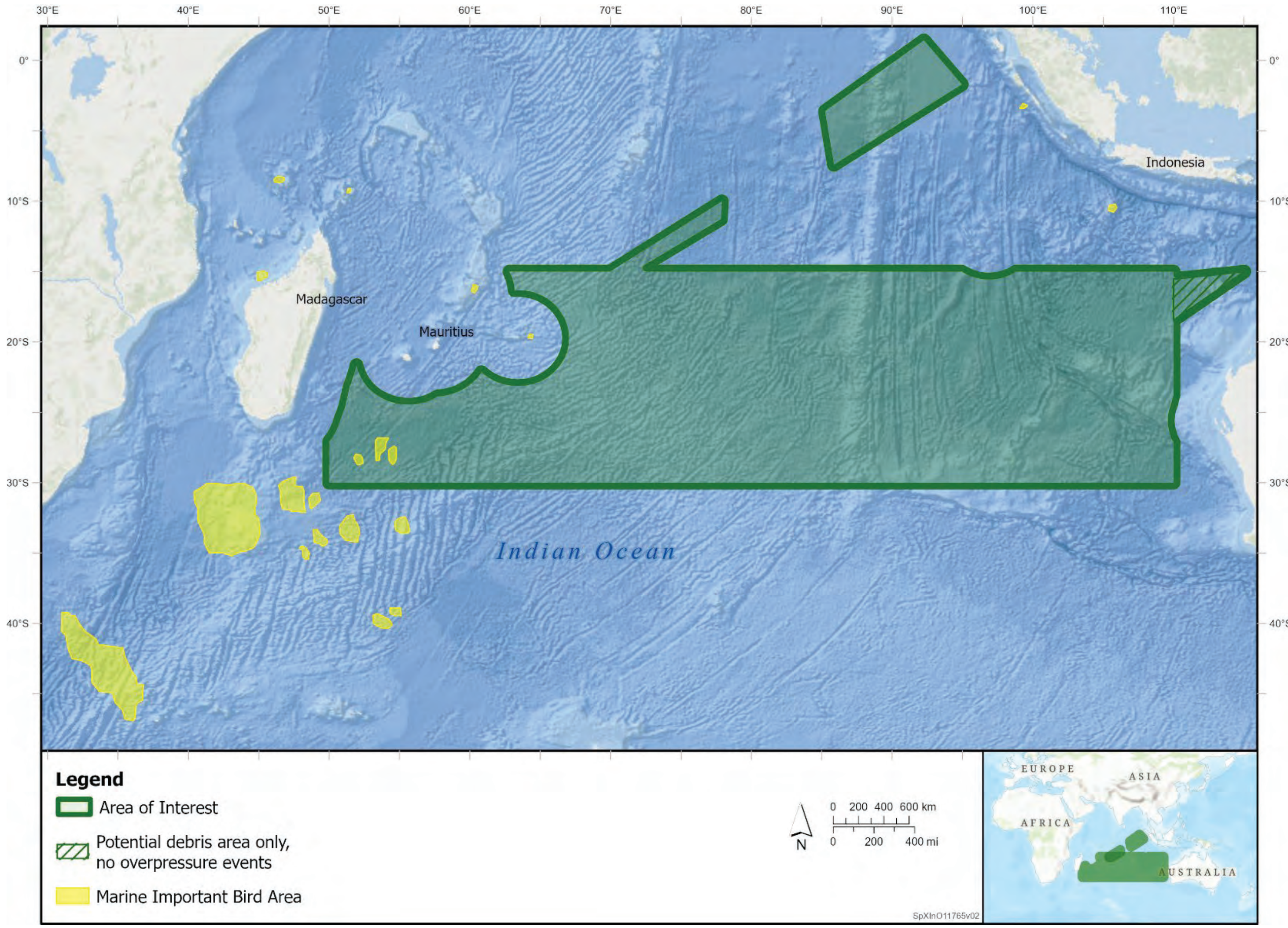
Map CM-4: Geomorphic Features within the Action Area



Source:

Taneja, R., O'Neill, C., Lackie, M., Rushmer, T., Schmidt, P., & Jourdan, F. (2015). 40Ar/39Ar geochronology and the paleoposition of Christmas Island (Australia), Northeast Indian Ocean. Gondwana Research, 28(1), 391-406.

Map CM-5: Known Benthic Communities within the Action Area



Source:

Chan, S., Crosby, M. J., Islam M. Z. and Tordoff, A. W. (2004) Important Bird Areas in Asia: Key Sites for Conservation. BirdLife International. http://datazone.birdlife.org/info/ibasasia

Map CM-6: Marine Important Bird Areas

ATTACHMENT 2: COMPREHENSIVE ANALYSIS OF SOUND ATTENUATION DURING EXPLOSIVE SCENARIOS INVOLVING A FULLY-PROPELLED STARSHIP

Comprehensive Analysis of Sound Attenuation during Explosive Scenarios Involving a Fully-Propelled Starship

Background

This document presents a methodology to determine the realistic incident pressure for a Starship with residual propellant impacting the ocean surface, with a focus on the sound pressure level.

Propellant would remain in the header tanks and the main tanks, approximately 30,650 kg and 70,000 kg, respectively. An explosion would most likely occur within the transfer tube, simultaneously igniting the headers and main as the fuel system is connected. SpaceX analyzed the combined explosive weight from the transfer tube, headers and main as a single explosion. SpaceX has demonstrated to the FAA that the most likely and reasonably foreseeable origin of an explosion during an intact Starship ocean landing is from inside the transfer tube of the vehicle.[1] Specifically, the FAA has concurred that the explosion due to impact, likely initiates a small distance above the water's surface. The SN10 explosion validates this theory, where an explosion originated in the transfer tube (Figure 1) and propagated outward. SpaceX has several examples of transfer tube failures (see Figure 2) as well as McGregor testing video's and is continually running tests to validate this theory as different iterations of Starship are developed.

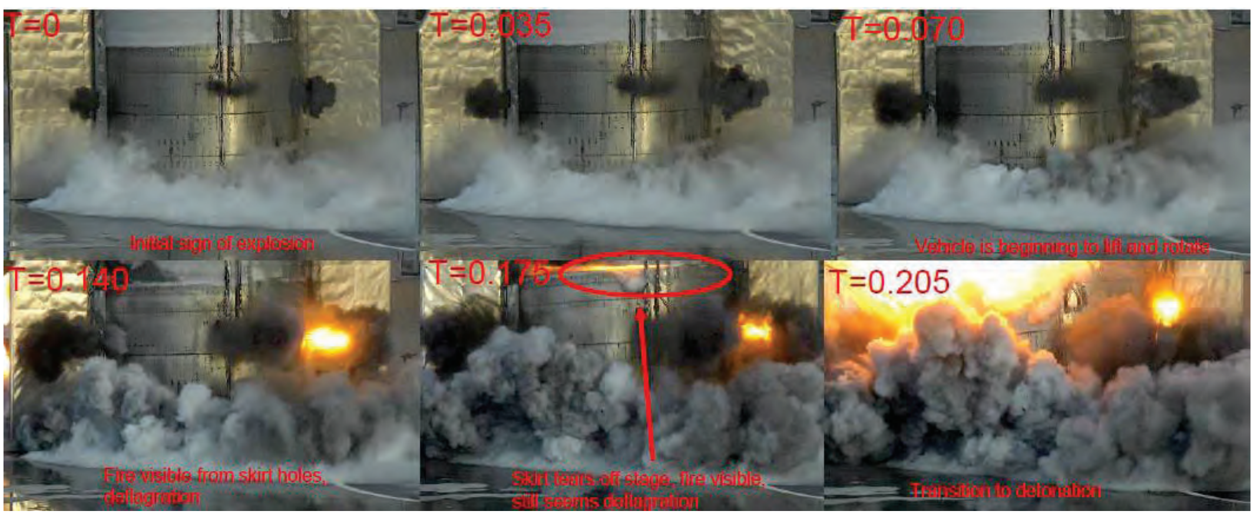


Figure 1: Frame-by-Frame video of SN10 explosion

[1] SpaceX 2022. Underwater Noise Analysis Methodology for Starship Orbital Test Flight Vehicle

Figure 2: SN9 Transfer Tube Failure of TXC-4907-08

The mixture of liquid oxygen (LOX) and liquid methane (LCH4) is expected to begin as a deflagration within Starship and then transition to a detonation which destroys the Starship. Hot components from orbital entry, particularly along steel cracks in the transfer tube, are likely ignition sources. Given that the mass of the transfer tube to flex is relatively high, it will have more inertia than the surrounding main tank or header tanks. This will cause the transfer tubes to flex through the central portion and exert stresses on the tube structure that it was not designed to handle. The explosion would generate a sound wave which starts within Starship and continues into atmospheric air before impacting the water. Prior methodology addressed this phenomenon and discussed the potential difference between air and oxygen in the tank.

The most probable scenario for Starship regarding potential impacts to endangered species is a horizontal belly flop at terminal velocity followed by an explosive event. The belly flop position is the most probable landing orientation because SpaceX plans to keep Starship in the horizontal position by adjusting the flap positions. Furthermore, SpaceX has simulated a 6 Degree Of Freedom Monte Carlo model of Starship orientation at impact with aerodynamic inputs validated by evidence from the suborbital test flights. These simulations show that Starship would belly flop assuming Starship fins remain in their expected configuration. These assumptions are validated by over 100 video records from developmental test scenarios archived at SpaceX.

Anomalies include a variety or outcomes beyond the planned nominal FAA licensed activity. This includes a wide range of scenarios from an explosion on the launch pad to use of the Automatic Flight Termination System to terminate the operation if the vehicle underperforms or deviates from a planned trajectory. Given the current FAA license application, any reentries or breakups prior to the Second Engine Cutoff (SECO) would be considered an anomaly. Any Starship configuration other than the aforementioned belly flop, such as nose down, would be considered an anomaly. As anomalies are not reasonably foreseeable, they are not appropriate for consideration during the analysis of effects or the overall Section 7 ESA consultation.

Under the horizontal belly flop scenario, the explosive distance from the transfer tube would be approximately 4.5m (14.8ft) above the ocean surface. Propellant quantity affects Starship's stability, influencing its descent and explosive dynamics. For the header tanks, an explosive weight of 3,647.35 kg was used based on an 11.9 percent yield, which is highly conservative based on a simulation of uncontained mixing between two close coupled masses of propellant and no barriers impeding their mixing after deflagration. The 11.9% yield was calculated using a STAR-CCM+ analysis and was performed assuming the entire masses of the header tanks were allowed to impact against the ocean surface, simulated as a hard ground. No tank skin is modeled, for the assumptions listed above. This allowed for maximum mixing between the propellants which yields highly conservative values based on a simulation of uncontained mixing between two close coupled masses of propellant and no barriers impeding their mixing after deflagration. For the main tanks, an explosive weight of 6,300 kg was used based on a 9% yield. The explosive remaining TNT yield within Starship would amount to approximately 9,947.35 kg.

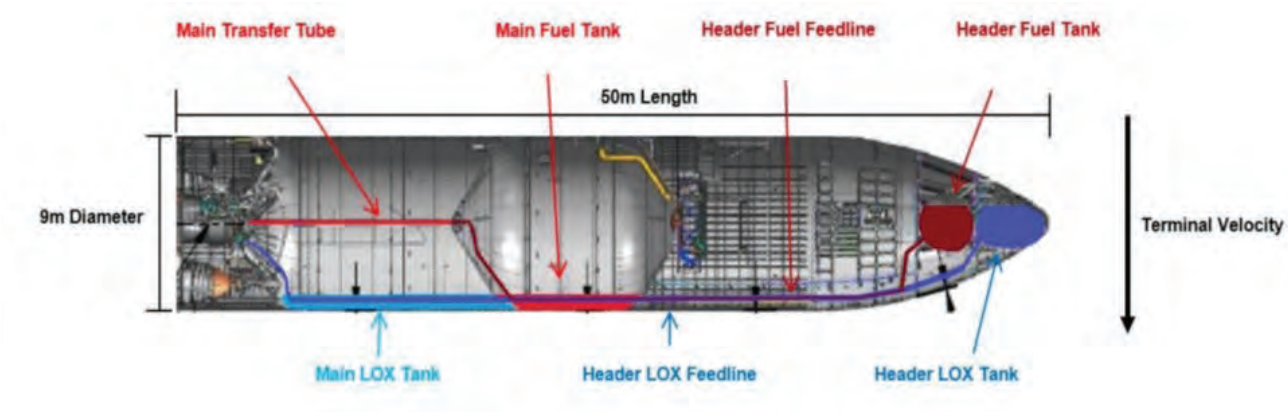


Figure 5. Starship Nominal Impact Conditions

Methodology

This study focuses on the noise impact of an in-air explosive yield from a fuel explosion in the Starship. The characteristics of the sound at a receiver, rather than at the source, are the relevant consideration for determining potential impacts. However, understanding these physical characteristics in a dynamic system with receivers moving over space and time is difficult. The Starship explosion is considered an impulsive source as defined by NMFS[2]. It produces a sound that is transient, brief (less than 1 second), broadband, and consists of a high peak sound pressure with rapid rise time and rapid decay. This is further verified by an explosive Starship event which took place on February 2, 2021. The SN9 exploded during a landing attempt at an altitude of 5ft from the ground. This can be approximated very precisely as a ground surface hemispherical burst for modeling purposes. The SN9 had 14,850 kg of propellant remaining. A measured (blast pressure sensor) peak pressure of 0.265psi at a distance of 740 ft was recorded (see red arrow on Figure 3).

Based on the known propellant remaining and SpaceX's cameras recording the event, the following data were recorded: (1) lack of uniform shock waves visible in the cameras, (2) most of the fuel burned in a low-pressure deflagration, (3) structures near the site did not exhibit signs of high-yield explosion (e.g. no broken windows) and (4) no reports of confirmed damage in the surrounding geographic area outside of impacts due to physical debris.

The SN9 explosive event occurred at the transfer tube and oxygen tank, and simultaneous detonations produced a single pressure waveform (Figure 3).

[2] 2018 Revision to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0) Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts, April 2018.

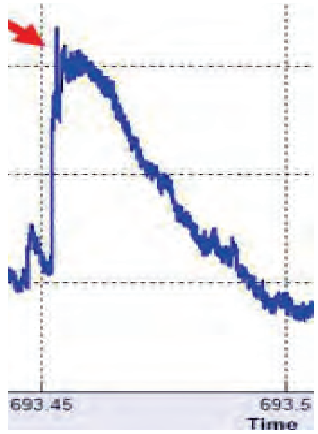


Figure 3. Starship Waveform

Determination to Use SPL

Sound exposure containing transient components (e.g., short duration and high amplitude; impulsive sounds) can create a greater risk of causing direct mechanical fatigue to the inner ear (as opposed to strictly metabolic) compared to sounds that are strictly non-impulsive. Often the risk of damage from these transient sounds does not depend on the duration of exposure. This is the concept of "critical level," where damage switches from being primarily metabolic to more mechanical. Short impulse duration can be less than the ear's integration time, leading to the potential to damage beyond the level the ear can perceive[2]. SpaceX believes its explosive event must consider direct mechanical fatigue and should model the impulsive sound pressure level (SPL).

Human noise standards recognize and provide separate thresholds for impulsive sound sources using the SPL metric[3]. Thus, weighted cumulative sound energy (SELcum) is not an appropriate metric to capture all the effects of impulsive sounds because it often violates the Equal Energy Hypothesis (EEH) and National Institute of Occupational Safety and Health Administration (NIOSH) standards.

SELcum assumes the potential for recovery from hearing loss after sound exposure ceases or between successive sound exposures, and as evidenced above, Starship will yield a single explosive event. SpaceX asserts the SELcum methodology is appropriate for in water activities with repetitive sound sources over a 24-hour period with a period greater than a second (e.g. pile driving, sonar or

[3] Occupational Safety and Health Administration (OSHA) 29 CFR 1910.95

air guns), but does not agree it represents the best model for Starship to determine permanent or temporary threshold shifts in marine species.

A Starship explosion starts as a deflagration, which is a subsonic explosion. An example of a deflagration is a candle burning, which has no pressure change or subsequent waveform. In the Starship vehicle, as the liquid oxygen flows out from the ruptured transfer tubes and vaporizes, it burns as a deflagration. When the amount of vaporized liquid oxygen in Starship reaches critical mass, the deflagration changes to a detonation, which is a supersonic explosion, and results in a waveform and pressure change. The detonation of Starship would be similar to a closed-up house with the gas left on at the stove. There is no explosion until a spark occurs and all the gas which has spread throughout the house explodes. When enough oxygen molecules have escaped in sufficient mass and come in contact with an ignition source (e.g. hot piece of metal), detonation of the Starship would occur. SPL is an appropriate metric to determine the sound peak pressure of the Starship explosion because the explosion is of short duration and high amplitude. Therefore, the explosion is most appropriately characterized as an impulsive sound and should be analyzed as a SPL rather than as SELcum.

Modeling of potential impacts to marine species due to rocket explosions using the SELcum metric is not fully validated. SELcum is inaccurate for this explosion because it considers the time of the deflagration plus the detonation and averages that as the cumulative event. This is an erroneous methodology for rocket explosions. Other explosive analyses, such as those performed by the U.S. Navy, deal with a detonation force, rather than deflagration to detonation. No current guidelines exist for analyzing the combination of deflagration into detonation. Therefore, SpaceX asserts that using the SPL is the appropriate metric for rocket explosions until an accurate method of assessing SELcum is developed for events involving deflagration and detonation.

Verification of this phenomenon can be seen in the SN 9 explosion where the peak pressure at 740 ft was measured to be .265 psi. Other measurements from the SN9 explosion are available, but this was the highest peak pressure measured. Using the DDESB Blast Effects calculator, we can determine the remaining propellant in the vehicle at the time of the explosion. Converting the .265psi to Pascal yields 1827.11Pa. Inputs to the DDESB Blast Calculator include:

1. Altitude: 5ft or 1.52m (pressure sensor was 5ft off the ground)
2. Distance to Explosion Site (ES): 740ft or 226m
3. Temperature: 15^{o}C

Using an iterative process in the total next explosive weight (NEW) to find the equivalent Incident Pressure of 1.8271kPa in the output section yields a total NEW of 103kg at an incident pressure of 1.826kPa. As stated above, the remaining measured propellant in the tank was 14,850kg at a 9% yield is 1336.5kg. The sound pressure readings indicate that the remaining propellant should be 103kg. Therefore, it can be assumed that 1233.5kg was in the deflagration stage (no pressure waveform developed) while only 103kg was in the detonation stage (1233.5kg + 103kg=1336.5kg) and generating a pressure waveform. This further strengthens the argument against using SELcum as a verifiable metric, because the deflagration does not cause a pressure wave and the majority of the propellant (over 92.3%) was consumed during the deflagration stage. SpaceX cannot determine the length of the pulse duration needed to determine the SELcum because it is unclear at this stage when that transition occurs.

For disclosure purposes, an analysis of SELcum has been included in Attachment 3 (including methodology and tables) with a pulse duration of 2.5ms, however FAA and SpaceX assert that SPL is the most appropriate metric for evaluating potential harassment and harm to marine species because the pulse rate duration is not an analytical or derived number.

Calculations

Having remaining propellant in the header and mains maximizes the probability of a successful landing at the intended location by providing propellant reserves and stability to the vehicle.

The *Kingery-Bulmash Blast Parameter Calculator*[4] calculates the blast-wave parameters of a hemispherical free field air-blast, based on the empirical relations developed by Kingery and Bulmash. It provides data for incident pressure, reflected pressure, incident impulse, reflected impulse, duration of positive pressure phase, time of arrival of the shock wave and shock front velocity. *These equations are widely accepted as authoritative engineering predictions for determining free-field pressures and loads on structures. The equations in this calculator are based on data from explosive tests using charge weights from less than 1kg to over 400,000 kg*. The calculator is based on the Kingery-Bulmash equations used to model a hemispheric, surface explosion, and should not be used for applications requiring the calculation of values for a spherical burst in the air. While the Starship explosion at the transfer tube is best modeled by a spherical model, the use of a hemispherical model is conservative and accounts for other sources of uncertainty such as the effects of propagation through gaseous oxygen. A hemispherical model was used during the SN9 event, and it is practical to assume at terminal velocity the difference between hitting ground and water is negligible. Therefore, this model is more conservative than the spherical model. Moving forward, SpaceX will be using one explosive event with a fully propelled Starship which amounts to 30,650kg of propellant remaining in the headers with a yield of 11.9% which equals 3,647.35kg of explosive equivalent weight. The main tank contains 70,000kg of propellant remaining with a yield of 9% which equals 6,300kg of explosive equivalent weight. Therefore, SpaceX expects the remaining propellant to be 9,947.35kg of explosive weight for a spherical burst. It can be assumed that during the explosion, half of the energy will be released into the air and the other half (representing the hemispherical component), will enter the water. Therefore, the total amount of remaining propellant will be halved to represent the energy

[4] Kingery-Bulmash Blast Parameter, https://unsaferguard.org/un-saferguard/kingery-bulmash.

entering the water as a hemispherical burst. This amounts to a charge weight of 4,973.68kg. This aligns with the *Kingery Bulmash Blast Calculator*.

As iterative Starship flights occur, the main objective is to land Starship back on land or on a barge, similar to the current Falcon boosters. This entails initiating a landing burn as Starship descends to the ocean surface. Previous Starship iterations were constrained and did not have headers and main tanks fully loaded with propellant. A landing burn was not feasible due to lack of propellant. The most probable fate for a fully propelled Starship would be a successful landing burn.

Inputs from the Kingery Bulmash calculator include:

1. Explosion Type-TNT
2. Charge Weight (kg)-4973.68
3. Range (m)-4.5m

Outputs include:

1. Incident Pressure (kPa) - 12111.15

A methodology exists to check the Kingery Bulmash incident pressure in air. Using the DDESB Blast Effects Computer-Open version 1.0 and the inputs above, the DDESB calculates the incident pressure to be 12056.3kg at a temperature of 15^{o}C. This represents a difference of less than .5% between the 2 models. Therefore, taking the higher incident pressure from the Kingery Bulmash Calculator yields the most conservative incident pressure in air as:

$$Pressure_{Air}\ (P_a)=12111.15\ kPa$$

and is recorded in the NMFS over pressurization tables.

To find the Incident pressure in water, the impedance between the air and water must be determined. An acoustic impedance calculator was used to find the specific acoustic impedance (Z) of air and seawater through which the pressure wave would propagate after the explosion. The speed of sound in a given medium (gas, liquid or solid) depends primarily upon how compressible it is. In solids and liquids, which are less compressible than gases, the speed of sound is faster.

Material	**Acoustic Impedance Z (kg m-2*s-1)**
Air (20^{o}C/68^{o}F)	414.5=Z_1
Seawater (20^{o}C/68^{o}F)	1558528=Z_2

Table 1.0 Acoustic Impedance Calculator http://omnicalculator.com/physics/acoustic-impedance

The acoustic impedance (Z) is a material's property that affects how sound travels through it. It represents the medium's resistance to the propagation of the sound, affecting its intensity. The higher the value of Z, the greater is the opposition to the transmission of the sound.

The acoustic impedance helps to determine what happens to the sound when it travels from one medium to another. When there is a severe impedance mismatch at the boundary of two materials, a fraction of the sound intensity is transmitted, and the rest is reflected. Using the following equation for transmission (T):

$$T=4Z_1Z_2/(Z_1+Z_2)^2 \qquad \text{(Equation 3)}$$

where:

Z_1=Impedance of Air
Z_2=Impedance of Seawater

$$T=[4(414.5)(1558528)]/[(414.5+1558528)]^2$$

T=.0010633 (sound intensity into seawater)

Therefore, using equation 3, only .0010633 of the sound energy is transmitted into seawater due to the impedance mismatch between air and water. SpaceX assumes an intensity transmission coefficient of .0326 which is approximately 30 times greater than the theoretical air/water boundary transmission coefficient. This conservative approach accounts for the limited scope of research into near-surface explosions and their transmission across the air/water boundary. SpaceX also did not model the impedance and transmission loss due to the stainless steel of the Starship and atmospheric air, even though all data currently validates that the explosion starts inside Starship (composed of stainless steel) at the transfer tube and propagates through the air before hitting the ocean surface. To solve for the pressure at the water surface we use equation 4 below:

$$P_w=T[P_a(Z_2/Z_1)^{1/2}] \qquad \text{(Equation 4)}$$

where:
P_a=12111.15kPa =12111150Pa
T=.0326
Z_2=1558528 Pa*s/m (Impedance of Seawater)
Z_1=414.5 Pa*s/m (Impedance of Air)

$$P_w=24210180.1 \text{ Pa}$$

or 24210.18 kPa (as recorded in the NMFS over pressurization tables)

NMFS states that for deep water where there is little to no interaction between the sound and the ocean floor that a 20 log R model is appropriate. This model is given in equation 5, where the noise is expressed as a sound pressure level (SPL).

$$SPL=20 \log (P_w/P_{ref}) \quad \text{(Equation 5)}$$

Where:
P_w=24210180 Pa
P_{ref}=1μPa

$$SPL=267.7 \text{ dB (re 1μPa)}$$

Conclusion

This study presents a comprehensive analysis of sound propagation during a Starship explosion. SpaceX aims to continue to gather more robust data to enhance the accuracy of predictive models for rocket explosions. This research contributes valuable insights into acoustic propagation in marine environments, with implications for environmental conservation and Starship design.

ATTACHMENT 3: SOUND EXPOSURE LEVELS CUMLATIVE NOISE METRIC

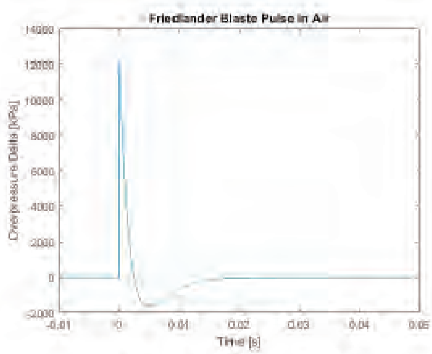
SPACEX

NMFS BLAST NOISE METRICS

Jan 25 2024

Initial Blast Overpressure

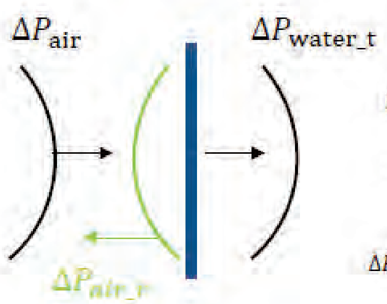
- Use a generic model to predict blast overpressure peak and pulse duration
  - SpaceX using a hemispherical spreading model for free-air blast (Kingery-Bulmash)
  - Conservative through hemispherical restriction and inherent TNT equivalent yield of propellant available on vehicle
  - Peak overpressure of 12,111 kPa, and impulse duration assumed to be 2.5 ms
- Friedlander waveform of overpressure is a commonly assumed and observed blast overpressure time series
  - Time domain representation of blast is useful in characterizing energy and impulse of blast
  - Peak pressure estimate has an inherent assumed impulse characteristic



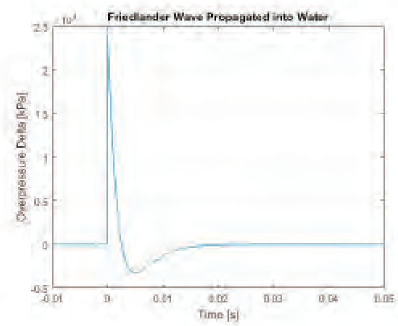
$$\Delta P(t) = P_0\left(e^{-\frac{t}{t^*}}\right)\left(1-\frac{t}{t^*}\right)$$

Air to Water Transmission

- Blast in air propagates through debris field and into water
  - Diffraction, shielding, and transmission loss through debris is complicated and not guaranteed to be uniform or available if majority of main tanks rupture on impact
  - Air-to-water transmission is a guaranteed impedance mismatch boundary that must be traversed. Because of impedance mismatch, some of initial incident wave is reflected. Intensity must drop from low to high impedance (air to water), but pressure amplitude can rise
- Spacex is using the analytical transmission coefficient of .0010633 where $\sqrt{.0010633}$ =.0356 for water entrance. SpaceX did not take advantage of other conservative choices including:
  - Transmission through a steel layer of the Starship vehicle / tanks when initial blast propagates from fluid mixing internal to the hull
  - Propagation distance in air before water entrance



$$I_i = I_r + I_t$$
$$I_r = R_c I_i \ ; \ I_t = (1 - R_c) I_i$$
$$1 - R_c = T_c = \frac{4Z_1Z_2}{(Z_1 + Z_2)^2}$$
$$I_w = I_t = T_c I_a$$
$$\Delta P_w = \sqrt{I_w Z_w} = \Delta P_a \sqrt{\left(\frac{Z_w}{Z_a}\right) T_c}$$



Sound Metrics and Marine Mammal Harm Thresholds

- Spacex estimates the air blast overpressure and the transmission into water
- Marine animals are far-field receivers to this initial pressure wave
  - Statistical estimate of population density and auditory weighting functions for animal sensitivity and physiology
  - Geometrical spreading of initial pressure wave produces a decaying sound intensity with distance squared to "receiver"

$$\frac{I_{rec}}{I_w} = \frac{1}{R^2}$$

- Area in km^2 for which harassment thresholds will be exceeded calculated given initial pulse transmitted into water
  - Assumes no attenuation of pressure pulse with depth (evaluated over an area represented at essentially zero depth)
- Expected animal population density (species / km^2) is multiplied by harassment area to provide the expected number of affected animals

$$R_{exceed} = \sqrt{\frac{I_w}{I_{thresh}}} = \frac{P_w}{P_{thresh}} \quad ; \quad R_{exceed} = 10^{\frac{L_{pk} - L_{thresh}}{20}}$$

$$A_{exceed} = \pi * (R_{exceed})^2$$

$$N_{affected} = (\rho_{species}) * (A_{exceed})$$

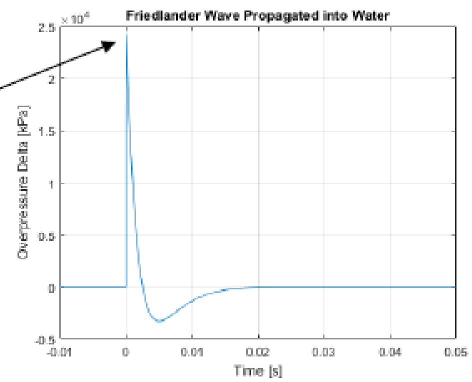
$$L_{pk} = 20 \log_{10}\left(\frac{P_w}{P_{ref}}\right)$$

$$L_{thresh} = 20 \log_{10}\left(\frac{P_{thresh}}{P_{ref}}\right)$$

Peak Sound Pressure Level (SPL)

- Peak SPL thresholds are ideal for impulsive noise sources when not averaged with a time window and using a "flat" frequency weighting
  - Can be identified in time domain with reference pressure ($1\mu Pa$)
  - Equivalent to a criteria of peak overpressure that causes harm

$$SPL = 20\log_{10}\left(\frac{P_0}{P_{ref}}\right) = 20\log_{10}\left(\frac{2.42e7}{1e{-6}}\right) = 267.7\text{ dB}$$



Peak SPL Compared to Harm Thresholds

- Initial level after water entrance:
- Lp (flat) = 267.7 dB, ref $1\mu Pa$

Hearing Group	PTS Impulsive Thresholds	TTS Impulsive Thresholds
Low-Frequency (LF) Cetaceans	*Cell 1* $L_{p,0\text{-}pk,flat}$: 219 dB $L_{E,LF,24h}$: 183 dB	*Cell 2* $L_{p,0\text{-}pk,flat}$: 213 dB $L_{E,LF,24h}$: 168 dB
Mid-Frequency (MF) Cetaceans	*Cell 4* $L_{p,0\text{-}pk,flat}$: 230 dB $L_{E,MF,24h}$: 185 dB	*Cell 5* $L_{p,0\text{-}pk,flat}$: 224 dB $L_{E,MF,24h}$: 170 dB

Blast Inputs	
TNT Yield (kg)	4973.68
Surface Pressure in Air (kPa)	12111.15
Surface Pressure in Water (kPa)	24210.18
Peak SPL dB (re 1 µPa)	267.7

Enter 4.5m Incident Pressure from https://unsaferguard.org/un-saferguard/kingery-bulmash

INPUTS	CALCS	RESULTS

ESA SPL for Indian Ocean

SPL Peak (Indian Ocean)			NMFS Thresholds (dB re 1 uPa)		Harassment Area (km²)		Species Harassment Results	
ESA Species Data (Indian Ocean)	Type	Density (per km²)	PTS	TTS	PTS	TTS	PTS	TTS
Blue Whale	LF cetacean	0.0000030	219	213	0.23182	0.92288	0.00000070	0.00000277
Fin Whale	LF cetacean	0.0008700	219	213	0.23182	0.92288	0.00020168	0.00080291
Sei Whale	LF cetacean	Unavailable	219	213	0.23182	0.92288	Unavailable	Unavailable
Sperm Whale	MF cetacean	0.00093	230	224	0.01841	0.07331	0.00001712	0.00006818
Green Turtle	Turtle	Unavailable	232	226	0.01162	0.04625	Unavailable	Unavailable
Hawksbill Turtle	Turtle	Unavailable	232	226	0.01162	0.04625	Unavailable	Unavailable
Leatherback Turtle	Turtle	Unavailable	232	226	0.01162	0.04625	Unavailable	Unavailable
Loggerhead Turtle	Turtle	Unavailable	232	226	0.01162	0.04625	Unavailable	Unavailable
Olive Ridley Turtle	Turtle	Unavailable	232	226	0.01162	0.04625	Unavailable	Unavailable
Species	Type	Density (per km²)	Onset of Physical Injury (dB re 1 uPa)		Injury Area (km²)		Species Injury Results	
Oceanic Whitetip Shark	Fish	Unavailable	206		4.63		Unavailable	Unavailable
Scalloped Hammerhead Shark	Fish	Unavailable	206		4.63		Unavailable	Unavailable

Cumulative or Equivalent Sound Exposure Level (SEL)

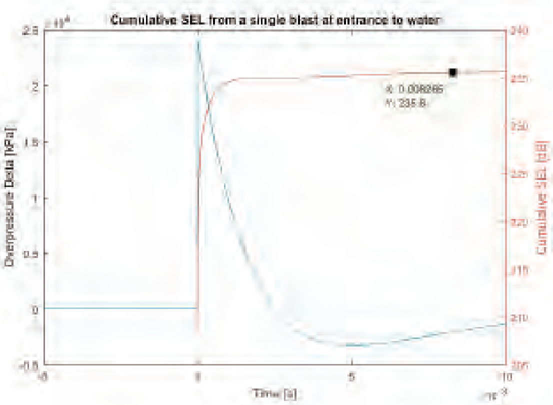
- SEL captures total sound exposure by integrating all pressure pulses or continuous noise exposure over a day and reducing it to the sound level which, if continuous for 1 second, would produce equivalent power
  - SpaceX is evaluating only one impulsive event
  - Trading time-integrated sound power this way assumes that only sound which is relevant to species harm over time is admitted. This is captured with a frequency weighting relevant to species hearing
  - Calculating SEL with no frequency weighting is overly conservative
- SEL can be calculated with a direct time series integration if available, or from a frequency domain representation of noise if available

Time domain:

$$SEL = 10\log_{10}\int_0^T \frac{P(t)^2}{P_{ref}^2}dt$$

Frequency domain:

$$SEL = 10\log_{10}\int_0^F \frac{E(f)Z_w}{P_{ref}^2}df$$



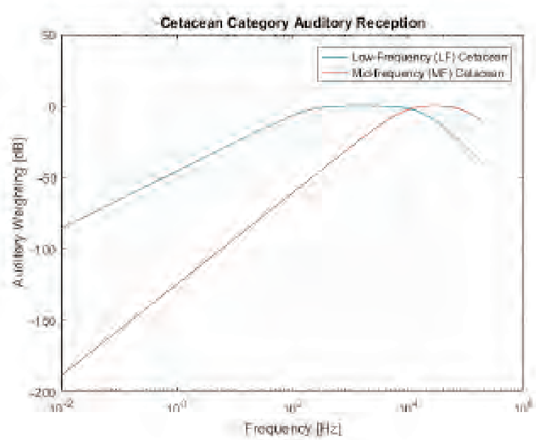
Auditory Response Weighting

- Auditory weighting function for low-frequency (LF) sensitive and mid-frequency (MF) sensitive cetaceans are provided in 2018 technical guidance revision from NMFS
- Weighting function is effectively a filter, which can be applied in either the time or frequency domain
  - SpaceX implementation of auditory weighting function as filter shown here

Hearing Group	*a*	*b*	f_1 (kHz)	f_2 (kHz)	*C* (dB)	*K* (dB)
Low-frequency (LF) cetaceans	1.0	2	0.2	19	0.13	179
Mid-frequency (MF) cetaceans	1.6	2	8.8	110	1.20	177
High-frequency (HF) cetaceans	1.8	2	12	140	1.36	152
Phocid pinnipeds (PW) (underwater)	1.0	2	1.9	30	0.75	180
Otariid pinnipeds (OW) (underwater)	2.0	2	0.94	25	0.64	198

* Equations associated with Technical Guidance's auditory weighting ($W_{aud}(f)$) and exposure functions ($E_{aud}(f)$):

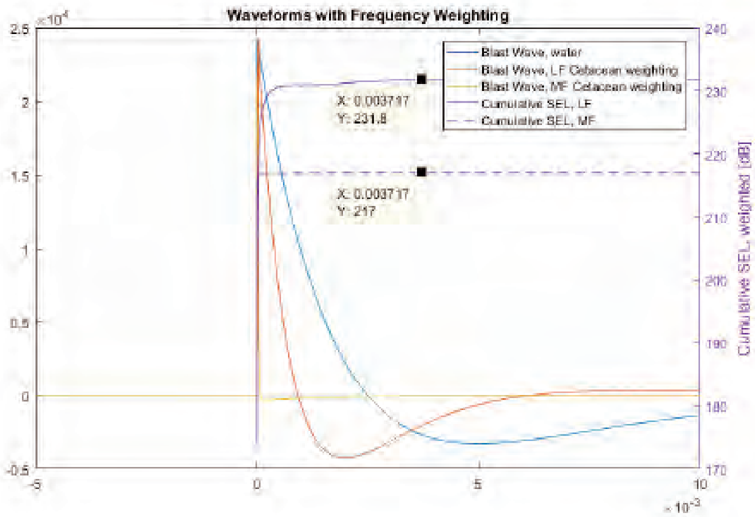
$$W_{aud}(f) = C + 10\log_{10}\left\{\frac{(f/f_1)^{2a}}{[1+(f/f_1)^2]^a[1+(f/f_2)^2]^b}\right\} \text{ dB}$$



Filtered Sound Exposure Levels

- Low pass and high pass combined filters, unique to each cetacean category, applied to blast waveform in time domain, from which auditory weighted SEL may be calculated

(unweighted) $L_{E,flat} = 235.6$ dB
(LF Weighting) $L_{E,LF} = 231.8$ dB
(MF Weighting) $L_{E,MF} = 217$ dB



Weighted SELcum Compared to Harm Thresholds

Initial level after water entrance:
SEL_cum (LF) = 231.8 dB, ref 1$\mu Pa^2 s$
SEL_cum (MF) = 217.0 dB, ref 1$\mu Pa^2 s$

Hearing Group	PTS Impulsive Thresholds	TTS Impulsive Thresholds
Low-Frequency (LF) Cetaceans	*Cell 1* $L_{p,0\text{-}pk,flat}$: 219 dB $L_{E,LF,24h}$: 183 dB	*Cell 2* $L_{p,0\text{-}pk,flat}$: 213 dB $L_{E,LF,24h}$: 168 dB
Mid-Frequency (MF) Cetaceans	*Cell 4* $L_{p,0\text{-}pk,flat}$: 230 dB $L_{E,MF,24h}$: 185 dB	*Cell 5* $L_{p,0\text{-}pk,flat}$: 224 dB $L_{E,MF,24h}$: 170 dB

			SELcum Weighted Impulse					
Species Data (Indian Ocean)			NMFS Thresholds (dB re 1 uPa)		Harassment Area (km^2)		Species Harassment Results	
Species	**Type**	**Density (per km^2)**	**PTS**	**TTS**	**PTS**	**TTS**	**PTS**	**TTS**
Blue Whale	LF cetacean	0.0000030	183	168	0.23831	7.53616	0.000001	0.000023
Fin Whale	LF cetacean	0.0008700	183	168	0.23831	7.53616	0.000207	0.006556
Sei Whale	LF cetacean	Unavailable	183	168	0.23831	7.53616	Unavailable	Unavailable
Sperm Whale	MF cetacean	0.00093	185	170	0.00498	0.15745	0.000005	0.000146
Green Turtle	Turtle	Unavailable	204	189	Unavailable	Unavailable	Unavailable	Unavailable
Hawksbill Turtle	Turtle	Unavailable	204	189	Unavailable	Unavailable	Unavailable	Unavailable
Leatherback Turtle	Turtle	Unavailable	204	189	Unavailable	Unavailable	Unavailable	Unavailable
Loggerhead Turtle	Turtle	Unavailable	204	189	Unavailable	Unavailable	Unavailable	Unavailable
Olive Ridley Turtle	Turtle	Unavailable	204	189	Unavailable	Unavailable	Unavailable	Unavailable
Species	**Type**	**Density (per km^2)**	**Onset of Physical Injury (dB re 1 uPa)**		**Injury Area (km^2)**		**Species Injury Results**	
Oceanic Whitetip Shark	Fish	Unavailable	187		Unavailable		Unavailable	Unavailable
Scalloped Hammerhead Shark	Fish	Unavailable	187		Unavailable		Unavailable	Unavailable

Hanson, Amy (FAA)

From: Hanson, Amy (FAA)
Sent: Wednesday, February 7, 2024 9:44 AM
To: Emily Chou - NOAA Federal
Cc: Lisamarie Carrubba - NOAA Federal; Zee, Stacey (FAA); Sherman, Steven; Zaccagnino, Jimmy; Baldwin, Robert; Cantin, Jacob (FAA); Murray, Michelle (FAA)
Subject: RE: Additional review and comments on revised SpaceX request

Emily,

Thank you again for your help on this. One last clarification statement is provided below:

Based on the information SpaceX has provided to the FAA to date, it is reasonably foreseeable to analyze the potential for up to a total of ten nominal operations, including up to a maximum of five overpressure events from Starship intact impact and up to a total of five reentry debris or soft water landings in the Indian Ocean, within a year of issuance of a NMFS concurrence letter. SpaceX has a near term goal of soft water landings by the end of 2024 and the ultimate goal of landing the Starship vehicle on land/barges to ensure reusability of the vehicle, however a high degree of uncertainty remains for the timing of successful missions to accomplish that goal. There are also potential vehicle changes that could affect future impact analyses. This is similar to SpaceX's prior development of the Falcon vehicle.

As noted in the February 2, 2024 letter, Starship breakup during reentry may be part of a nominal operation and would not create an overpressure event. Debris and soft water landings are not likely to adversely affect any species.

Based on all the information in the February 2, 2024 letter and the additional clarification information above the FAA anticipates this documentation to proceed through the informal consultation process.

Thank you.

Amy

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
1315 East-West Highway
Silver Spring, Maryland 20910

3/7/24

Refer to NMFS No: OPR-2024-00211

Ms. Stacey Zee
Manager, Operations Support Branch
U.S. Dept. Transportation, Federal Aviation Administration
Office of Commercial Space Transportation
800 Independence Ave SW, Suite 325
Washington, DC 20591

RE: Concurrence Letter for the Endangered Species Act Section 7 Consultation for FAA's Proposed Licensing of SpaceX Starship-Super Heavy Operations in the Indian Ocean

Dear Ms. Zee:

On February 5, 2024 the National Marine Fisheries Service (NMFS) received your request for a written concurrence that the Federal Aviation Administration's (FAA) licensing of the Space Exploration Technologies Corporation's (SpaceX) Starship-Super Heavy operations in the Indian Ocean is not likely to adversely affect species listed as threatened or endangered or critical habitats designated under the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531 et seq.). This response to your request was prepared by NMFS pursuant to section 7(a)(2) of the ESA, implementing regulations at 50 CFR § 402, and agency guidance for preparation of letters of concurrence (LoC).

This letter underwent pre-dissemination review using standards for utility, integrity, and objectivity in compliance with agency guidelines issued under section 515 of the Treasury and General Government Appropriations Act of 2001 (Data Quality Act; 44 U.S.C. 3504(d)(1) and 3516). A complete record of this informal consultation is on file at NMFS Office of Protected Resources in Silver Spring, Maryland.

Consultation History

- **November 21, 2023:** NMFS received via email from FAA a project specific review request for 5 Starship hard landings in the Indian Ocean per year under the existing programmatic concurrence for FAA for space launch and reentry (PLoC; OPR-2021-02908).
- **December 6, 2023:** NMFS requested, via email to FAA, more information regarding the proposed action. This included information on any effects from previous Starship-Super Heavy flights and breakups, the number of anticipated flights, number of anticipated explosions, sperm whale densities, expected flight trajectories, orientation of Starship landing, and clarification on the Indian Ocean Landing Area and ESA-listed species present therein. In this email, NMFS also informed FAA that some aspects of the proposed action could not be covered under the existing PLoC because the Indian Ocean

landings area is outside the action area of the PLoC and the PLoC does not cover effects from explosions upon landings.

- **December 11, 2023:** NMFS met with FAA and SpaceX to discuss NMFS's review of the project specific review request and information requested in the December 6, 2023 email. SpaceX made NMFS aware that they were going to revise their analysis of Starship's explosion based on information gathered about Starship's landing orientation during the most recent flight, which occurred on November 18, 2023.
- **January 9, 2023:** NMFS received, via email, FAA's revised request for informal consultation and a partial response to our requests for additional information (e.g., effects from previous Starship-Super Heavy flights/breakups, clarification on the Indian Ocean Landing Area were not provided).
- **January 18, 2024:** NMFS and FAA met to discuss whether the Starship-Super Heavy operations in the Indian Ocean, as described in the consultation request, constitute a single and complete project. NMFS also inquired about the number and probability of explosions. Based on information provided by SpaceX regarding the number of Starship vehicles that will be expended upon landing in the Indian Ocean, NMFS proposed a separate stand-alone consultation for Starship-Super Heavy operations to the Indian Ocean. This would include the requested 5 flights per year, for a period of 4 years (totaling 20 flights) until Starship-Super Heavy is reusable.
- **January 22, 2024:** NMFS requested, via email to FAA, additional information to allow NMFS to assess the action, including: 1) whether SpaceX will continue landings in the Pacific Ocean and if larger explosions are expected there as well, 2) any data on the probability of explosion, and 3) technical information supporting the analysis of potential explosions and their acoustic impacts.
- **January 23, 2024:** NMFS received from FAA a report on the outcome of Starship-Super Heavy Flight 2 (per NMFS's request for additional information). NMFS met with FAA and SpaceX to discuss technical comments on the potential acoustic impacts of the action, and some of NMFS's comments on the revised consultation request.
- **January 30, 2024:** NMFS requested, via email, additional information on the Flight 2 report and provided additional comments on the revised consultation request. Requests for additional information on the fate report included information on debris characterization, any vessel transit routes to debris, and any reports of protected species by the dedicated onboard observer. In this email, NMFS also provided, at the request of FAA and SpaceX, documentation on 1) NMFS's use of the two metrics to assess acoustic impacts from explosions, and 2) how NMFS assesses take.
- **February 1, 2024:** NMFS received, via email, the Indian Ocean Landing Area KMZ file from SpaceX (per NMFS's request for additional information).
- **February 5, 2024:** NMFS received, via email, an updated consultation request from FAA and responses to our requests for additional information, and met with FAA and SpaceX regarding consultation schedule, launch schedules, and the scope of the consultation.
- **February 7, 2024:** NMFS received an amendment to the consultation request via email from FAA. FAA amended the consultation request from 5 flights in 1 year (2024) to 10 flights within 1 year from the date when the letter of concurrence is received by FAA.
- **February 16, 2024:** NMFS met with FAA and SpaceX regarding the technical analysis of the potential explosive events and NMFS's anticipated reporting requirements.

- **February 20, 2024:** NMFS sent, via email to FAA, requests for additional information on the updated consultation request and reporting requirements needed to proceed with an informal consultation.
- **February 22, 2024:** NMFS received responses to our requests for additional information via email from FAA. NMFS provided, via email, additional questions on Super Heavy's landing area in the Gulf of Mexico in relation to the recent final listing of queen conch and characterization of anomalies.
- **February 23, 2024:** NMFS received, via email from SpaceX, the Gulf of Mexico landing area for Super Heavy. FAA provided a response regarding NMFS's question on anomalies. FAA and NMFS further clarified anomalies on a call on February 27, 2024.

PROPOSED ACTION AND ACTION AREA

The ESA regulations at 50 CFR § 402.02 define "action" to mean all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies in the United States or upon the high seas. The existing PLoC covers Starship-Super Heavy launches and launch operations (e.g., weather balloon deployment, pre-launch surveillance) from the Boca Chica Launch Site and Super Heavy landings (expended Super Heavy vehicles and barge/floating platform landings) in the Gulf of Mexico portion of the programmatic action area. The PLoC also covers launch failure anomalies (see OPR-2021-02908).

The proposed action for this consultation is FAA's proposed issuance of a vehicle operator license(s) for SpaceX Starship-Super Heavy operations upon the high seas in the Indian Ocean. NMFS is consulting on the proposed actions that would be authorized under the license(s). Based on current best available information on the Starship-Super Heavy launch vehicle provided by FAA and SpaceX, this consists of 10 Starship-Super Heavy flights over a one-year period, with up to 5 Starship hard landings in the Indian Ocean. Similar to the April 2023 LoC (OPR-2023-00318) for Starship landing in the North Pacific Ocean with the possibility of one hard landing, a Starship hard landing entails Starship exploding upon impact with the ocean's surface. Starship hard landings in the Indian Ocean will consist of both main and header tanks exploding upon impact, rather than only the main tank as was the case in the April 2023 LoC. The area of the Indian Ocean where Starship will land (referred to as the Indian Ocean Landing Area; Figure 1) is generally between latitudes 15 degrees (°) and 30° South, in waters greater than 200 nautical miles (NM; 370 kilometers [km]) from any land mass. The remaining flights will end in a combination of 1) Starship breaking up upon reentry and generating a debris field in the Indian Ocean Landing Area, or 2) a soft-water landing in the Indian Ocean Landing Area where Starship lands vertically in the water, aft end down, and then tips over, landing intact and sinking. The following subsections provide a description of the proposed Starship-Super Heavy launch vehicle and Starship landings.

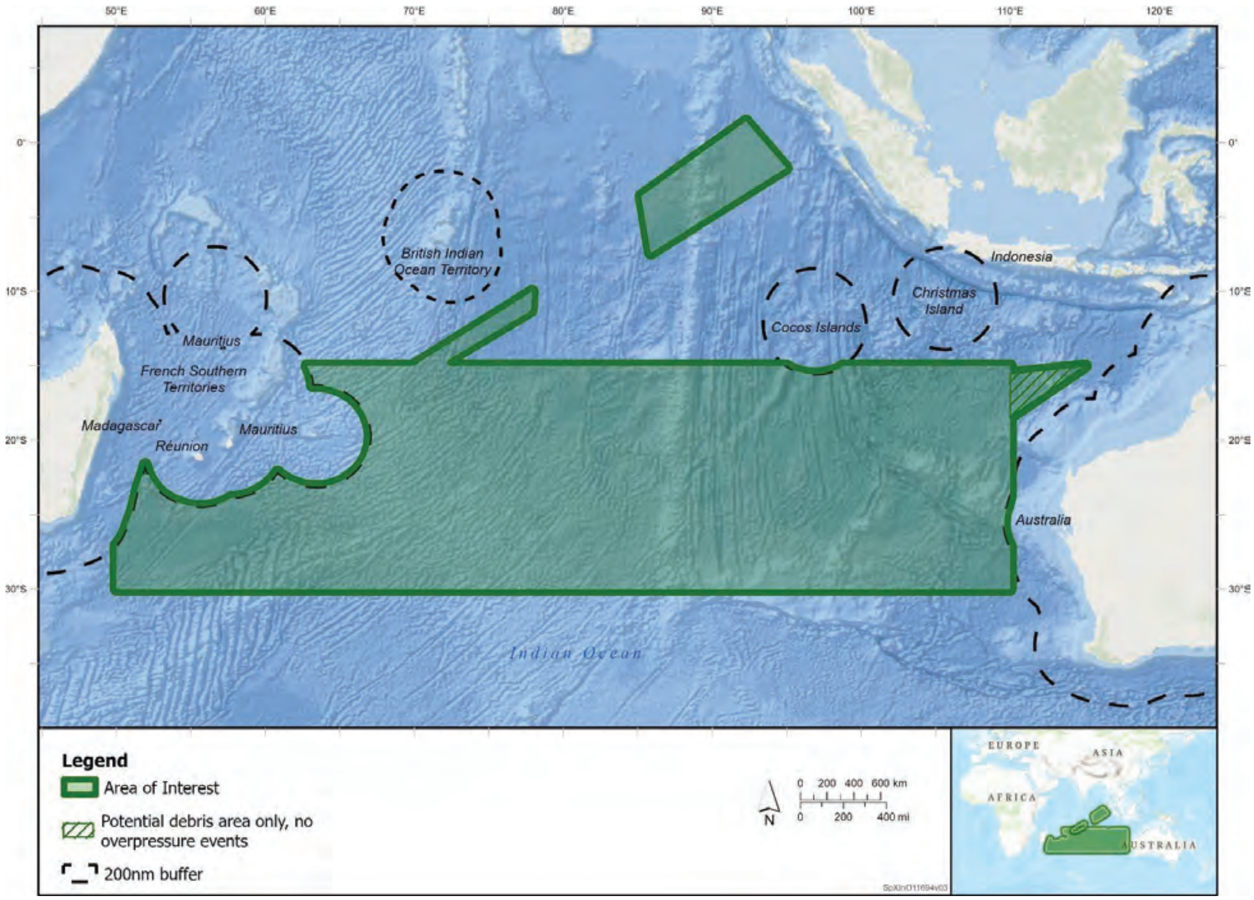


Figure 1. Map of the Indian Ocean Landing Area.

Starship-Super Heavy Launch Vehicle

SpaceX's Starship-Super Heavy launch vehicle is approximately 397 feet (ft; 121 meters [m]) tall by 29.5 ft (9 m) in diameter, and is comprised of 2 stages: Super Heavy is the first stage (or booster) and Starship (the spacecraft) is the second stage. Super Heavy will land back on Earth shortly after vertical launch (takeoff). Super Heavy operations are suborbital and Super Heavy is not considered by the FAA to be a reentry vehicle because it has not completed one orbit around the Earth. These first stage landings are considered part of a launch and are covered under the PLoC.

Starship is a reentry vehicle, which is a vehicle designed to return from Earth orbit or outer space to Earth.

Starship Reentry and Landing Operations

SpaceX's goal is to work towards reusability of the Starship-Super Heavy launch vehicle during the flights considered under this consultation. Full reusability entails Starship and Super Heavy landing back at the launch site or on an ocean-going barge or floating platform, which would then be towed back to port. SpaceX expects to attempt Starship soft-water landings within the 2024 calendar year. However, while working towards reusability, some Starship vehicles will be expended (i.e., disposed of in the ocean). In those cases, Starship will land in the Indian Ocean. Starship is expected to land in the Indian Ocean Landing Area, where an explosive (overpressure) event may occur if Starship is intact when it impacts the surface of the ocean (i.e., a hard landing). Up to 5 Starship hard landings are expected, and the remaining flights are expected to end in either Starship 1) breakup upon reentry with a debris field in the Indian Ocean Landing Area, or 2) soft-water landing in the Indian Ocean Landing Area.

After separation from Super Heavy and ascent engine cutoff, Starship will retain residual propellant in the main and header tanks. Following the in-space coast phase, Starship will begin its passive descent. During descent, when Starship is supersonic, a sonic boom with a maximum predicted overpressure of approximately 2.2 psf will be generated. Some residual propellant, approximately 30,650 kilograms (kg; 67,572 pounds [lbs]) in the header tanks and approximately 70,000 kg (154,324 lbs) in the main tanks, will remain in Starship. Starship may impact the Indian Ocean in the Indian Ocean Landing Area horizontally, intact, and at terminal velocity (i.e., the steady speed achieved by a freely falling object. An explosion will most likely originate in the fuel transfer tube (Figure 2), which will simultaneously ignite the main and header tanks because the fuel system is connected. For flights ending with a Starship breakup upon reentry, a debris field is expected within the Indian Ocean Landing Area. For flights ending with a Starship soft-water landing, Starship will land vertically within the Indian Ocean Landing Area, aft end down, and then will tip over, landing intact horizontally and sinking (i.e., no debris field).

Debris created by either the Starship explosion or from Starship breakup upon reentry will create a debris field comprised of mostly heavyweight metals and some composite (e.g., carbon fiber) materials. SpaceX expects that the majority of Starship debris (stainless steel) will sink rapidly, due to the weight and composition of the steel. Some lighter items may float or stay suspended in the water column before sinking. Impact-related debris from an explosion is expected to be contained within approximately 0.5 NM (1 km) of the landing point. Regardless of the termination of Starship in the Indian Ocean Landing Area (explosion, breakup upon reentry, or soft-water landing), there will be no Starship recovery or debris salvage operations in the Indian Ocean.

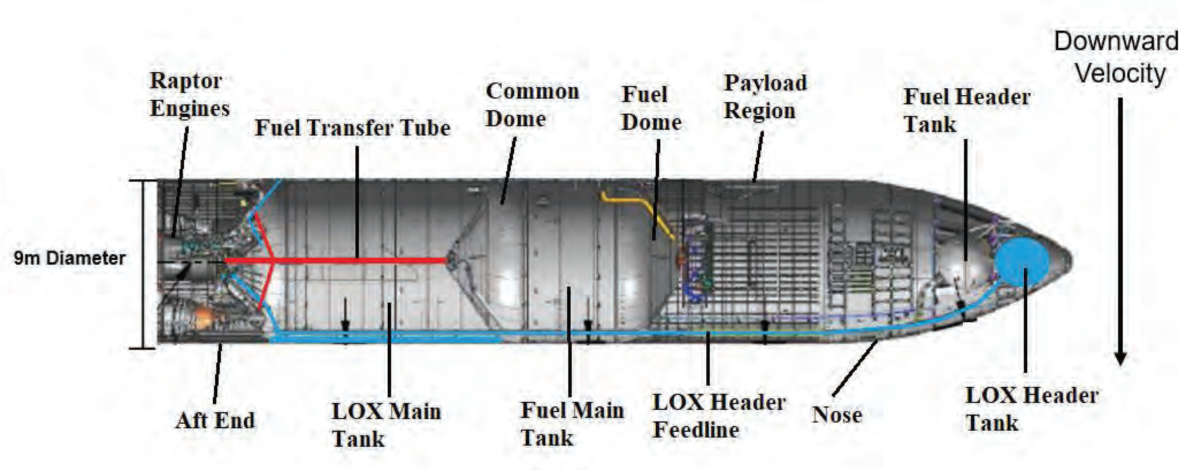


Figure 2. Starship vehicle and location of fuel transfer tube (origin of explosion).

Each flight's mission is different, depending on SpaceX's goals for the flight. Therefore, where Starship is expended (within the Indian Ocean Landing Area) and what constitutes an anomaly[1] (not covered under this consultation) may differ for each flight. For Flight 3 (the first flight occurring after issuance of this letter of concurrence), the only anticipated operation is Starship's intact horizontal landing in the Indian Ocean Landing Area at terminal velocity creating an explosive event. Any other landing or breakup will be considered an anomaly for Flight 3.

Project Design Criteria and Reporting Requirements

As a condition of the FAA's proposed issuance of a vehicle operator license on SpaceX Starship-Super Heavy operations as described above, SpaceX must comply with the Project Design Criteria (PDCs) and Environmental Protection Measures as described in the PLoC (Appendix I – Project Design Criteria).

Given uncertainties, the experimental nature of the Starship-Super Heavy vehicle, and the potential for similar operations in the future, NMFS seeks to gather as much data as possible on the proposed operations to inform future effects analyses. Therefore, in addition to the implementation of the PDCs and the annual reporting requirement under the PLoC, FAA, in coordination with SpaceX, will provide a report after each Starship-Super Heavy flight. After each Starship-Super Heavy flight, FAA will provide information to NMFS detailing the results of launch and landings, based on available telemetry data received from the vehicles, including:

1. Whether Starship and Super Heavy resulted in an anomaly or nominal landing, and where (expressed in the last known GPS location) the anomaly or landing occurred.
2. The debris catalog generation, approximate location, and any other information that can corroborate assumptions about the debris and/or debris field from a launch failure anomaly (of each vehicle).
3. Whether Starship landings occurred in the expected manner (i.e., belly flop or soft-water landing or atmospheric breakup with debris field within the Indian Ocean landing area). For landings resulting in explosion, information reported to NMFS shall include the amount of fuel/propellant remaining in main and header tanks, Starship orientation upon landing, debris catalog generation, and any other data that can corroborate whether the assumptions about the explosion and area of impact (physically and acoustically) were appropriate.

Reports after each flight should be submitted 30 days prior to the following flight, to allow time for NMFS to review the information. The reports should be submitted electronically to nmfs.hq.esa.consultations@noaa.gov with the subject line "Starship-Super Heavy [Flight #] Report, OPR-2024-00211."

Action Area

The action area is defined in 50 CFR § 402.02 as "all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action." The proposed

[1] The definition of an anomaly under 14 CFR (Aeronautics and Space) § 401.7 is "any condition during licensed or permitted activity that deviates from what is standard, normal, or expected, during the verification or operation of a system, subsystem, process, facility, or support equipment."

action for this consultation will take place in the Indian Ocean (Indian Ocean Landing Area; Figure 1).

ESA-Listed Species and Critical Habitat in The Action Area

The ESA-listed threatened and endangered species under NMFS' jurisdiction listed in Table 1 are known to occur, or could reasonably be expected to occur, in the Indian Ocean action area, and may be affected by stressors produced by the proposed action. Detailed information about the biology, habitat, and conservation status of the species listed in Table 1 can be found in their status reviews, recovery plans, Federal Register notices, and other sources at https://www.fisheries.noaa.gov/topic/endangered-species-conservation.

Table 1. ESA-listed threatened and endangered species potentially occurring in the action area that may be affected by the FAA's proposed authorization of a license(s) to SpaceX for Starship-Super Heavy operations.

Species	ESA Status	Critical Habitat	Recovery Plan
Marine Mammals - Cetaceans			
Blue Whale (*Balaenoptera musculus*)	E – 35 FR 18319	-- --	07/1998 11/2020
Fin Whale (*Balaenoptera physalus*)	E – 35 FR 18319	-- --	75 FR 47538 07/2010
Sei Whale (*Balaenoptera borealis*)	E – 35 FR 18319	-- --	12/2011
Sperm Whale (*Physeter macrocephalus*)	E – 35 FR 18319	-- --	75 FR 81584 12/2010
Marine Reptiles			
Green Turtle (*Chelonia mydas*) – East Indian-West Pacific DPS	T – 81 FR 20057	-- --	-- --
Green Turtle (*Chelonia mydas*) – North Indian DPS	T – 81 FR 20057	-- --	-- --
Green Turtle (*Chelonia mydas*) – Southwest Indian DPS	T – 81 FR 20057	-- --	-- --
Hawksbill Turtle (*Eretmochelys imbricata*)	E – 35 FR 8491	63 FR 46693*	57 FR 38818 08/1992 – U.S. Caribbean, Atlantic, and Gulf of Mexico 63 FR 28359

			05/1998 – U.S. Pacific
Leatherback Turtle (*Dermochelys coriacea*)	E – 35 FR 8491	44 FR 17710 and 77 FR 4170*	10/1991 – U.S. Caribbean, Atlantic, and Gulf of Mexico 63 FR 28359 05/1998 – U.S. Pacific
Loggerhead Turtle (*Caretta caretta*) – North Indian Ocean DPS	E – 76 FR 58868	-- --	-- --
Loggerhead Turtle (*Caretta caretta*) – Southeast Indo-Pacific Ocean DPS	T – 76 FR 58868	-- --	-- --
Loggerhead Turtle (*Caretta caretta*) – Southwest Indian Ocean DPS	T – 76 FR 58868	-- --	-- --
Olive Ridley Turtle (*Lepidochelys olivacea*) – All Other Areas/Not Mexico's Pacific Coast Breeding Colonies	T – 43 FR 32800	-- --	-- --
Fishes			
Oceanic Whitetip Shark (*Carcharhinus longimanus*)	T – 83 FR 4153	-- --	1/2023 (Draft)
Scalloped Hammerhead Shark (*Sphyrna lewini*) – Indo-West Pacific DPS	T – 79 FR 38213	-- --	-- --

DPS=distinct population segment; ESU=evolutionarily significant unit; E=endangered; T=threatened; FR=Federal Register

** Not in the action area. There are no designated critical habitats in the action area because critical habitat may only be designated in areas within the jurisdiction of the U.S. (50 CFR § 424.12).*

Effects Analysis

The applicable standard to find that a proposed action is not likely to adversely affect ESA-listed species or designated critical habitat is that all of the effects of the action are expected to be discountable, insignificant, or wholly beneficial. Discountable effects relate to the probability of exposure. For an effect to be discountable, it must be extremely unlikely to occur. Insignificant effects relate to the probability of a response given an exposure and include those effects that are undetectable, not measurable, or so minor that they cannot be meaningfully evaluated. Insignificant is the appropriate effect conclusion when effects will not cause a response that can be measured or detected. Beneficial effects have an immediate positive effect without any adverse effects to the species or habitat.

The following subsections identify the potential stressors and analyze the potential effects of the FAA's proposed issuance of a license(s) to SpaceX for Starship-Super Heavy operations to the Indian Ocean on the ESA-listed species in the action area. Stressors are any physical, chemical, or biological agent, environmental condition, external stimulus, or event that modifies the land, water, or air occupied by an ESA-listed species or its designated critical habitat. Potential stressors to ESA-listed species from the proposed activities include the following:

- Direct contact from Starship or Starship debris;
- Ingestion of material from unrecovered floating debris; and
- Acoustic stressors, including exposure to sonic booms and impulse noise from stage landings, and explosive event upon Starship's landing in the Indian Ocean.

Potential effects to the ESA-listed species from these stressors are discussed in the following sections.

Direct Contact from Starship and Starship Debris

Starship and Starship debris falling and landing in the Indian Ocean have the potential to affect ESA-listed species in the action area. The primary concern is direct contact from an object landing on an ESA-listed marine mammal, sea turtle, or fish, because the impact of a vehicle or debris striking an ESA-listed species may result in injury or mortality to the individuals that are struck.

The area within which Starship and Starship debris will land is relatively small compared to the area over which species can be distributed in the Indian Ocean. Because some of the ESA-listed species considered in this consultation are distributed across these ocean basins, species densities are relatively low overall. For example, in the Indian Ocean, the highest density for ESA-listed species is 0.0009 individuals per square kilometer (km^2) for sperm whales (U.S. Navy 2019). Compared to the Indian Ocean Landing Area, Starship is relatively small (50 m [165 ft] tall and 9 m [29.5 ft] in diameter). Further, though debris size and mass would vary, the largest debris is expected to measure approximately 1.83 m [6 ft] wide and 3.66 [12 ft] m long. Therefore, the probability of a direct impact to an ESA-listed species is extremely unlikely.

The same conclusion was reached when analyzing the Joint Flight Campaign missile testing from the Pacific Missile Range Facility (OPR-2021-02470). The Biological Evaluation for the Joint Flight Campaign utilized the best available density data for ESA-listed marine mammals and sea turtles, which is from the U.S. Navy's Marine Species Density Databases for training and testing areas in the Pacific (U.S. Navy 2017). Species densities were averaged across the study area within a proposed drop zone, and the highest estimated densities across seasons were used to represent animal densities in the entire drop zone. For a single flight test from the Pacific Missile Range Facility, the maximum number of estimated animal exposures for any ESA-listed species was for humpback whales, at 0.00001 individuals, corresponding to a 1 in 100,000 chance of contacting a humpback whale during a single test from the Pacific Missile Range Facility.

Materials have been expended from rocket launches for decades with no known interactions with any of the ESA-listed species considered in this consultation. Although commercial space launch and reentry operations are increasing, based on the current best available science, we believe it is extremely unlikely for an ESA-listed species to be directly struck by Starship or Starship debris. Therefore, the potential effects to ESA-listed species from a direct impact by Starship or Starship debris are discountable. We conclude that direct impact from Starship or Starship debris to ESA-listed marine mammals, sea turtles, and fishes in the action area from the proposed action may affect, but is not likely to adversely affect these species.

Ingestion

Unrecovered floating debris in the ocean have the potential to affect ESA-listed species in the action area. Individuals of ESA-listed species foraging in the area could ingest pieces of unrecovered floating debris from expended Starships. Although there have been many recent studies on debris ingestion, mainly of micro- and macroplastics, in marine mammals and sea turtles (e.g., Kühn and van Franeker 2020; Zantis et al. 2021), a majority of ingested debris types were related to fishing (e.g., nets, lines, ropes) and everyday plastic items (e.g., candy wrappers, plastic bags, polystyrene; Baulch and Perry 2014; Unger et al. 2016). There have been no studies to date on ingestion of debris originating from space launch and reentry activities.

Given that the unrecovered floating Starship debris is likely to be scattered and not concentrated, and that it should only be available in the upper portions of the water column for approximately 1–2 weeks, the potential for exposure of ESA-listed species to this debris is extremely low and therefore discountable. Also, none of the ESA-listed species considered in this consultation forage at the seafloor; therefore, the likelihood of them encountering ingestible material once it has settled over the long-term is expected to be extremely unlikely to occur and thus discountable.

We conclude that the risk of ingesting pieces of unrecovered floating debris to ESA-listed marine mammals, sea turtles, and fishes in the action area because of the proposed action may affect, but is not likely to adversely affect these species.

Acoustic Stressors

Potential acoustic stressors to ESA-listed species from the proposed action include sonic booms and impulse noise from Starship landings in the ocean, and expected explosive event(s) upon Starship's landing in the Indian Ocean Landing Area.

NMFS uses acoustic thresholds to predict how an animal's hearing will respond to sound exposure (see https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-acoustic-technical-guidance).

For marine mammals, acoustic thresholds are different based on marine mammal hearing groups (Table 2). Marine mammal hearing groups are used to acknowledge that not all marine mammal species have identical hearing or susceptibility to noise-induced hearing loss. They are also used to establish marine mammal auditory weighting functions.

Table 2. Marine mammal hearing groups.

Hearing Group	Generalized Hearing Range*
Low-frequency (LF) cetaceans (baleen whales)	7 Hz – 35 kHz
Mid-frequency (MF) cetaceans (dolphins, toothed whales, beaked whales, bottlenose whales)	150 Hz – 160 kHz
High-frequency (HF) cetaceans (true porpoises, *Kogia*, river dolphins, Cephalorhynchid, *Lagenorhynchus cruciger* & *L. australis*)	275 Hz – 160 kHz
Phocid pinnipeds (PW) (underwater) (true seals)	50 Hz – 86 kHz
Otariid pinnipeds (OW) (underwater) (sea lions and fur seals)	60 Hz – 39 kHz

Hz=Hertz; kHz=kiloHertz

***** *Represents the generalized hearing range for the entire group as a composite (i.e., all species within the group), where individual species' hearing ranges are typically not as broad. Generalized hearing range chosen based on ~65 dB threshold from normalized composite audiogram, with the exception for lower limits for LF cetaceans (Southall et al. 2007) and PW pinniped (approximation).*

Sonic Booms and Impulse Noise

A sonic boom will be generated during Starship landings in the ocean. Due to the shape and size of Starship, as well as the altitude at which Starship would generate a sonic boom, the FAA does not expect the overpressure to exceed 1–2 psf. The maximum overpressure for a Starship reentry is 2.2 psf. An overpressure of 1 psf is similar to a thunderclap. Boom intensity, in terms of psf, is greatest under the flight path and progressively weakens with horizontal distance away from the flight path.

Overpressure from sonic booms are not expected to affect marine species such as ESA-listed fishes, underwater. At the altitude where the reentering vehicle generates a sonic boom, acoustic energy in the air does not effectively cross the air-water boundary and most of the sound energy is reflected off the water's surface (Richardson et al. 1995). Additionally, underwater sound pressure levels from in-air noise are not expected to produce a measurable response from ESA-listed species.

Previous research conducted by the U.S. Air Force supports this conclusion with respect to sonic booms, indicating the lack of harassment risk for protected marine species in the water (U.S. Air Force Research Laboratory 2000). The U.S. Air Force researchers determined that the threshold for harassment of marine mammals and sea turtles from impulsive sound is a peak pressure of 12 pounds per square inch (psi) in the water. However, to produce 12 psi in water, a surface (in-air) pressure of approximately 900 psf is needed. The researchers point out that a sonic boom of 50 psf at the ocean surface is rare (U.S. Air Force Research Laboratory 2000). Thus illustrating that it would take a much greater sonic boom than would be generated by Starship (maximum 2.2 psf) landings to create an acoustic impact underwater that could cause a measurable response in ESA-listed marine mammals, sea turtles, or fishes. Therefore, any effect from the sonic booms on ESA-listed species while underwater would be insignificant.

ESA-listed marine mammals and sea turtles in the action area could be exposed to the overpressures from sonic booms in the air when they are surfacing to breathe. However, the chance of both events happening at the same time (i.e., species surfacing and a sonic boom occurring) is extremely low, given the low species densities and considering the length of a sonic boom is less than 1 second (less than 300 milliseconds). There is little information on how cetaceans and sea turtles may respond to sonic booms.

In summary, it is extremely unlikely that an ESA-listed marine mammal or sea turtle would surface close to Starship at the exact moment to be exposed to a sonic boom in the air; therefore, the effects are discountable. Acoustic effects from a sonic boom to ESA-listed marine mammals, sea turtles, or fishes underwater are not expected to be measurable; therefore, the effects are insignificant. Therefore, sonic booms may affect, but are not likely to adversely affect, ESA-listed marine mammals, sea turtles, and fishes.

Noise from Starship Explosive Event

Although it is difficult to determine exact occurrence and effects of the Starship landing and subsequent explosion, SpaceX provided the best available information based on previous launches and tests of similar vehicles, and NMFS defers to their expertise here. SpaceX's analysis is summarized below.

When Starship impacts the water horizontally (i.e., a belly flop position) in the Indian Ocean Landing Area, some propellant will remain in the header (30,650 kg [67,572 lbs]) and main (70,000 kg [154,324 lbs]) tanks. Upon impact, LOX and LCH_4 will mix, resulting in a deflagration within Starship before transitioning to a detonation, which would destroy Starship. The origin of the explosion will be the fuel transfer tube. The mass of the fuel transfer tube to flex is relatively high, so it will have more inertia than the header and main tanks, and will crack first, leading to the failure of the fuel transfer tube. Thus, the origin of the explosion will be approximately 14.8 ft (4.5 m) above the ocean's surface (i.e., the location of the fuel transfer tube when Starship is horizontal). The explosion will simultaneously ignite the header and main tanks because the fuel system is connected. Based on an 11.9% explosive yield, the header tanks will retain 3,647.35 kg (8,041 lbs) in explosive weight. The main tanks' explosive weight of 6,300 kg (13,889 lbs) is based on a 9% explosive yield. Therefore, the total remaining explosive weight is 9,947.35 kg (21,930 lbs). SpaceX analyzed the combined explosive weight from the fuel transfer tube (amount depends on how much fuel is sent from the main and header tanks, but is included in the total explosive weight), main tanks, and header tanks as a single explosion. The explosion will generate a sound wave, which starts within Starship and continues into the air before impacting the water.

To calculate the underwater acoustic effects from the Starship explosion, SpaceX used a hemispherical model. SpaceX expects a total 9,947.35 kg (21,930 lbs) explosive weight for a spherical model; thus, for a hemispherical model, they expect that half of the explosive weight (4,973.68 kg [10,965 lbs]) will be directed towards the water and the other half released into the air. Because the air-water boundary is within the nearfield of the explosion, there is likely significant coupling between the explosion and the water, and the portion of the acoustic wave intensity that is transmitted into the water will likely be higher than when a normal acoustic wave reaches the air-water boundary. Thus, SpaceX used an intensity transmission coefficient of 0.0326. SpaceX concluded this is a conservative approach that accounts for the limited scope of research into near-surface explosions and their transmission across the air-water boundary. This resulted in an estimate of 267.7 decibels referenced to a pressure of 1 microPasal (dB re 1μPa) peak sound pressure level. Using this value, SpaceX calculated the distance to insignificant response thresholds. The ensonified areas within which species could respond to acoustic stressors are then calculated as a circle. Insignificant responses are anticipated outside of the ensonified areas listed in Table 3.

Table 3. ESA-listed species in the Indian Ocean Landing Area, hearing/species group, minimum threshold for a response, and ensonified areas related to the explosive event within which there could be a response.

Species	Hearing/Species Group	Minimum Threshold to Response* (dB re 1 μPa)	Ensonified Area (km^2)
Blue Whale	Low-frequency cetacean	213	0.92
Fin Whale	Low-frequency cetacean	213	0.92
Sei Whale	Low-frequency cetacean	213	0.92
Sperm Whale	Mid-frequency cetacean	224	0.07
Green, Hawksbill, Leatherback, Loggerhead, and Olive Ridley Turtles	Sea turtle	226	0.05
Oceanic Whitetip Shark, Scalloped Hammerhead Shark	Fish	206	4.63

** Note peak sound pressure level thresholds are used.*

To estimate the number of exposures resulting from the explosive event, species densities were multiplied by the ensonified areas (Table 4). The best available density data for some ESA-listed marine mammals in the Indian Ocean were obtained from the U.S. Navy's Final Supplemental Environmental Impact Statement/Supplemental Overseas Environmental Impact Statement for Surveillance Towed Array Sensor System Low Frequency (SURTASS LFA) Sonar in 2019 (U.S. Navy 2019). Areas modeled in U.S. Navy (2019) do not completely cover the Indian Ocean Landing Area, but the modeled area of Northwest Australia, does overlap with the eastern portion of the Indian Ocean Landing Area. It is worth noting that the Northwest Australia modeled area is based on data from the Eastern Tropical Pacific (U.S. Navy 2019). This is because survey data in the Indian Ocean are limited or non-existent, while the Eastern Tropical Pacific has been extensively surveyed for marine mammals and is an area with similar oceanographic and ecological characteristics as the Northwest Australia modeled area (U.S.

Navy 2019). Therefore, available densities for blue, fin, and sperm whales were obtained from U.S. Navy (2019).

Table 4. ESA-listed species densities in the Starship Indian Ocean Landing Area and calculations for the estimated number of exposures that would amount to more than insignificant related to the explosive event.

Species	Density (individuals per km^2)	Ensonified Area (km^2)	Estimated Number of Exposures more than Insignificant
Blue Whale	0.000003	0.92	0.0000028
Fin Whale	0.00087	0.92	0.000803
Sperm Whale	0.00093	0.07	0.0000682

Densities for ESA-listed sei whales, sea turtle species, oceanic whitetip sharks, and scalloped hammerhead sharks in the Indian Ocean Landing Area were not available in U.S. Navy (2019). There are very little data on sei whales that may occur in the action area. Based on data from the Ocean Biodiversity Information System's Spatial Ecological Analysis of Megavertebrate Populations (OBIS-SEAMAP; Halpin et al. 2009), there have been observations of sei whales off Northwest Australia, near the eastern boundary of the Indian Ocean portion of the action area. However, sei whales generally prefer more temperate waters than those that make up the majority of the Indian Ocean Landing Area, and have been detected between 40° and 50° South in the southern Indian Ocean and in the Southern Ocean (Miyashita et al. 1995; Calderan et al. 2014). Therefore, we expect that sei whale densities in the Indian Ocean Landing Area will be lower than the available densities of blue, fin, and sperm whales. In addition, given the small ensonified area within which more than insignificant responses are expected for sei whales (> 1 km^2), we believe that the estimated number of exposures that would be more than insignificant for sei whales would be lower than that for blue, fin, and sperm whales.

Data on sea turtles in the middle of ocean basins is limited because of challenging conditions and logistics of conducting surveys offshore. North Indian Ocean DPS, Southwest Indian Ocean DPS, and East Indian-West Pacific DPS of green turtles may occur in the action area. Nesting beaches occur in countries near the western and eastern boundaries of the Indian Ocean Landing Area, and coastlines much further north (NMFS 2007; Seminoff et al. 2015). These DPSs of green turtles forage mainly in seagrass beds found in coastal waters, but may move into and transit through oceanic zones. Southwest Indian Ocean DPS, Southeast Indo-Pacific DPS, and North Indian Ocean DPS of loggerhead turtles may occur in the action area. Foraging areas for these DPSs of loggerhead turtles are generally coastal (Rees et al. 2010; Harris et al. 2018; Robinson et al. 2018). Juveniles in the North Indian Ocean may undertake trans-equatorial movements (Dalleau et al. 2014). In fact, the few sighting records of ESA-listed sea turtles within the Indian Ocean Landing Area are of a tagged loggerhead turtle migrating north-south through the westernmost portion of the Indian Ocean Landing Area (Halpin et al. 2009; Dalleau et al. 2014). Southwest Indian Ocean DPS individuals also migrate between foraging and nesting areas, though these migration corridors are generally close to shore (Harris et al. 2015; Harris et al. 2018) and outside of the Indian Ocean Landing Area. The Southeast Indo-Pacific DPS generally forages off coastal Western Australia to Indonesia (Casale et al. 2015). Olive ridley turtles appear to be most abundant in coastal waters of the northern Indian Ocean (NMFS 2014), although satellite tagging of 1 individual showed movement to waters deeper than 656 ft (200 m; Rees et al. 2012). Hawksbill turtles in the eastern Indian Ocean generally forage in waters less than 328 ft (100 m) deep (Fossette et al. 2021). Leatherback turtles occur throughout the Indian Ocean (Hamann et al. 2006; Nel 2012). Satellite tagging of post-nesting leatherback turtles in South Africa showed that less than half of the tagged individuals moved south and then east into oceanic waters of the Indian Ocean, below the Indian Ocean Landing Area (Robinson et al. 2016). Leatherback nesting populations in the southwest Indian Ocean (e.g., South Africa) and northeast Indian Ocean (e.g., Sri Lanka, Andaman Islands) total approximately 100 nesting females, and between 100–600 nesting females per year, depending on the island, respectively (Hamann et al. 2006). The number of nesting females (the only population estimates available) is relatively small given the large Indian Ocean Landing Area. Therefore, we expect that densities of ESA-listed sea turtles in the Indian Ocean Landing Area will be lower than the available densities of blue, fin, and sperm whales. In addition, given the small ensonified area within which significant responses could be expected for ESA-listed sea turtles (0.05 km^2), we believe that the estimated number of exposures that would be more than insignificant for ESA-listed sea turtles will be lower than that for blue, fin, and sperm whales.

Little data exist on oceanic whitetip sharks and Indo-West Pacific DPS of scalloped hammerhead sharks in the Indian Ocean. Most data come from fisheries bycatch data, collected by the Indian Ocean Tuna Commission, and there are no quantitative stock assessments for either species. Oceanic whitetip sharks are generally found offshore in the open ocean, on the outer continental shelf, or around oceanic islands in deep waters, and prefer warm (> 20°C; Bonfil et al. 2008) open ocean waters between 10° North and 10° South latitude, which overlaps with the Indian Ocean Landing Area (NMFS 2017). Oceanic whitetip sharks can dive to deep waters, though it is believed that these are short-duration foraging dives (NMFS 2017). Oceanic whitetip sharks have been bycaught in tuna purse seine fisheries adjacent to the western boundary of the Indian Ocean Landing Area (Lopetegui-Eguren et al. 2022), and have also been bycaught in the Spanish longline swordfish fishery (Ramos-Cartelle et al. 2012) that overlaps the Indian Ocean Landing Area. However, the majority of oceanic whitetip sharks bycaught in the Indian Ocean were caught between latitudes 0° and 10° South, outside of the Indian Ocean Landing Area. Oceanic whitetip shark bycatch within the Indian Ocean Landing Area is likely higher than what would be expected with standard survey data, because fishing vessels put out bait that attracts predators like the oceanic whitetip shark. Anecdotal reports suggest that oceanic whitetip sharks have become rare throughout most of the Indian Ocean over the past 20 years (IOTC 2015). Although scalloped hammerhead sharks can be found in warm temperate and tropical waters down to nearly 3,280 ft (1,000 m), they are most often found in coastal waters (IOTC 2013). Therefore, we expect that densities of oceanic whitetip sharks and scalloped hammerhead sharks in the Indian Ocean Landing Area will be lower than the available densities of blue, fin, and sperm whales. In addition, given the small ensonified area within which non-insignificant responses could be expected for ESA-listed fishes (> 5 km^2), we believe that the estimated number of exposures that would be more than insignificant for ESA-listed fishes will be lower than that for blue, fin, and sperm whales.

Given the low estimated exposures that could amount to an effect beyond insignificant, we expect that potential effects of an explosive event, as calculated by SpaceX, on ESA-listed species to be extremely unlikely and therefore discountable.

Conclusion

Based on this analysis, NMFS ESA Interagency Cooperation Division concurs with the FAA that the proposed action may affect, but is not likely to adversely affect, ESA-listed species and designated critical habitat.

Conservation Recommendations

Section 7(a)(1) of the ESA directs Federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on ESA-listed species or critical habitat, to help implement recovery plans or develop information (50 C.F.R. § 402.02).

We make the following discretionary conservation recommendations that we believe are consistent with this obligation and therefore should be considered by FAA in relation to their 7(a)(1) responsibilities. These recommendations will provide information for future consultations involving launch and reentry vehicle operations that may affect ESA-listed species.

- We recommend that FAA gather acoustic data on the expected explosive event. Sound source verification may help to more accurately determine the impacts of this explosion scenario in the future.
- The action agency should coordinate with the NMFS ESA Interagency Cooperation Division to foster collaboration with the NOAA Marine Debris Program (MDP), in order to evaluate how activities of the MDP may apply to debris that originates from space launch and reentry operations (e.g., expended vehicle components).

The FAA should notify the ESA Interagency Cooperation Division of any conservation recommendations implemented as part of activities included in this consultation so NMFS is aware of actions undertaken that minimize or avoid adverse effects on ESA-listed species or their critical habitat. This information can be included in annual reports.

Reinitiation Of Consultation

Reinitiation of consultation is required and shall be requested by the federal action agency, where discretionary federal involvement or control over the action has been retained or is authorized by law and:

1. New information reveals effects of the action that may affect an ESA-listed species or designated critical habitat in a manner or to an extent not previously considered (e.g., reinitiation may be triggered if Starship lands in the Indian Ocean in a way that is not described in this consultation);
2. The identified action is subsequently modified in a manner that causes an effect to the ESA-listed species or designated critical habitat that was not considered in this concurrence letter (e.g., if any recovery actions will occur in the Indian Ocean); or
3. A new species is listed or critical habitat designated that may be affected by the identified action (50 C.F.R. § 402.16).

Please direct questions regarding this letter to Emily Chou, Consulting Biologist, at (301) 427-8483 or emily.chou@noaa.gov, or me at (240) 723-6321 or tanya.dobrzynski@noaa.gov.

Sincerely,

DOBRZYNSKI.TANYA.JANINE.1365846517 Digitally signed by DOBRZYNSKI.TANYA.JANINE.1365846517 Date: 2024.03.07 16:49:55 -05'00'

Tanya Dobrzynski
Chief, ESA Interagency Cooperation Division
Office of Protected Resources
National Marine Fisheries Service

Cc: Amy Hanson, FAA

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Appendix I – Project Design Criteria

Project design criteria (PDCs) are identified as part of a programmatic consultation and are applicable to future projects implemented under the program. In the case of this consultation, PDCs include environmental protection measures developed by the FAA to limit the effects of launch operations. These environmental protection measures will lead to avoidance and minimization of effects to ESA-listed species and designated critical habitat in the action area to assist in the conservation of these resources.

General PDCs applicable to this consultation:

- Launch and reentry operations will be conducted by the USSF, NASA, or an FAA-licensed (or permitted) commercial operator from a launch site identified in Table 1. Launch preparations will occur in compliance with standard operating procedures and best management practices currently implemented at these existing launch vehicle facilities.
- Launch operations will utilize launch vehicles identified in Table 3.
- Launch activities, including suborbital landings and splashdowns, and orbital reentry activities will occur in the proposed action area at least 5 NM offshore the coast of the United States or islands. The only operations component that will occur near shore will be watercraft transiting to and from a port when recovering spacecraft or launch vehicle components, or possibly for surveillance.
  - No launch operator will site a landing area in coral reef areas.
  - No activities will occur in or affect a National Marine Sanctuary unless the appropriate authorization has been obtained from the Sanctuary.
- Landing operations will not occur in the aquatic zone extending 20 NM (37 km) seaward from the baseline or basepoint of each major rookery and major haul-out of the Western Distinct Population Segment (DPS) Steller sea lion located west of 144° West.
- Launch abort testing will only occur in the Atlantic Ocean from CCAFS or KSC as previously analyzed (SER-2016-17894, FPR-2017-9231). In addition:
  - It will not occur in designated critical habitat for the North Atlantic right whale.
  - It will not occur during the North Atlantic right whale winter calving season from November to mid-March.
- Utilize all feasible alternatives and avoid landing in Rice's whale core habitat distribution area as much as possible. No more than one splashdown, reentry and recovery of the Dragon capsule, will occur in Rice's whale core habitat distribution area per year. No other operations, spacecraft, launch or reentry vehicle landings, or expended components will occur in Rice's whale core habitat distribution area. The Rice's whale core habitat distribution area map (Figure 1) and GIS boundary can be accessed here: https://www.fisheries.noaa.gov/resource/map/rices-whale-core-distribution-area-map-gis-data.

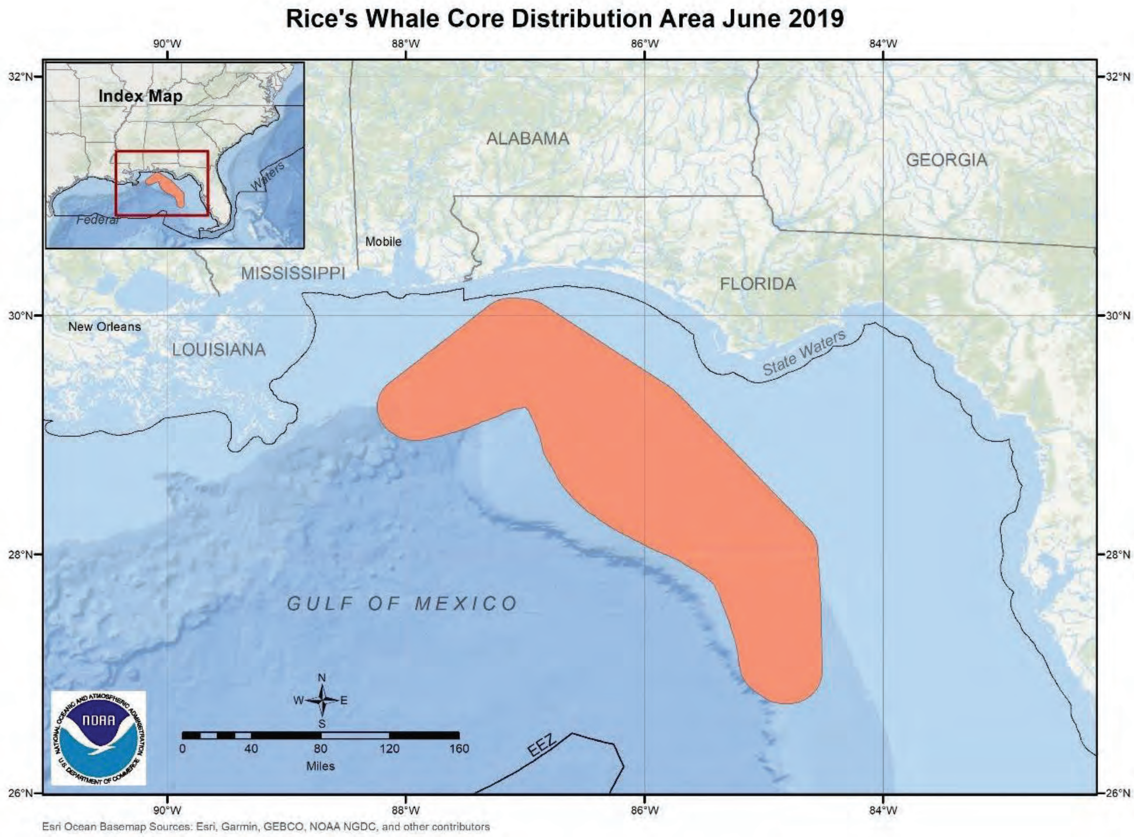

Figure 1. Rice's Whale Core Distribution Area in the Gulf of Mexico.

Education and Observation

- Each launch operator will instruct all personnel associated with launch operations about marine species and any critical habitat protected under the ESA, and species protected under the MMPA that could be present in the operations area.[2] The launch operator will advise personnel of the civil and criminal penalties for harming, harassing, or killing ESA-listed and MMPA-protected species.
- Each launch operator will provide a dedicated observer(s) (e.g., biologist or person other than the watercraft operator that can recognize ESA-listed and MMPA-protected species) that is responsible for monitoring for ESA-listed and MMPA-protected species with the aid of binoculars during all in-water activities, including transiting marine waters for surveillance or to retrieve boosters, spacecraft, other launch-related equipment or debris.
  - When an ESA-listed or MMPA-protected species is sighted, the observer will alert vessel operators to apply the Vessel Operations protective measures.
  - Dedicated observers will record the date, time, location, species, number of animals, distance and bearing from the vessel, direction of travel, and other relevant information, for all sightings of ESA-listed or MMPA-protected species.

[2] The FAA is responsible for ensuring ESA compliance. The launch operator is responsible for MMPA compliance. Measures to protect all marine mammals are included here for animal conservation purposes.

- Dedicated observers will survey the launch recovery area for any injured or killed ESA-listed or MMPA-protected species and any discoveries will be reported as noted below.

Reporting Stranded, Injured, or Dead Animals

- Each launch operator will immediately report any collision(s), injuries or mortalities to, and any strandings of ESA-listed or MMPA-protected species to the appropriate NMFS contact listed below, and to Cathy Tortorici, Chief, ESA Interagency Cooperation Division by e-mail at cathy.tortorici@noaa.gov.
  - For operations in the Gulf of Mexico and Atlantic Ocean: 727-824-5312 or via email to takereport.nmfsser@noaa.gov, and a hotline 1-877-WHALE HELP (942-5343).
  - For operations on the west coast/Pacific Ocean: 562-506-4315 or via email to Justin.Viezbicke@noaa.gov, and a hotline for whales in distress 877-767-9245.
  - For operations near Alaska, statewide hotline: 877-925-7773.
  - Additional regionally organized contact information is here: https://www.fisheries.noaa.gov/report.
- In the Gulf of Mexico and Atlantic Ocean waters near Florida, each launch operator will report any smalltooth sawfish sightings to 941-255-7403 or via email Sawfish@MyFWC.com.
- Each launch operator will report any giant manta ray sightings via email to manta.ray@noaa.gov.
- In the Atlantic Ocean, each launch operator will report any injured, dead, or entangled North Atlantic right whales to the U.S. Coast Guard via VHF Channel 16.

Vessel Operations

All watercraft operators will be on the lookout for and attempt to avoid collision with ESA-listed and MMPA-protected species. A collision with an ESA-listed species will require reinitiation of consultation. Watercraft operators will ensure the vessel strike avoidance measures and reporting are implemented and will maintain a safe distance by following these protective measures:

- Maintain a minimum distance of 150 ft from sea turtles.
- In the Atlantic Ocean, slow to 10 knots or less and maintain a minimum distance of 1,500 ft (500 yards) from North Atlantic right whales.
- In the Gulf of Mexico, slow to 10 knots or less and maintain a minimum distance of 1,500 ft (500 yards) from Rice's whale [formerly Gulf of Mexico Bryde's whale]. If a whale is observed but cannot be confirmed as a species other than a Rice's whale, the vessel operator must assume that it is a Rice's whale.
- Maintain a minimum distance of 300 ft (100 yards) from all other ESA-listed and MMPA-protected species. If the distance ever becomes less than 300 ft, reduce speed and shift the engine to neutral. Do not engage the engines until the animals are clear of the area.
- Watercraft operators will reduce speed to 10 knots or less when mother/calf pairs or groups of marine mammals are observed.
- Watercraft 65 ft long or longer will comply with the Right Whale Ship Strike Reduction Rule (50 CFR § 224.105)[3] including reducing speeds to 10 knots or less in Seasonal

[3] See: http://www.fisheries.noaa.gov/pr/shipstrike/.

Management Areas or in Right Whale Slow Zones, which are dynamic management areas established where right whales have been recently seen or heard.
    - The Whale Alert app automatically notifies when entering one of these areas.
- Check various communication media for general information regarding avoiding ship strikes and specific information regarding North Atlantic right whale sightings in the area. These include NOAA weather radio, U.S. Coast Guard NAVTEX broadcasts, and Notices to Mariners.
    - There is also an online right whale sightings map available at https://apps-nefsc.fisheries.noaa.gov/psb/surveys/MapperiframeWithText.html.
- Attempt to remain parallel to an ESA-listed or MMPA-protected species' course when sighted while the watercraft is underway (e.g., bow-riding) and avoid excessive speed or abrupt changes in direction until the animal(s) has left the area.
- Avoid vessel transit in the Rice's whale core distribution area. If vessel transit in the area is unavoidable, stay out of the depth range of 100 m to 425 m (where the Rice's whale has been observed; Rosel et al. 2021) as much as possible and go as slow as practical, limiting vessel speed to 10 knots or less.
- No operations or transit will occur at night in Rice's whale core distribution area.

Aircraft Procedures

Spotter aircraft will maintain a minimum of 1,000 ft over ESA-listed or MMPA-protected species and 1,500 ft over North Atlantic right whales. Additionally, aircraft will avoid flying in circles if marine mammals or sea turtles are spotted to avoid any type of harassing behavior.

Hazardous Materials Emergency Response

In the event of a failed launch operation, launch operators will follow the emergency response and cleanup procedures outlined in their Hazardous Material Emergency Response Plan (or similar plan). Procedures may include containing the spill using disposable containment materials and cleaning the area with absorbents or other materials to reduce the magnitude and duration of any impacts. In most launch failure scenarios, at least a portion (if not most) of the propellant will be consumed by the launch/failure, and any remaining propellant will evaporate or be diluted by seawater and biodegrade over time (timeframes are variable based on the type of propellant and environmental conditions, but generally hours to a few days).