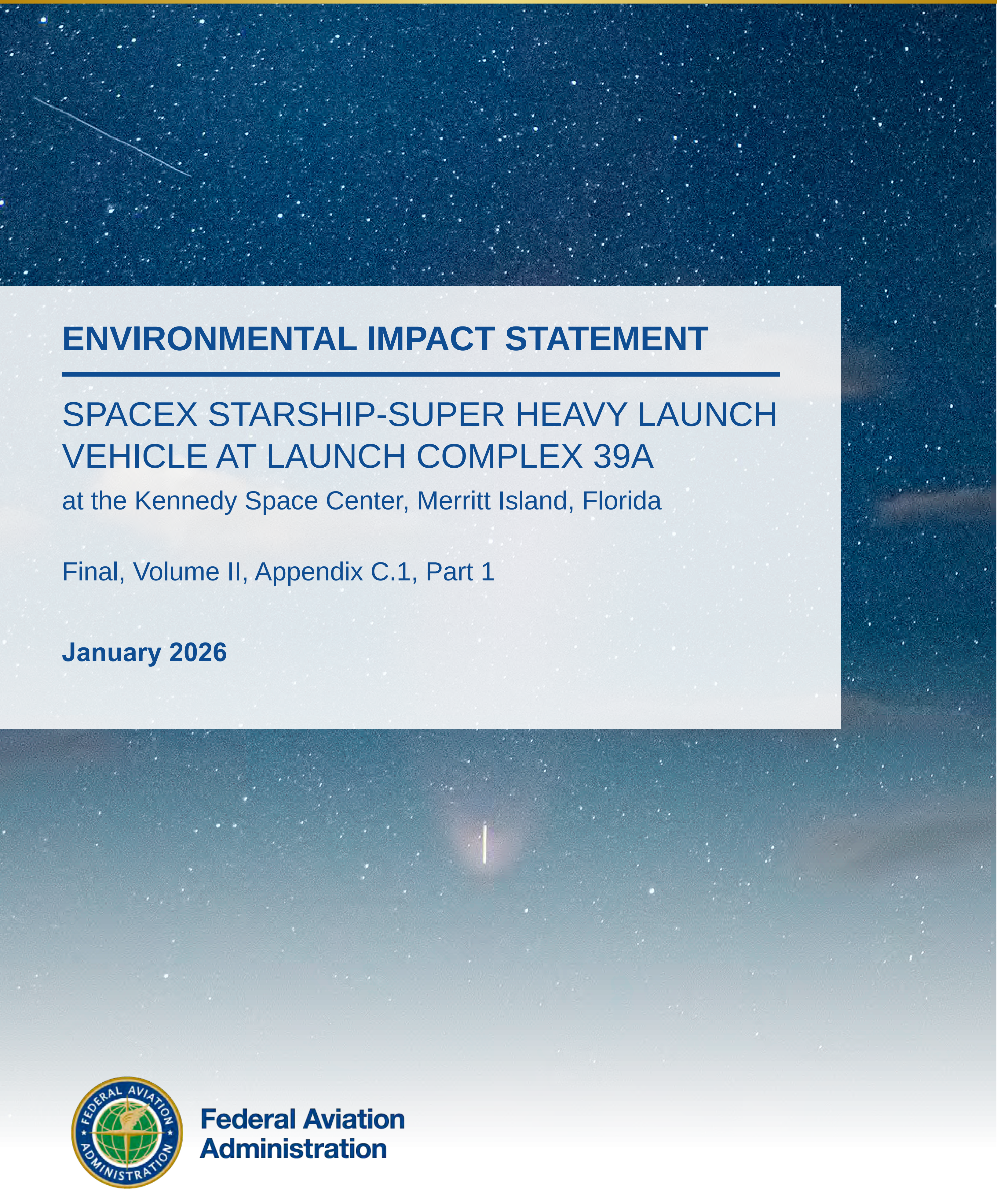

ENVIRONMENTAL IMPACT STATEMENT

SPACEX STARSHIP-SUPER HEAVY LAUNCH VEHICLE AT LAUNCH COMPLEX 39A

at the Kennedy Space Center, Merritt Island, Florida

Final, Volume II, Appendix C.1, Part 1

January 2026

Federal Aviation Administration

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Appendix C *Resource Area Supporting Information*

C.1 Noise Assessment and Noise Assessment Appendix

Federal Aviation Administration

Memorandum

Date: September 15, 2025

To: Stacey Zee, Manager, Operations Support Branch, Office of Commercial Space Transportation (AST)

From: David Senzig, Acting Manager, Noise Division., Office of Environment & Energy (AEE) DAVID ALAN SENZIG 2025.09.15 11:34:23 -04'00'

Subject: Noise Modeling Methodology for the SpaceX Starship and Super Heavy Booster Operations at Kennedy Space Center Launch Complex 39A

The Office of Environment and Energy (AEE) has reviewed the proposed non-standard noise modeling methodology to be used in the Environmental Assessment involving SpaceX launches and landings of their Starship and Super Heavy Booster spacecraft at Kennedy Space Center's Launch Complex 39A (LC-39A).

As the FAA does not currently have an approved propulsion noise model for launch vehicles, in accordance with FAA Order 1050.1F in place at the time of the analysis, all non-standard noise analysis in support of the noise impact analysis for the National Environmental Policy Act (NEPA) must be approved by AEE. This letter serves as AEE's response to the method proposed in the July 16 memo outlining the 44 Starship and Super Heavy launches at LC-39A.

The proposed methodology appears to be adequate for modeling propulsion for launch vehicles; therefore, AEE concurs with the methodology proposed for this project. Please understand that this approval is limited to this particular instance. Any additional projects using this or other launch noise methodologies or variations of launch vehicle will require separate approval.

C.1.1 Noise Assessment

STARSHIP ROCKET NOISE ASSESSMENT FOR FLIGHT AND TEST OPERATIONS AT KENNEDY SPACE CENTER LAUNCH COMPLEX 39A

TN 25-01

May 2025

Prepared for:

Leidos, Inc.

Acknowledgements

***This document was prepared as*:**

KBR Technical Note TN 25-01 (Final Version 4)

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Professional Services Agreement No. P01032655407

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Cover Image By Space Exploration Technologies Corp. - SpaceX

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Executive Summary

Space Exploration Technologies Corporation (SpaceX) is proposing to conduct flight operations and testing of the Starship launch vehicle at Launch Complex 39A (LC-39A) at Kennedy Space Center (KSC), Florida. Starship is a two-stage fully reusable super heavy-lift launch vehicle capable of carrying crew and cargo to Earth orbit, the Moon, Mars and beyond. The Starship launch vehicle, referred to as Starship, includes the first stage Super Heavy (or booster), and the second stage Starship spacecraft. To support environmental studies for Federal Aviation Administration (FAA) and National Aeronautics and Space Administration (NASA) actions, KBR, Inc. conducted this noise modeling study to estimate the single event and cumulative noise levels in the vicinity of LC-39A from future Starship launches, Starship spacecraft and booster landings, and static fire tests of both vehicles. Starship operations at LC-39A would consist of 44 annual operations of each of these types of flight and ground test events and this noise study assumed 50 percent of these operations would occur at nighttime. Rocket noise and sonic boom exposures were assessed for all proposed Starship operations at LC-39A along with other related operational scenarios including the study Baseline (which describes the cumulative noise exposure from past rocket operations within the last 12 months prior to this analysis), the No Action Scenario (which describes the cumulative noise exposure from all approved future actions which have completed their environmental review), the Proposed Action (including the No Action operations plus the proposed Starship operations at LC-39A), and the Reasonably Foreseeable Future Actions scenario (which includes the Proposed Action for LC-39A plus the proposed Starship operations at Space Launch Complex 37 (SLC-37) at Cape Canaveral Space Force Station (CCSFS). While the focus of this study is the Starship operations at LC-39A and associated noise exposures, a similar noise modeling study was conducted in parallel to evaluate the proposed Starship operations at SLC-37, as these results were needed to estimate noise exposure for the Reasonably Foreseeable Future Actions scenario.

The RNOISE model, which computes far field noise levels in the community, was used to estimate rocket noise from Starship flight and test operations at LC-39A and noise from SpaceX's Falcon 9 and Falcon Heavy operations at CCSFS and KSC; all other launch operations at CCSFS and KSC were modeled in a separate study and combined with the Falcon 9 and Falcon Heavy operations to create the Baseline and No Action noise models for this study. SpaceX provided the operations data for all their vehicles required to conduct noise modeling of the individual flight and test events, including orbital launch and Starship spacecraft and booster landing trajectories, engine operating data, and static fire test parameters. The PCBoom model was used to compute single-event sonic boom contours of peak overpressure from the same Starship flight operations at LC-39A and for the Falcon 9 and Falcon Heavy operations that are part of the Baseline and No Action scenarios.

The noise and sonic boom modeling included weather variations. SpaceX provided five weather data sets representing seasonal and daytime and nighttime profiles at Cape Canaveral. Noise results were obtained for all weather variations; Annual Mean results, typically used for environmental noise assessments, are presented in this report while the noise results representing the other four weather variations (Summer Day, Summer Night, Winter Day, and Winter Night) are included in an appendix to this report.

Starship orbital launch events are the loudest single rocket noise events of all the flight and test operations assessed in this modeling study. First, considering single event noise levels, the higher Maximum A-weighted Sound Level (L_{Amax}) contours (100 dB – 140 dB) are located within about 8 miles of LC-39A; the 100 dB contour is located within the KSC property and CCSFS property except for areas over the Banana River and Indian River. The L_{Amax} 90 dB contour extends west of the Indian River into Titusville. L_{Amax} levels are less than NASA's 108 dBA upper noise limit guideline for hearing conservation, at distances greater than approximately 5 miles from the launch pad. The 111 dB and 120 dB Maximum Unweighted Sound Level (L_{max}) contours, used to conservatively assess the potential for structural damage, are approximately 22 miles and 10 miles from the launch pad, respectively; the L_{max} 120 dB contour is within the KSC and CCSFS properties, whereas the L_{max} 111 dB contour extends beyond Titusville to the west and Cocoa Beach to the south (one damage claim is expected per 1,000 households exposed at 111 dB). Similarly, Super Heavy static fire tests have a low probability of causing structural damage with the estimated L_{max} 111 dB contour also extending west of Titusville. The extent of the rocket noise exposures for all other Starship spacecraft and booster flight and test operations would be less than the noise exposure for launch. Cumulatively, these subsonic noise events would not cause significant impacts to residents in communities outside of CCSFS and KSC, as determined by the Day-Night Average Sound Level (DNL) 65 dB threshold for land use compatibility; although depending on their location, rocket noise from individual launch, landing, and static fire test events are expected to be heard by people in the nearby, surrounding communities, including Merritt Island, Titusville, Port St. John, Allenhurst, and the City of Cape Canaveral; under certain circumstances, when atmospheric conditions favor long-range sound propagation, noise may be heard by people in communities located even farther away from LC-39A. However, due to the estimated levels and frequency of events, these individual noise events are not expected to cause general annoyance or pose health concerns, though noise complaints may occur.

Cumulative rocket noise levels were assessed for all Starship operations combined as well as for the four primary study scenarios: Baseline, No Action, Proposed Action, and Reasonably Foreseeable Future Actions. The estimated DNL 65 dB contours for all these scenarios are estimated to be entirely within the CCSFS and KSC properties. Similarly, DNL was also assessed at the twenty-four study points of interest, for each scenario, and there are no residential areas outside of CCSFS and KSC exposed to DNL above 65 dB.

Additional supplemental metrics were assessed at the study points of interest (POIs) to provide a better understanding of the potential impacts from rocket noise events, including Speech Interference, Classroom Learning Interference, Probability of Awakening, Potential for Hearing Loss, and the Potential for Structural Damage. Due to most residential areas and schools being located relatively far (5+ miles) away from LC-39A, and due to the infrequency of Starship operations (e.g., compared with operations at a military airfield), the assessment for most of the supplemental metrics indicates minor impact with the exception that probability of awakenings is close to or above 10 percent at most POIs. The probability of awakenings is to be taken as a conservative, rough estimate since no current, standardized method of assessment exists and additional research needs to be done to evaluate sleep disturbance. To address the other supplemental metrics, the highest number of speech interfering events per daytime hour (0.02), that would potentially be experienced at 11 of the 24 POIs, is equal to 9 speech interfering events per month or nearly 110 speech interfering events per year. The potential for classroom learning interference was screened by checking if any of the seven schools evaluated would be exposed to exterior Leq(8hr) levels greater than 60 dB; which equates to an interior noise level of 45 dB Leq(8hr) with windows open and represents the threshold at which studies have found classroom learning is affected. Since none of the schools would be exposed to exterior levels this high, no further analysis is warranted. There is the potential for hearing loss for workers at KSC and CCSFS launch facilities, where noise mitigation programs are implemented; however, the noise levels would be below the minimum level/time threshold in the communities adjacent to KSC and CCSFS.

Sonic boom exposures were assessed for the flight operations at LC-39A: Starship launches, Starship spacecraft reentry/landings and booster landings. The sonic boom from a Starship launch at LC-39A would occur over the Atlantic Ocean after the vehicle pitches over during ascent, making it unlikely that people would be exposed to this noise event. The estimated sonic boom footprints for Starship spacecraft reentry/landing events at LC-39A indicate overpressure contours from 1 psf to 1.7 psf shown along and to the side of the trajectory. Near the landing site there is an oval shaped boom footprint region (with a reported maximum overpressure level of 1.72 psf). The 1 psf contour is estimated to extend about 30 miles west of the landing site, west of Titusville. Booster landings would generate the greatest sonic boom exposure of the three flight operations: boom levels near the LC-39A landing pad would be greater than 20 psf; boom levels on CCSFS and KSC properties would range from 4 to 10 psf in areas away from the landing pad; residents outside of the CCSFS and KSC properties would experience lower boom levels ranging from 1 to 4 psf (some residents in the northern half of the city of Cape Canaveral could experience boom levels above 4 psf). The highest boom levels offshore are between 10 and 20 psf just east of LC-39A. While exposure to sonic booms at these levels can annoy and startle people and may interfere with their sleep, these levels pose no realistic risk of causing hearing damage.

Cumulative sonic boom levels were also estimated, using C-weighted Day-Night Average Sound Level (CDNL), for the projected annual landing operations at LC-39A. CDNL values from Starship spacecraft landing operations are all below the impulsive noise limit of 60 dBC for acceptable land uses. Super Heavy booster landings would result in CDNL values at most POIs that exceed the 60 dBC noise limit, primarily because of the high number of nighttime landing operations. Thus, whereas cumulative noise impacts due to rocket noise (or subsonic noise) would not be significant in the communities around KSC and CCSFS, cumulative sonic boom impacts, primarily due to booster landings, would be considered significant in areas where the threshold for land use compatibility (CDNL 60 dBC) is exceeded; these include the communities of Cape Canaveral, Cocoa Beach, Cocoa, and parts of Titusville.

The noise results for proposed Starship operations at SLC-37 are similar, except SLC-37 is approximately 5 miles south of LC-39A and would have 76 annual operations of each type (launch, landings and static fire tests of both vehicles) compared with 44 annual operations of each type at LC-39A.

Noise exposure results for the four operation scenarios analyzed (Baseline, No Action, Proposed Action, and Reasonably Foreseeable Future Actions), along with Starship operations at LC-39A alone, are presented in the report and are summarized in the Noise Exposure Assessment Summary in Section 8.

1 INTRODUCTION

1.1 BACKGROUND

Space Exploration Technologies Corporation (SpaceX) proposes to conduct launch, reentry, and ground test operations of their Starship launch vehicle at Kennedy Space Center (KSC) Launch Complex 39A (LC-39A). Under the supervision of the Federal Aviation Administration (FAA) Office of Commercial Space Transportation as lead agency, and with the National Aeronautics and Space Administration (NASA) participating as a cooperating agency, SpaceX is preparing an Environmental Impact Statement (EIS) to evaluate the potential environmental impacts of proposed infrastructure construction and Starship operations. To support the EIS, KBR, Inc. has estimated noise levels for the Starship operations at LC-39A. The Starship spacecraft, which is currently under development, has a length of seventy meters and a diameter of nine meters, will be attached to a Super Heavy booster rocket (length of eighty meters) to form the Starship launch vehicle intended to provide long-duration cargo- and passenger-carrying capability. Both vehicles have vertical take-off and landing (VTOL) capability and are fully reusable. The Starship spacecraft would use nine Raptor engines that each provide sea-level thrust of about 3.19 Meganewtons (MN) (or 6.45 million (MM) pound-force total) during flight operations and static fire tests. The Super Heavy, or booster, would use thirty-five Raptor engines that each provide sea-level thrust of about 2.94 MN (or 23.1 MM pound-force total) during launch and static fire tests.

This noise study was conducted to estimate single event and cumulative noise levels, including rocket noise and sonic boom exposure, from future Starship launches, Starship spacecraft and booster Return to Launch Site (RTLS) landings, and static fire tests of both vehicles at LC-39A. SpaceX provided the following operations data for noise modeling:

- Orbital launch trajectory for the Starship from liftoff to stage separation, including Raptor engine operating data and nominal ascent thrust profile.
- Starship spacecraft and booster RTLS (descent/landing) trajectories with descent thrust profiles.
- Static fire test parameters for the Starship spacecraft and booster.
- Projected annual daytime and nighttime launches, landings, and static fire tests of these vehicles at LC-39A using a 50/50 daytime/nighttime split.
- Weather profile variations for Cape Canaveral, including seasonal and daytime/nighttime profiles.

Rocket noise levels were estimated for proposed Starship flight and static test operations of both vehicles at LC-39A using the RNOISE[1,2] model. RNOISE is a far-field (distances beyond several hundred feet) community noise model for rocket noise assessment. Sonic boom exposures due to Starship operations at LC-39A were estimated using the PCBoom model[3,4]; PCBoom computes single-event sonic boom footprints, including contours of peak overpressure and signatures from any supersonic vehicle executing arbitrary maneuvers in a three-dimensional atmosphere. This report presents the estimated results for Starship single event and cumulative noise exposures at LC-39A along with cumulative noise estimates for other existing and future rocket operation scenarios at Cape Canaveral Space Force Station (CCSFS) and KSC. Comparison of the results from these study scenarios, described below, are used to assess the change in noise exposure due to proposed Starship operations at LC-39A.

1.2 Operational Scenarios Analyzed

1.2.1 Baseline Scenario

The Baseline (or Existing) operations scenario and cumulative rocket noise levels were developed by Blue Ridge Research and Consulting (BRRC) in a separate study and report titled "Cape Canaveral Space Force Station and Kennedy Space Center DNL Noise Contours"[5], dated 20 November 2024. The BRRC report describes the launch, landing, and static fire test operations that were conducted between 1 September 2023 and 31 August 2024 at all active CCSFS and KSC rocket facilities. Note that the Baseline operations, as defined in this report (described in Section 3.1 below) are based on all the non-SpaceX operations included in the BRRC report plus all the existing annual SpaceX Falcon 9 and Falcon Heavy operations which were modeled separately as part of the current effort; Day-Night Average Sound Level (DNL) contour results, described following, from both efforts were combined to produce the Baseline DNL contours for CCSFS and KSC reported herein. Additionally, Baseline cumulative sonic boom levels, associated with SpaceX's Falcon 9 and Falcon Heavy landing operations, were estimated as part of the current effort.

1.2.2 No Action Scenario

The No Action (Maximum) scenario was also developed in BRRC's study[5] and includes the planned future operations and cumulative rocket noise levels from all approved future actions that have completed their environmental review. Like the Baseline operations and noise exposure, the No Action operations and associated noise exposure, as defined in this report (described in Section 4.1 below), are based on all the non-SpaceX operations included in the BRRC report plus all the No Action annual SpaceX Falcon 9 and Falcon Heavy operations which were modeled separately as part of the current effort; Day-Night Average Sound Level (DNL) contour results from both efforts were combined to produce the No Action DNL contours for CCSFS and KSC reported herein. No Action cumulative sonic boom levels for SpaceX Falcon 9 and Falcon Heavy operations were also estimated as part of the current effort.

1.2.3 Proposed Action Scenario

The Proposed Action Scenario consists of the proposed Starship operations at LC-39A plus the No Action operations. The Proposed Action noise results are compared with the No Action noise results (in Section 8) to assess the change in noise exposure that would result from implementing the proposed Starship operations at LC-39A. Proposed Starship annual operations are described in Section 5.1.

1.2.4 Reasonably Foreseeable Future Actions Scenario

For the purposes of this study, the Reasonably Foreseeable Future Actions Scenario is defined to include the Proposed Action Scenario plus the proposed Starship operations at CCSFS Space Launch Complex 37 (SLC-37). Proposed Starship operations at SLC-37 and the cumulative noise exposures defining the Reasonably Foreseeable Future Actions Scenario are described in Section 7.

Cumulative noise levels are among the primary measures used when assessing noise impact from rocket operations. The FAA's metric for assessing cumulative subsonic (or rocket) noise is DNL (A-weighted) with a 65 dBA significance threshold; the FAA defines a "significant impact" due to noise as any noise sensitive area[6] exposed to noise greater than DNL 65 dBA following implementation of the federal action and experiencing a 1.5 dBA or greater increase in noise due to the federal action[7]. Similarly, the FAA's metric for assessing cumulative noise from supersonic operations (i.e., sonic boom exposure) is the C-weighted Day-Night Average Sound Level (CDNL) with a 60 dBC significance threshold. Both metrics are discussed further in this report, though they are mentioned here since they are the primary metrics used to compare the cumulative noise results estimated for each of the study scenarios analyzed.

1.3 Proposed Starship Operations at Kennedy Space Center (LC-39A)

The Starship operations planned to occur at LC-39A include 44 annual operations, with a 50/50 daytime/nighttime split, of each type including: Starship orbital launch, Starship spacecraft reentry/landing, and Super Heavy descent/landing. The 44 annual booster landings would utilize three different flight paths including a nominal heading 80 percent of the time (from an 80-degree heading), north bounding heading (from 40-degrees) 10 percent of the time, and a south bounding heading (from 115-degrees) 10 percent of the time. Figure 1 shows a representation of these trajectories at LC-39A (scale bar at bottom right = 1 mile). Starship would launch to the east, Starship spacecraft landings would descend from west to east prior to landing at LC-39A, and booster landings would descend from east to west prior to landing at LC-39A.

1.3.1 Noise Events Associated with Starship Operations at LC-39A

Starship operations at LC-39A and SLC-37 would include the same types of flight and test operations. Static fire test operations would occur with either vehicle mounted vertically to a test stand with engines oriented towards the ground. A typical flight operations sequence, shown on Figure 2 (courtesy of SpaceX), illustrates the operational events comprising a Starship launch at LC-39A and booster landing; in this diagram, the booster is shown returning to an offshore platform, however all landings assessed in this study are at LC-39A (or SLC-37 when including cumulative noise from SLC-37). It is useful to describe certain elements of this flight operations sequence, specifically the ones that generate noise events heard in the communities adjacent to KSC and CCSFS. Event numbers 1 through 5 and their associated times shown in the diagram will be referred to. Starship launch (indicated as Booster Stage Launch) occurs at the start of the flight operations sequence (1), at T+0 seconds (s), when the highest rocket noise levels, from all Starship and booster engine operations, would be heard in the nearby communities (the highest levels would occur at different times during the liftoff and ascent, depending on the receiver location, but after the vehicle has gained some altitude). During the ascent phase, the two-stage vehicle would generate a sonic boom once it has reached supersonic speeds and is in the process of pitching over to target the intended orbit; the sonic boom generated during ascent will occur entirely over the Atlantic Ocean and will not be noticed by anyone inland.

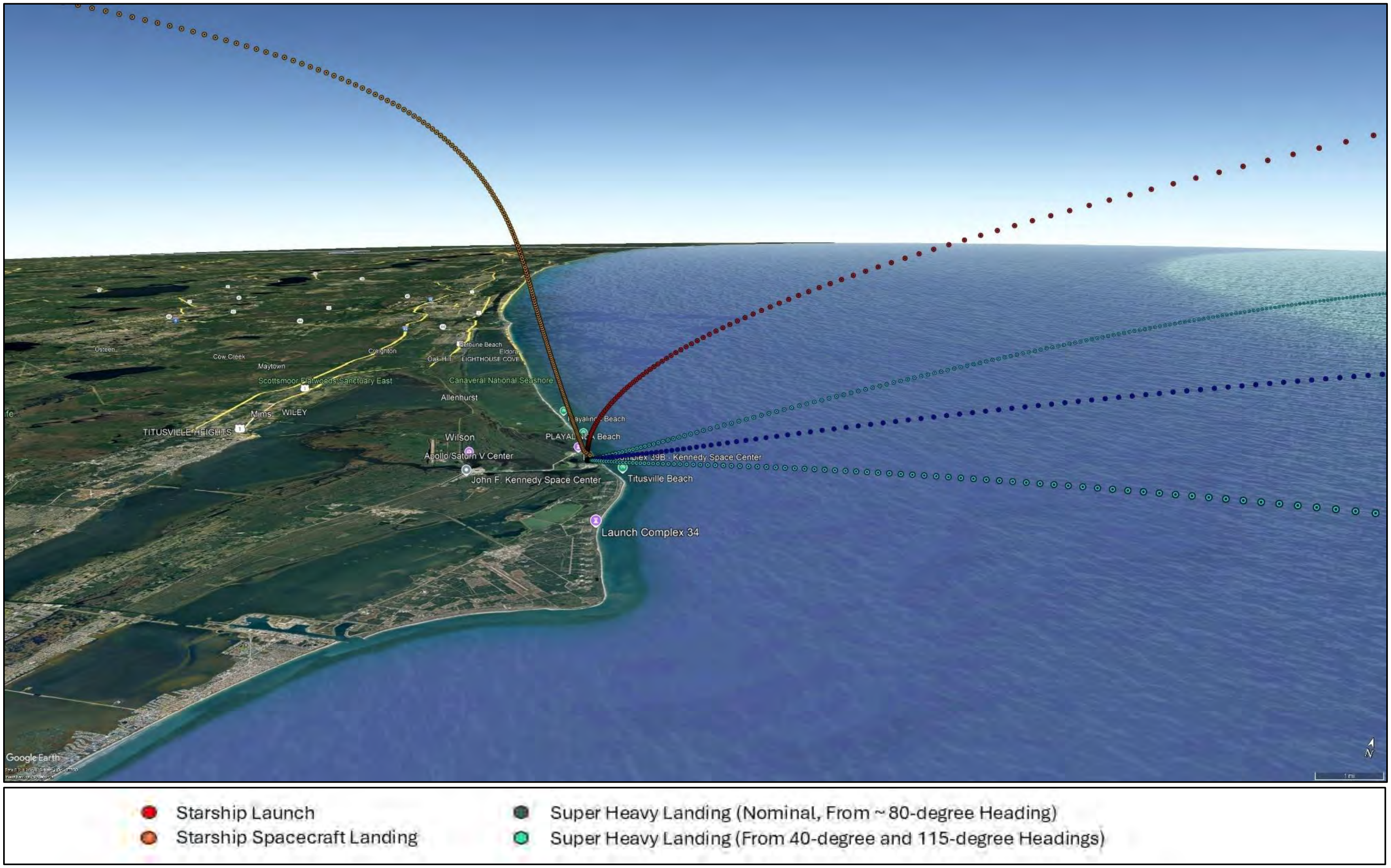

Figure 1. Starship Launch and Starship Spacecraft and Super Heavy (Booster) Landing Flight Trajectories at LC-39A

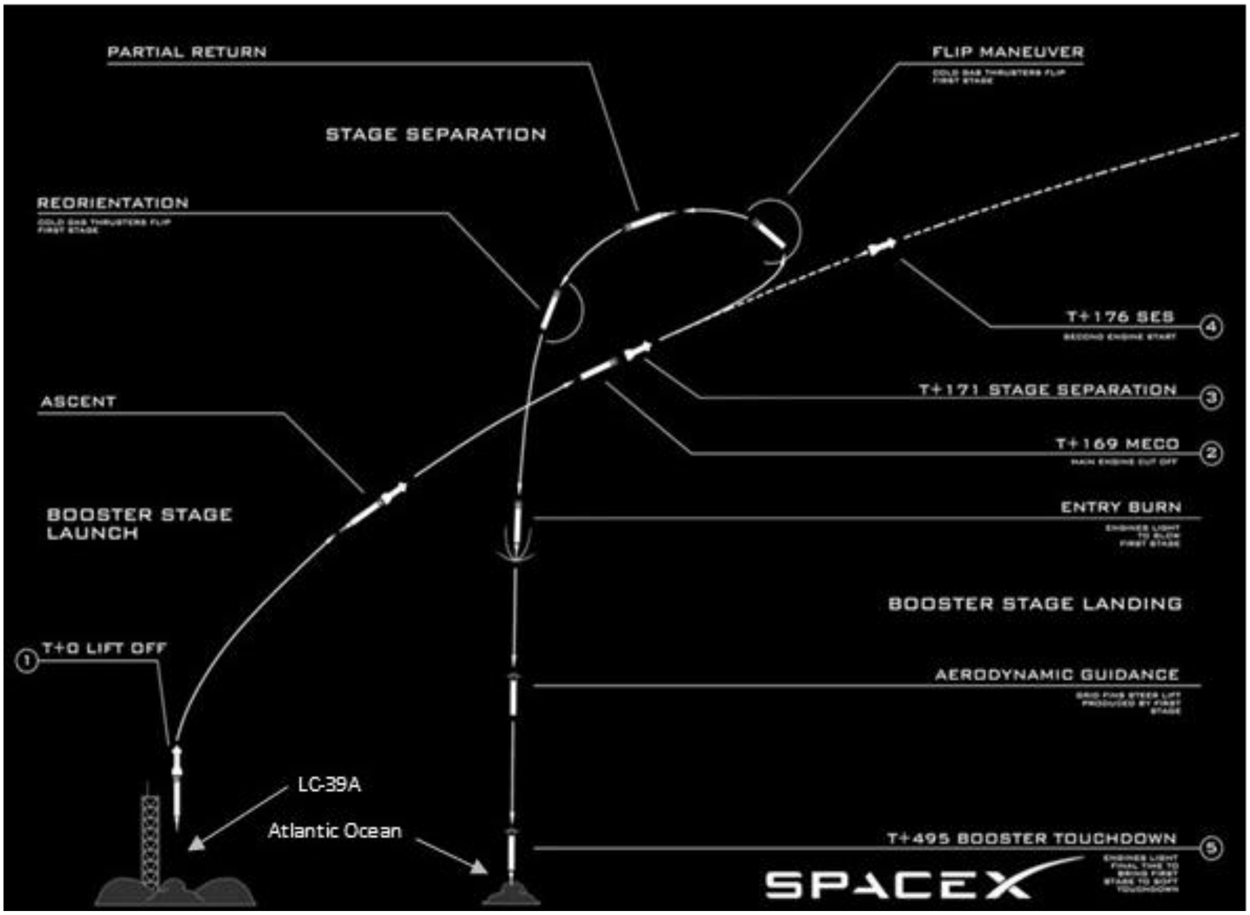

Figure 2. Flight Operations Sequence of Starship Orbital Launch and Landing Events

Main Engine Cutoff (2) occurs at T+169 s, followed soon by Stage separation (3) at T+171 s and Second Engine Start (4) at T+176 s as the second stage Starship spacecraft continues to orbit while the booster stage executes a reorientation and flip maneuver to change course for landing back at LC-39A. While events 2 through 4 do not generate noticeable noise events, the remaining noise events that would be heard in communities near KSC and CCSFS include rocket noise during the Booster Touchdown (5) at T+495 s [at LC-39A], rocket noise during the Starship spacecraft landing at LC-39A, and the sonic booms generated by both vehicles during the descent phases of their flights. The Starship spacecraft descent is along a west to east flight path like past Space Shuttle Landings though the Starship spacecraft performs its own reorientation maneuver to prepare for a vertical landing at LC-39A like the booster. These are the proposed Starship operations and noise events that were analyzed at LC-39A (and similarly at SLC-37 for the Reasonably Foreseeable Future Actions Scenario). Note that LC-39A is about 5 miles north of SLC-37.

1.4 Document Structure

The remaining sections of this report starting with Section 2 provide a description of the rocket noise and sonic boom modeling studies conducted including the study design, modeling and assessment methodologies including the primary noise metrics and their assessment guidelines and the use of additional supplemental metrics. The Baseline operations at CCSFS and KSC and the associated cumulative rocket noise and sonic boom exposures are presented in Section 3. Section 4 presents the No Action operations at CCSFS and KSC and the associated cumulative rocket noise and sonic boom exposures. Proposed Starship operations at LC-39A and the associated rocket noise and sonic boom exposure levels, including single event and cumulative levels, are presented in Section 5. The Proposed Action noise exposure levels are shown in Section 6 and the Reasonably Foreseeable Future Action noise exposure levels are presented in Section 7. A noise exposure assessment summary is provided in Section 8, comparing the results for all the operational scenarios studied. The study conclusions are presented in the Executive Summary and the references listed in Section 9.

2 NOISE MODELING AND ASSESSMENT

2.1 MODELING STUDY DESIGN

A modeling study was initially designed to permit assessment of various weather conditions and trajectory variations for the booster landings. At the phase of the project when modeling was to begin, SpaceX provided a fixed utilization schedule for three proposed booster landing trajectories, described previously as including a nominal heading (from 80-degrees) 80 percent of the time, north bounding heading (from 40-degrees) 10 percent of the time, and south bounding heading (from 115-degrees) 10 percent of the time. This fixed the number of booster landing trajectories to three and the percent utilizations were accounted for in the cumulative noise analyses. To further make the parameter variations reasonable in number, the five different flight and test operations (i.e., Starship orbital launch, Starship spacecraft reentry/landing, booster descent/landing, and static fire tests of both vehicles) were analyzed as a group for each of the weather variations examined.

SpaceX developed five weather variation data sets from Cape Canaveral historical weather data. These data sets represent seasonal and daytime and nighttime conditions at the Cape, referred to as: Annual Mean, Summer Day, Summer Night, Winter Day, and Winter Night. Upper air data sets were developed from balloon launch data including atmospheric pressure, temperature, relative humidity, wind speed and wind direction; balloon data generally do not go above 60,000 feet altitude, so an atmosphere extension, based on the U.S. Standard Atmosphere[8], was applied to these data sets. Mean surface wind (rose) data were also provided for these five representative weather periods. Table 1 shows an example of the upper air data for Annual Mean conditions and Figure 3 shows wind rose data for the same conditions.

The complete set of modeled Starship noise results generated for this study, including noise contour sets and noise levels at the study points of interest (POIs), includes the following Starship operational events and weather variations:

- Single event rocket noise contours and POI results at LC-39A, including multiple metrics, for each individual Starship operation (orbital launch, Starship spacecraft landing, booster landings with 3 trajectories, Starship spacecraft static fire test, and booster static fire test) and for all five weather conditions for each event. An example of the effects the different weather variations have on a select single event contour (level) is shown in Figure 4.

- Cumulative rocket noise contours and POI results at LC-39A, in terms of DNL, combining the noise results for each individual Starship operation, for each representative weather condition.
- Single event sonic boom contours and POI results at LC-39A, including multiple metrics, for each individual Starship operation and for all five weather conditions for each event.
- Cumulative sonic boom exposure contours and POI results at LC-39A, in terms of CDNL, combining the sonic boom exposure results for each individual Starship operation for all five representative weather conditions.
- All the above datasets were also generated for Starship operations at SLC-37 (since the cumulative results at SLC-37 are part of the Reasonably Foreseeable Future Actions scenario in this study).
- All results of the Baseline, No Action, Proposed Action, and Reasonably Foreseeable Future Actions Scenarios required for the noise assessment for LC-39A.

The modeled noise contours and POI results represent a sizeable database of noise results for proposed Starship operations at LC-39A. Since noise assessments are typically presented for local, annual mean weather conditions, this report focuses on the annual mean results generated from the modeling study and all noise exposure assessments are based on those results. All modeled noise results, including all the other weather variations analyzed, are presented in the Noise Appendix.

Table 1. Cape Canaveral Upper Air Historical Data: Annual Mean Conditions

Height (Feet)	Temperature (Kelvin)	Pressure (Millibar)	Relative Humidity (%)	Wind Speed (Knots)	Wind Direction (Degrees)
0	298.5	1000	72.5	11.5	244.6
2,000	293.0	950	77.0	7.2	160.3
3,500	290.4	900	72.5	7.0	181.5
5,000	288.0	850	66.1	7.1	208.5
6,000	287.0	825	62.4	6.9	204.5
6,500	284.7	800	53.2	10.1	243.4
7,500	284.5	775	52.5	8.1	232.0
8,500	283.4	750	49.2	7.8	230.7
10,000	276.3	700	31.2	16.6	267.7
11,500	261.3	650	8.1	10.6	127.7
13,500	259.1	600	7.9	14.8	321.8
16,000	260.1	550	7.7	31.4	265.9
18,000	254.1	500	1.5	27.8	299.0
21,000	253.0	450	2.5	42.5	268.5
23,500	245.6	400	2.6	35.6	287.9
26,500	240.6	350	3.3	28.5	303.9
30,000	235.5	300	4.2	31.8	300.3
34,500	225.3	250	22.4	44.6	265.1

Height (Feet)	Temperature (Kelvin)	Pressure (Millibar)	Relative Humidity (%)	Wind Speed (Knots)	Wind Direction (Degrees)
37,000	222.9	225	26.2	49.4	264.9
39,000	226.1	200	4.1	49.2	277.2
42,000	218.5	175	8.1	47.4	262.5
45,500	212.8	150	11.9	44.6	272.4
49,000	210.3	125	8.3	37.8	270.8
53,500	206.5	100	11.0	29.7	273.5

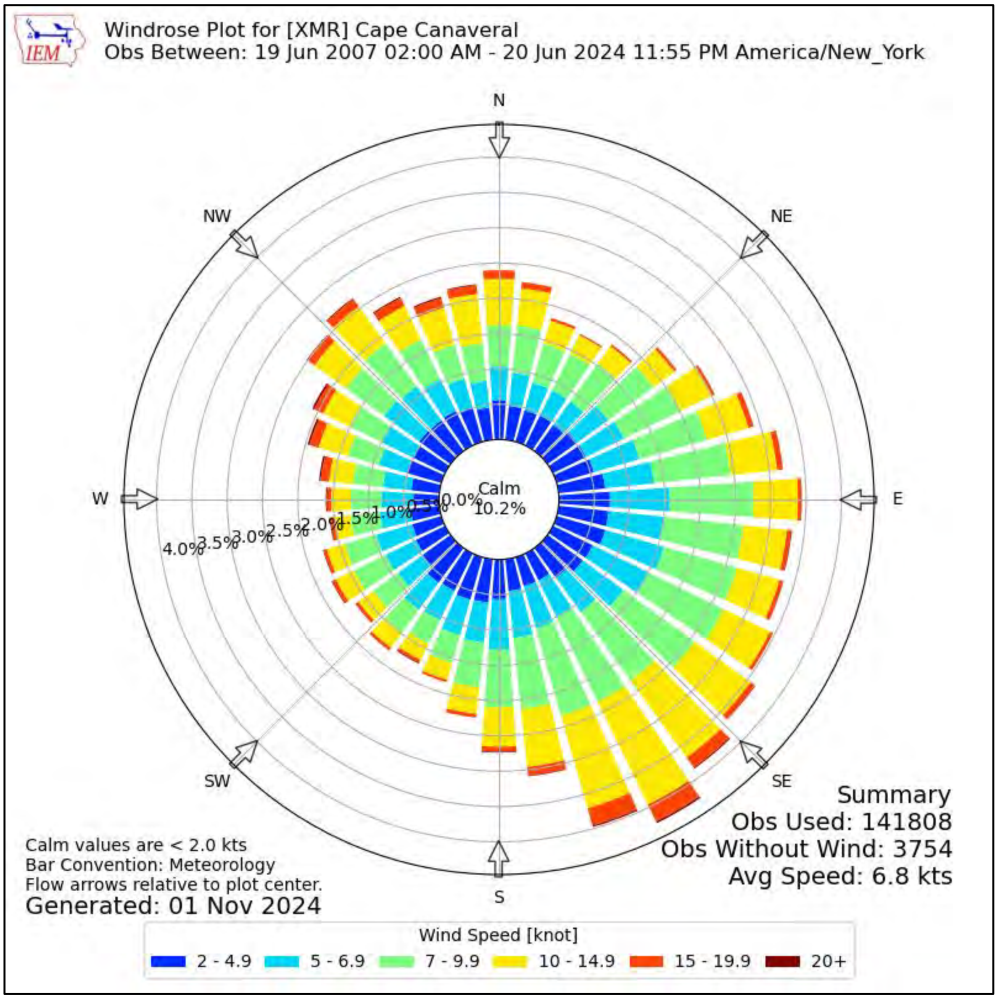

Figure 3. Cape Canaveral Wind (Rose) Historical Data: Annual Mean Conditions

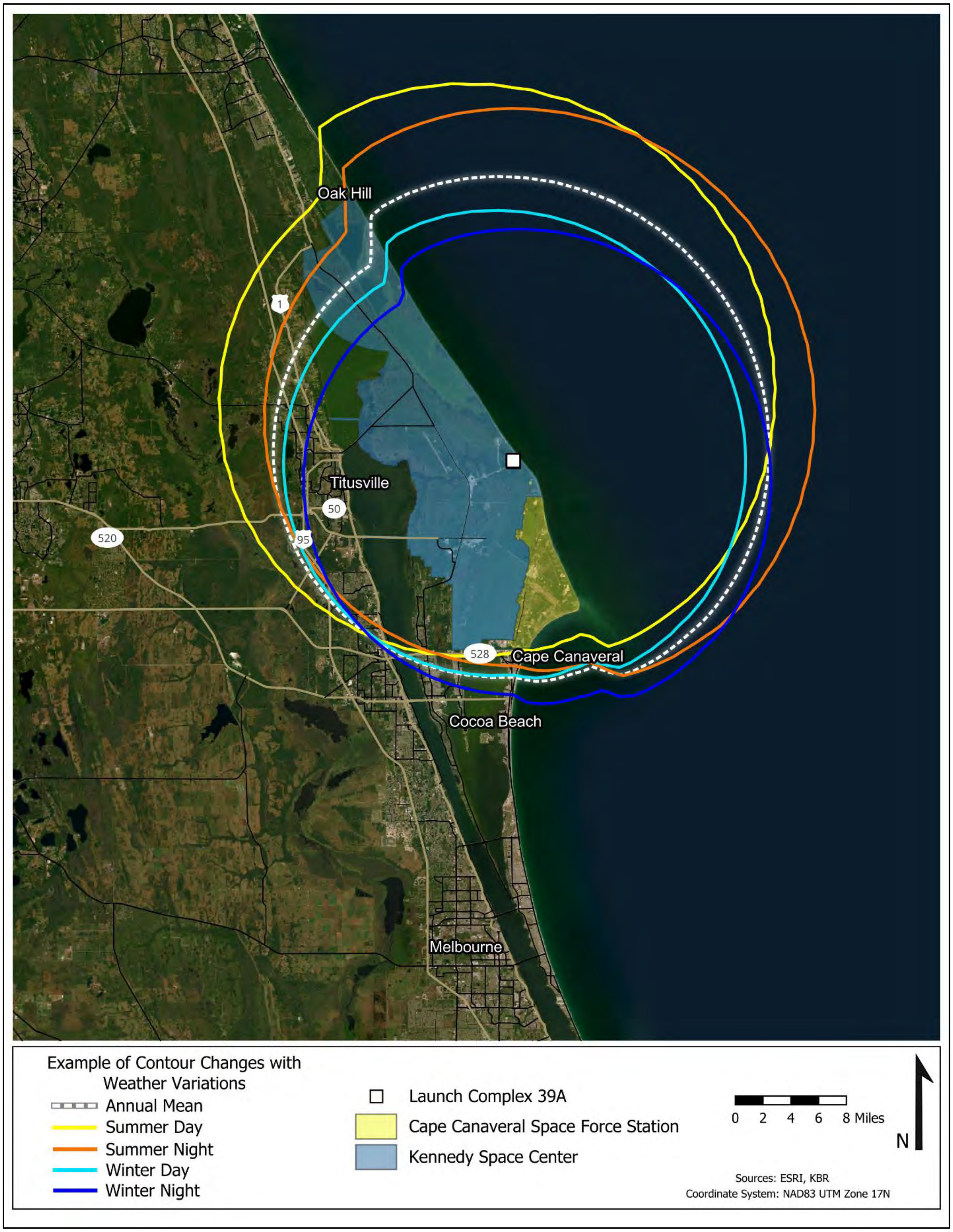

Figure 4. Example of Weather Variation Effects on Modeled Noise Contours At LC-39A

2.1 Rocket Noise Assessment Methodology

2.1.1 Rocket Noise Model

Rockets generate significant noise from the combustion process and turbulent mixing of the exhaust flow with the surrounding air. Figure 5 is a sketch of rocket noise. There is a supersonic potential core of exhaust flow, surrounded by a mixing region. Noise is generated in this directional flow with the highest noise levels at an angle of about 50 degrees, on average, from the direction of the exhaust flow. The fundamentals of predicting rocket noise were established by Wilhold et al.[9] for moving rockets and by Eldred et al.[10] for static firing. Sutherland[11] refined modeling of rocket source noise, improving its consistency relative to jet noise theory. Based on those fundamentals, Wyle has developed the PAD model for near field rocket noise[12] and the RNOISE model for far field noise in the community. RNOISE was used for the current analysis.

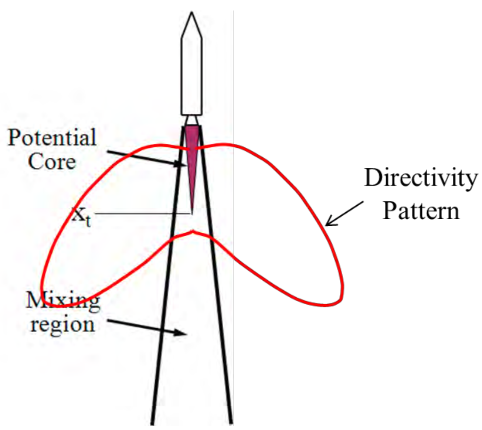

Figure 5. Rocket Noise Source

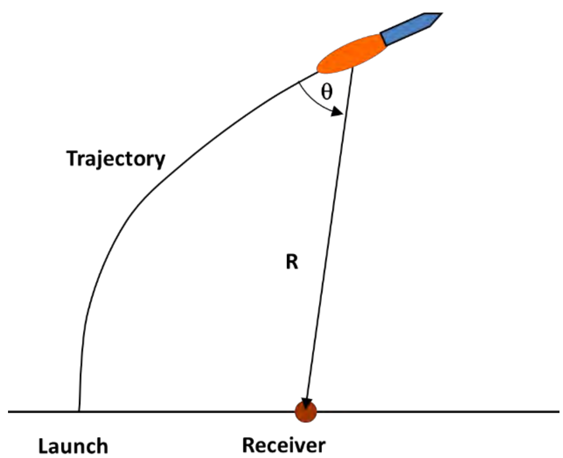

Figure 6. Modeling Rocket Noise at the Ground

Figure 6 is a sketch of far field rocket noise as treated by RNOISE. The vehicle's position and attitude are known from the trajectory. Rocket noise source characteristics are known from the engine properties, with thrust and exhaust velocity being the most important parameters. The emission angle and distance to the receiver are known from the flight path and receiver position. Noise at the ground is computed accounting for distance, ground impedance,[13] and atmospheric absorption of sound.[14] RNOISE propagates the full spectrum to the ground, accounting for Doppler shift from vehicle motion. It is a time simulation model, computing the noise at individual points or on a regular grid for every time point in the trajectory. Propagation time from the vehicle to the receiver is accounted for, yielding a spectral time history at the ground (including a range of frequencies from 1 Hz to 16 kHz). A variety of noise metrics can be computed from the calculated noise field and the metrics commonly used to assess rocket noise are described in the following section.

2.1.2 Primary Noise Metrics

FAA Order 1050.1F[7] specifies Day-Night Average Sound Level (DNL) as the standard metric for community noise impact analysis, but also specifies that other supplemental metrics may be used as appropriate for the circumstances. DNL is appropriate for continuous noise sources, such as airport noise and road traffic noise. The noise metrics used for rocket noise analysis are:

- DNL, as defined by FAA Order 1050.1F;
- SEL, the Sound Exposure Level, for individual events;
- L_{Amax}, the maximum A-weighted overall sound pressure level (OASPL), for individual events;
- L_{max}, the maximum unweighted OASPL, for individual events; and
- One third octave spectra at certain sensitive receptors.

As mentioned, DNL is necessary for policy. The next three metrics provide a measure of the impact of individual events; SEL and L_{Amax} are A-weighted and L_{max} is un-weighted. Loud individual events can pose a hearing damage hazard to people and can also cause adverse reactions by animals. Adverse animal reactions can include flight, nest abandonment, and interference with reproductive activities. L_{max} along with spectra, may be needed to assess potential damage to structures and adverse reaction of species whose hearing response is not like that of humans.

L_{Amax} is appropriate for community noise assessment of a single event, such as a rocket launch or static fire test. This metric represents the highest A-weighted integrated sound level for the event in which the sound level changes value with time. Slowly varying or steady sounds are generally integrated over a period of one second. L_{Amax} is important in judging the interference caused by a noise event with conversation, TV listening, sleep, or other common activities. Similarly, L_{max} is the highest unweighted integrated sound level for the event, used to assess the potential for structural damage. Although A-weighted maximum sound level provides some measure of the intrusiveness of the event, it does not completely describe the total event, because it does not include the duration that the sound is heard.

SEL is a composite metric that represents both the level of a sound and its duration. Individual time-varying noise events (e.g., aircraft overflights) have two main characteristics: a sound level that changes throughout the event and a period during which the event is heard. SEL provides a measure of the total acoustic energy transmitted to the listener during the event, but it does not directly represent the sound level heard at any given time. For example, during an aircraft flyover, SEL would include both the maximum noise level and the lower noise levels produced during onset and recess periods of the overflight. Mathematically, it represents the sound level of a constant sound that would, in one second, generate the same acoustic energy as the actual time-varying noise event. For a rocket launch, SEL is expected to be greater than L_{Amax}.

2.1.3 Noise Assessment Guidelines

Land Use Compatibility Guidelines for Cumulative Noise Exposure

As previously mentioned, DNL represents the average sound level for annual average daily aircraft events which are used to assess cumulative noise exposure. FAA's published 14 Code of Federal Regulations (CFR)

Part 150 defines land use compatibility guidelines for aviation noise exposure that are also applicable to rocket noise exposure. These guidelines consider land use compatibility for different uses over a range of DNL noise exposure levels, including the adoption of DNL 65 dBA as the limit for residential land use compatibility.

Hearing Conservation

In this study, the highest noise levels from Starship flight and test operations are expected to occur in the vicinity of the launch and landing pads at LC-39A (on KSC property) and at the adjacent CCSFS property. The KSC Hearing Loss Prevention Program[15] provides suitable guidelines to protect human hearing from long-term, continuous exposures to high noise levels and aid in the prevention of noise-induced hearing loss (NIHL). KSC's permissible daily noise exposure limits include a L_{Amax} of 108 dBA (slow response) for a duration of 2 minutes or less. This is the criteria used in this study to evaluate areas around launch, landing, and static fire test sites that would require implementing a hearing conservation program, i.e., areas within the L_{Amax} 108 dBA contour. This level was chosen as an indicator of when a hearing conservation program should be implemented since the received levels from most proposed flight and test operations, individually or together, are not expected to exceed this level for more than 2 minutes on any given day.

Structural Damage Potential

The potential for structural damage due to Starship rocket engine noise events is assessed using criteria developed from two separate studies. The first is based on a study of structural damage claims from rocket static firing tests which indicates that, based on Maximum Unweighted Sound Level (L_{max}), approximately one damage claim will result per 100 households exposed at 120 dB and one damage claim will result per 1,000 households exposed at 111 dB[16]. The second, less conservative criteria is based on conclusions from a recent study to ascertain whether range activities (i.e., test, evaluation, demilitarization, and training activities of items such as weapons systems, ordinance, and munitions) would cause structural damage. This study concluded that structural damage becomes improbable below 140 dB [Maximum Un-weighted or linear Sound Level (L_{max})]. No glass or plaster damage is expected below 140 dB and no damage is expected below 134 dB[17].

2.1.4 Supplemental Noise Metrics

As noted in Section 2.1.2, DNL is the standard metric for community noise impact analysis. And while DNL is a cumulative metric that is appropriate to estimate the overall noise environment at military airfields, civilian airports, and now space launch facilities, the Department of Defense (DoD) Noise Working Group (DNWG) provides guidance on the use of additional metrics to fully describe the noise impacts to noise sensitive locations. The DoD expands upon DNL with the following supplemental metrics described in the DNWG guidelines[18]; note that L_{Amax} and SEL, which are included in the guidelines, and are the basis for two of the supplemental metrics, Speech Interference and Residential Sleep Disturbance, were defined previously in Section 2.1.2:

- Number of Events at or above a specified threshold (NA) or Time Above a threshold (TA),

- Equivalent Sound Level (L_{eq}), a cumulative noise metric that represents the average sound level (on a logarithmic basis) over a specified period; the period specified for L_{eq} is typically provided and relates to a type of activity being assessed (e.g., L_{eq}(24) for 24 hours). An L_{eq}(8) is used in this study to represent a typical school day,
- Probability of Awakening (PA).

NA, L_{eq}, and TA use a specified period of time that can include an average 24-hour day, daytime (7 a.m. (0700) to 10 p.m. (2200)), nighttime (10 p.m. (2200) to 7 a.m. (0700)), school day (7 a.m. (0700) to 3 p.m. (1500)), or other time period appropriate for the analysis. The supplemental metrics used in this study are described in the following sections.

2.1.4.1 Potential for Hearing Loss

Considerable data on hearing loss have been collected and analyzed by the scientific/medical community, and it has been well established that continuous exposure to high noise levels will damage human hearing. People exposed to high noise environments may experience temporary or permanent hearing loss; those exposed over a long period of time are at an increased risk of experiencing permanent hearing loss. While various government organizations have defined noise thresholds, based on L_{eq}, to protect workers from noise exposure during their lifetime working period (40 hours per week over 40 years), the DoD uses a screening threshold for residences of DNL 80 dB to ensure a conservative approach to assessing the potential for hearing loss[19]. If residences are identified within the DNL 80 dB exposure area, then additional analysis should be carried out using L_{eq}.

2.1.4.2 Speech Interference

Interference with speech disturbs normal social activities and can be a leading contributor to annoyance. In residential areas, concern is about the effect that noise has on face-to-face conversations, telephone conversations, and watching television. Aircraft and spacecraft noise events can disrupt these types of activities when indoor L_{Amax} exceeds 50 dB because word intelligibility decreases at that level[20]. This study determines the number of potential speech interfering events per average daytime hour (from 7 a.m. until 10 p.m.) at all noise sensitive receptors selected for assessment, also referred to as points of interest (POIs). This speech interference assessment is targeted primarily at POIs other than schools, since schools are assessed separately using Classroom Learning Interference; however, each POI may be considered to include other types of noise sensitive receptors nearby (such as residences near a school).

2.1.4.3 Classroom Learning Interference

Noise in the classroom can adversely affect student's speech communication and interfere with learning. Various governmental organizations have developed criteria for classroom noise impacts using L_{eq} and the number of interfering events. DoD recommends an exterior Leq of 60 dB (equivalent to 45 dB interior Leq with windows open) as a screening criteria to determine schools at risk of classroom learning affects[18]. Schools that exceed an exterior L_{eq} of 60 dB are further analyzed by counting the number of events per hour above an interior L_{Amax} of 50 dB, which equates to the highest permissible classroom level for speech intelligibility. Interior sound levels are determined from exterior levels with a noise reduction applied for the building (15 dB for windows open and 25 dB for windows closed). The TA 50 dB has also been determined as a measure of the time that students are potentially impacted.

2.1.4.4 Residential Sleep Disturbance

Elevated noise levels above the background may cause sleep disturbance which can prevent people from falling asleep or wake them from sleep. A method formerly relied upon to estimate the percent awakenings (PA) is described in ANSI/Acoustical Society of America (ASA) S12.9-2008/Part 6[21] which was endorsed by the DNWG[22]. It should be noted that as of July 2018, the ANSI and ASA have withdrawn the 2008 standard noting that the 2008 Standard for calculating at least one behavioral awakening per night would lead to unreliable and difficult-to-interpret predictions of transportation noise-induced sleep disturbance (ANSI/ASA 2018)[22]. Also notable is that ANSI/ASA S12.9-2008/Part 6[21] is based on studies of airport noise environments and multiple nighttime noise events; Proposed Action Starship launches (and associated landings) during nighttime would include several noise events with the landings occurring several minutes after each launch, whereas Starship spacecraft and Super Heavy nighttime static fire tests would each normally occur as one noise event. Without a current, standard method to estimate PA, and with the limitations noted for Starship nighttime operations, this study estimates PA using the FICAN updated (1997) recommended dose-response curve[24], interpreted to be the "maximum percent of the exposed population expected to be behaviorally awakened" for a given residential population.

The FICAN 1997 relationship, Percent Awakenings = $0.0087 \times [SEL - 30]^{1.79}$, provides a method to estimate PA from at least one noise event per night. This relationship utilizes the estimated interior SEL resulting from proposed nighttime Starship operations to provide a conservative estimate (based on the most recent sleep disturbance studies at the time) of the percentage of the population that would be awakened at least once per night. Percent awakening results at the study POIs are presented for Starship launches and both windows open and windows closed cases.

2.2 SONIC BOOM ASSESSMENT METHODOLOGY

2.2.1 Sonic Boom Model

A sonic boom is the wave field about a supersonic vehicle. As the vehicle moves, it pushes the air aside. Because flight speed is faster than the speed of sound, the pressure waves can't move away from the vehicle, as they would for subsonic flight, but stay together in a coherent wave pattern. The waves travel with the vehicle. Figure 7 is a classic sketch of sonic boom from an aircraft in level flight[25]. It shows a conical wave moving with the aircraft, much like the bow wave of a boat. While Figure 7 shows the wave as a simple cone, whose ground intercept extends indefinitely, temperature gradients in the atmosphere generally distort the wave from a perfect cone to one that refracts upward, so the ground intercept goes out to a finite distance on either side. A sonic boom is not a onetime event as the aircraft "breaks the sound barrier" but is often described as being swept out along a "carpet" across the width of the ground intercepts and the length of the flight track. Booms from steady or near-steady flight are referred to as carpet booms.

The waveform at the ground is generally an "N-wave" pressure signature, as sketched in the figure, where compression in the forward part of the vehicle and expansion and recompression at the rear coalesce into a bow shock and a tail shock, respectively, with a linear expansion between.

Figure 7 is drawn from the perspective of aircraft coordinates. The wave cone exists as shown at a particular time but is generated over a time period. Booms can also be viewed from the perspective of rays propagating relative to ground-fixed coordinates. Figure 8 shows both perspectives. The cone represents rays that are generated at a given time, and which reach the ground at later times. The intercept of a given ray cone with the ground is called an "isopemp." When computing sonic booms the ray perspective is appropriate, since one starts the analysis from the aircraft trajectory points and each isopemp is identified with flight conditions at a given time. As sketched in Figure 8, the isopemps are forward facing crescents.

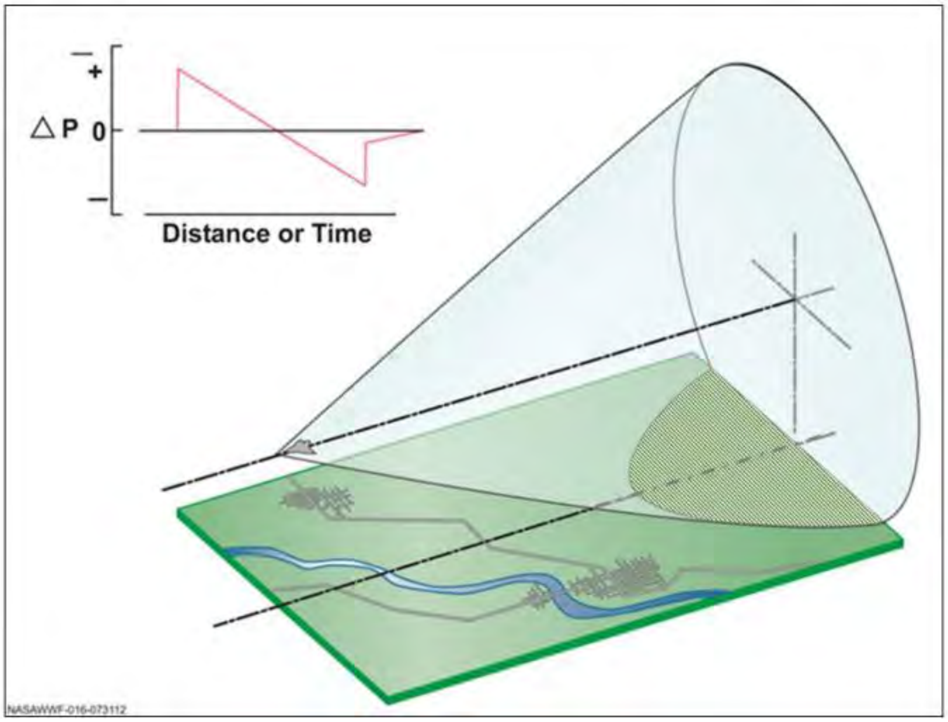

Figure 7. Sonic Boom Wavefield (Vehicle in Level Flight)

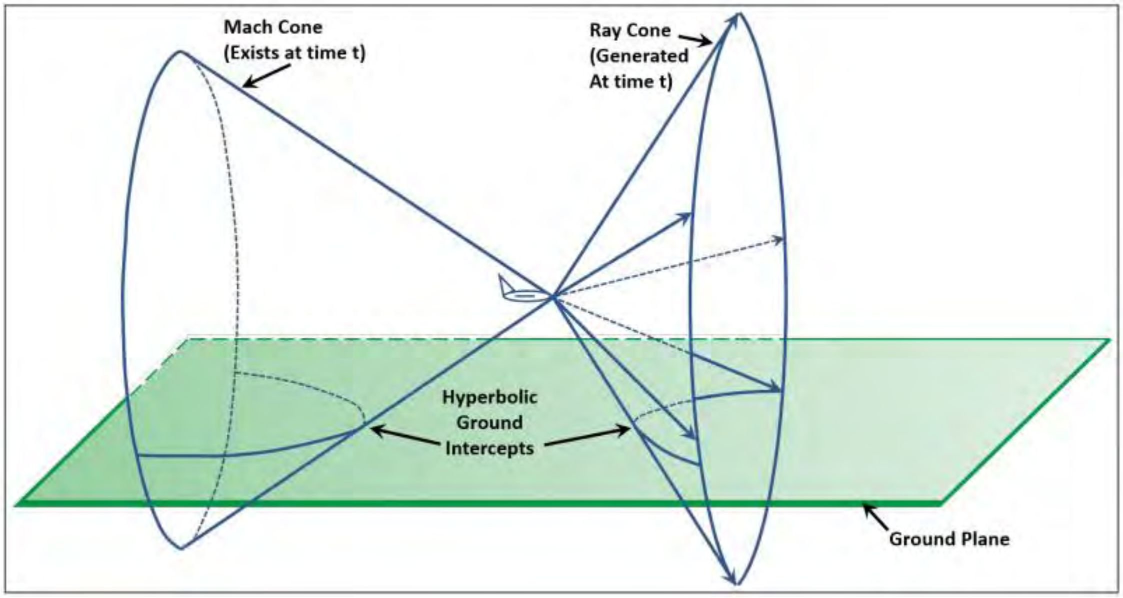

Figure 8. Wave versus Ray Viewpoints

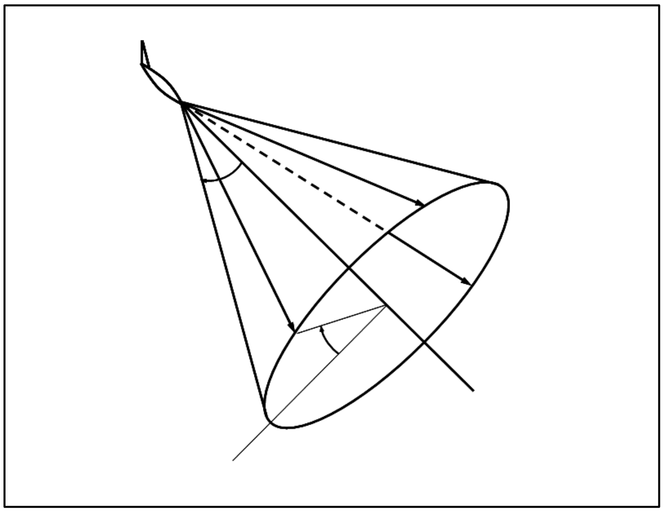

Figure 9. Ray Cone in Diving Flight

Figures 7 and 8 are drawn for steady level flight. If the aircraft climbs or dives, the ray cone tilts along with it. Figure 9 shows a ray cone in diving flight. At the angle in the figure the isopemp would still be a forward-facing crescent but would wrap around further than shown in Figure 8. In a steeper dive the isopemp could go full circle. If the vehicle is climbing at an angle steeper than the ray cone angle, there will be no boom at the ground. During very steep descent (near vertical) and at high Mach numbers the rays can be emitted at a shallow enough angle that they would refract upward and not reach the ground. For a descending vehicle that eventually decelerates to subsonic speed, some part of the trajectory will generate boom that reaches the ground.

Supersonic vehicles can turn and accelerate or decelerate. That affects the boom loudness, and under some conditions cause focused superbooms. Figure 10 is a sketch of rays from an accelerating aircraft. As the Mach number increases the ray angles steepen. The rays cross and overlap, with the focus along the "caustic" line indicated in the figure. The boom on a focusing ray is a normal N-wave before it gets close to the caustic, is amplified by a factor of two to five as it reaches the caustic, then is substantially attenuated as a "post-focus" boom after it passes the caustic.

Figure 11 shows the isopemps for this type of acceleration focus. The focal zone is the concentrated region at the left end of the footprint. The maximum focus area – where the boom is more than twice the unfocused normal boom – is very narrow, generally a hundred yards or less.

Sonic boom levels were estimated for SpaceX operations at KSC and CCSFS, including proposed Starship, Starship spacecraft, and booster flight operations at LC-39A and SLC-37, using the PCBoom model[3,4]; PCBoom computes single-event sonic boom footprints, including contours of peak overpressure and signatures from any supersonic vehicle executing arbitrary maneuvers in a three-dimensional atmosphere.

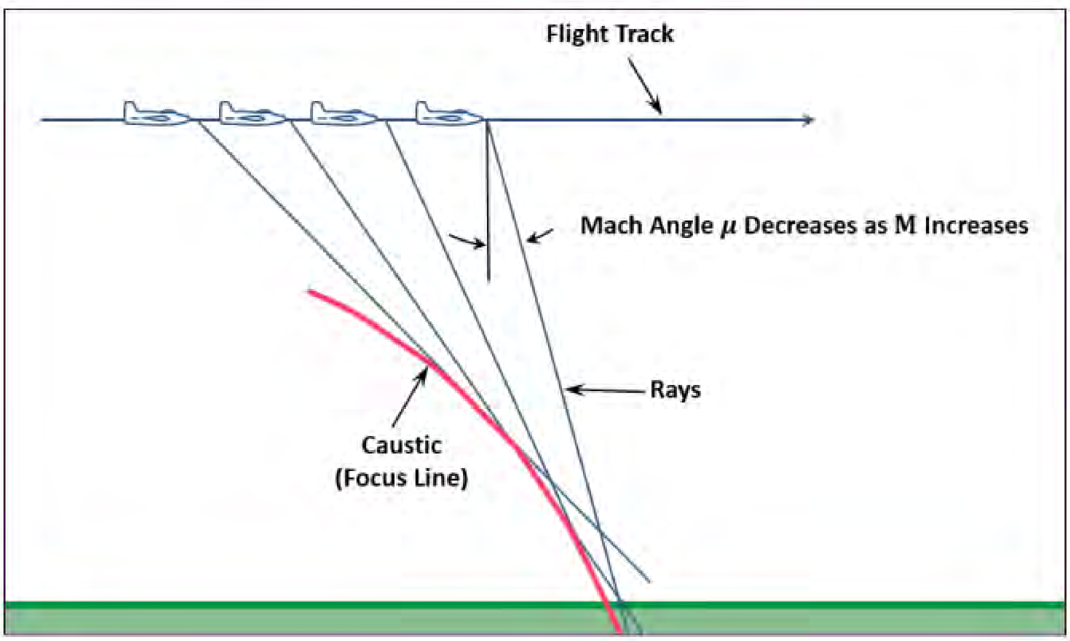

Figure 10. Ray Crossing and Overlap in an Acceleration Focus

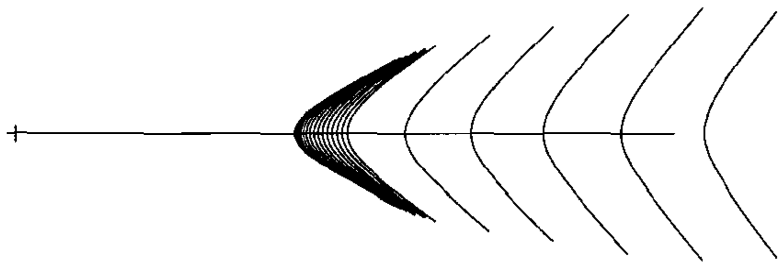

Figure 11. Isopemp Overlap in an Acceleration Focus

2.2.2 Sonic Boom Metrics

Sonic boom exposure is reported for single events as peak overpressure, within the boom footprint or at a particular location, in units of pounds per square foot (psf). Cumulative sonic boom exposure is reported using the C-weighted Day-Night Average Sound Level (CDNL) metric.

2.2.2.1 Supplemental Analyses for Sonic Boom Assessment

Two supplemental analyses are used in this report to further characterize noise impacts from supersonic operations; residential sleep disturbance and the potential for structural damage.

Residential Sleep Disturbance – Based on a review of existing sleep studies, Pearsons, Barber, and Tabachnick (1989)[25] developed a preliminary dose-response relationship for awakenings due to impulsive noise exposure as follows: % Awakened or Aroused = 2.32(CSEL) - 184.9

Potential for Structural Damage – Based on the FAA's Hershey and Higgins 1976 report "*Statistical Model of Sonic Boom Structural Damage"*,[26] and the Department of the Air Force's (DAF) Haber and Nakaki 1989 report "*Sonic Boom Damage to Conventional Structures"*,[27] which describe similar damage probabilities for different structural components for various sonic boom exposure levels; 2 psf and 4 psf are used in this report to assess the potential for structural damage, since areas off KSC and CCSFS properties are most likely to be exposed to booms, within this range of levels, from booster landing operations; 2 psf is also considered to be the low threshold level for glass breakage.

This report continues with descriptions and results of the noise modeling and assessments conducted for all the operational scenarios studied in connection with the proposed Starship operations at LC-39A:

- Baseline Scenario at CCSFS and KSC – Section 3
- No Action Scenario at CCSFS and KSC – Section 4
- Proposed Starship operations at LC-39A – Section 5
- Proposed Action Scenario, including proposed Starship operations at LC-39A plus all KSC and CCSFS operations that define the No Action Scenario – Section 6
- Reasonably Foreseeable Future Actions Scenario, including the Proposed Action Scenario (for LC-39A) plus the Proposed Action Starship operations at SLC-37 – Section 7

3 BASELINE SCENARIO

3.1 BASELINE OPERATIONS AT KSC AND CCSFS

Baseline launch vehicle flight and test operations at KSC and CCSFS are listed in Table 2. These operations are organized in the launch, landing, and static fire event categories and then by facility (KSC or CCSFS), launch complex, and by vehicle or program name, followed by the annual number of daytime (0700-2200) and nighttime (2200-0700) operations. These represent the operations that were conducted over the 12-month period (1 September 2023 – 31 August 2024).

Table 2. Baseline Launch, Landing, and Static Fire Test Operations at KSC and CCSFS

Event	Facility	Complex	Vehicle/Program	Day	Night	Total
Launch	KSC	LC-39A	SpaceX Falcon 9	10.2	6.8	17
		LC-39A	SpaceX Falcon Heavy	1.8	1.2	3
	CCSFS	SLC-37	ULA Delta IV Heavy	1	0	1
		SLC-40	SpaceX Falcon 9	37.2	24.8	62
		SLC-41	ULA Atlas V 501 (0 SRBs)	1	0	1
		SLC-41	ULA Atlas V N22 (2 SRBs)	1	0	1
		SLC-41	ULA Atlas V 551 (5 SRBs)	1	1	2
		SLC-41	ULA Vulcan VC2S	0	1	1
			Total	**53.2**	**34.8**	**88**
Landing	CCSFS	LZ-1/LZ-2	SpaceX Falcon 9 Booster	4.2	2.8	7
		LZ-1/LZ-2	SpaceX Falcon Heavy Booster	3.6	2.4	6
			Total	**7.8**	**5.2**	**13**
Static Fire	KSC	LC-39A	SpaceX Falcon 9	10.2	6.8	17
		LC-39A	SpaceX Falcon Heavy	1.8	1.2	3
	CCSFS	SLC-40	SpaceX Falcon 9	37.2	24.8	62
			Total	**49.2**	**32.8**	**82**

3.2 BASELINE ROCKET NOISE EXPOSURE: DNL CONTOURS

Figure 12 shows the DNL contours for the Baseline operations in Table 2, including DNL 65-85 dBA in 5 dB increments; these contours represent the cumulative subsonic noise environment due to rocket noise. The DNL 65 dBA contour, which represents the significance threshold for noise sensitive areas, is entirely within the KSC and CCSFS properties. Baseline DNL exposure is summarized in Section 8.

3.3 BASELINE SONIC BOOM EXPOSURE: CDNL CONTOURS

Figure 13 shows the CDNL contours for the Baseline operations in Table 2, including only the CDNL 60 dBC contour, which represents the significance threshold for noise sensitive areas. The CDNL 60 dBC contour does not extend beyond the CCSFS property line due to the low annual number of landing events; landings are the only type of spacecraft operation that results in sonic boom exposure over land in Florida. Section 8, which summarizes and compares the noise results for each operational scenario, includes more details about the Baseline CDNL exposure.

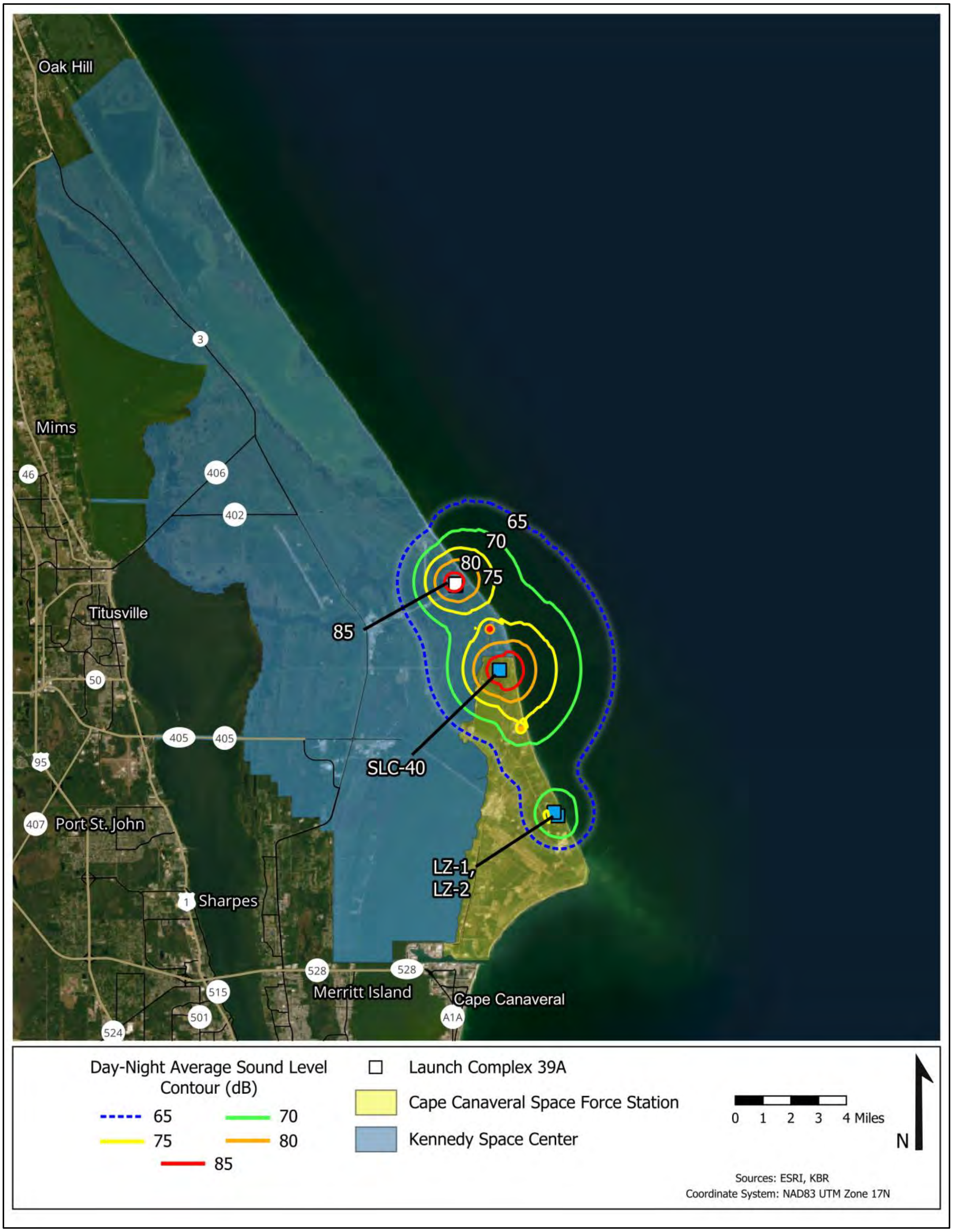

Figure 12. KSC and CCSFS Baseline Rocket Noise Exposure: DNL Contours

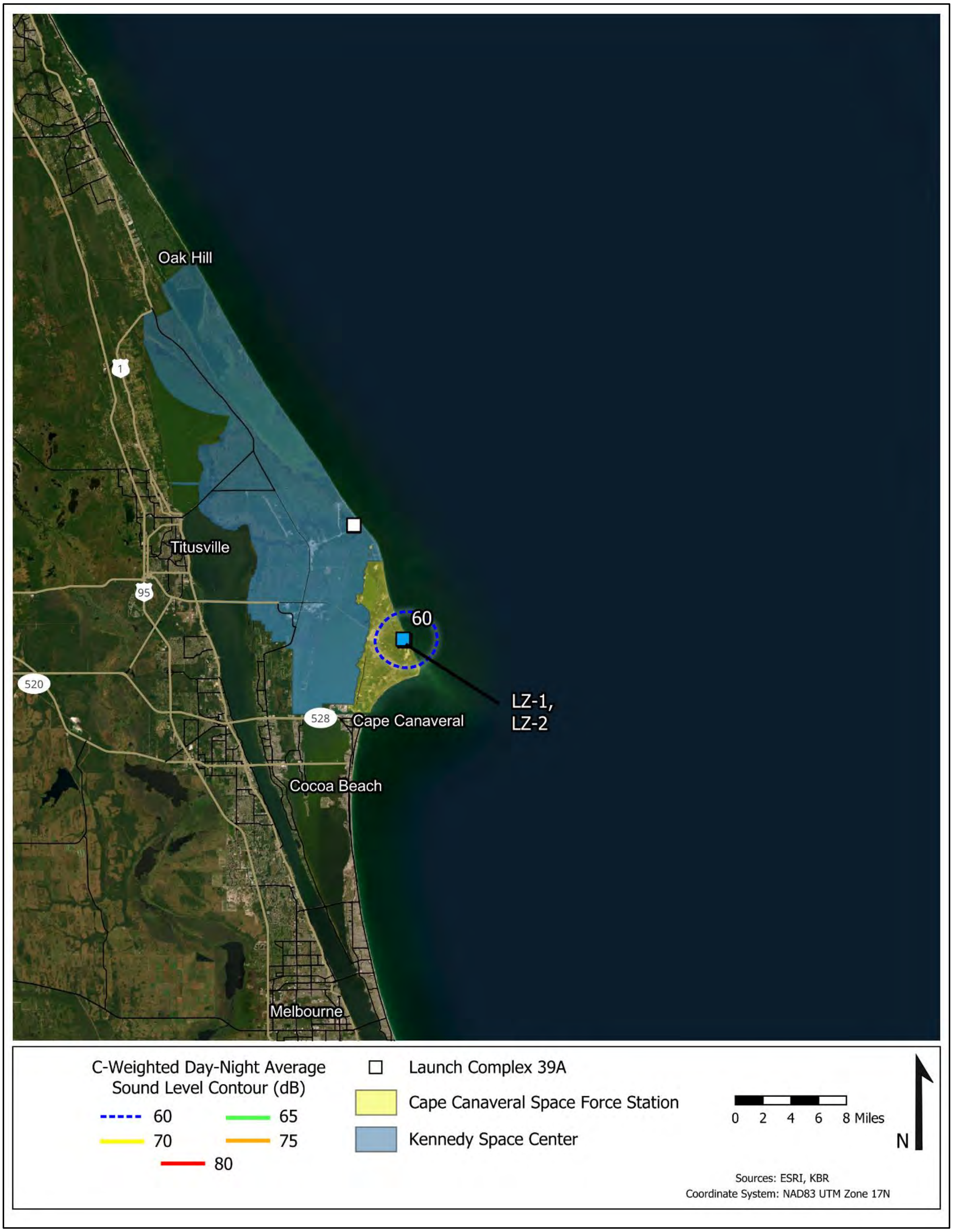

Figure 13. KSC and CCSFS Baseline Sonic Boom Exposure: CDNL Contours

4 NO ACTION SCENARIO

4.1 NO ACTION OPERATIONS AT KSC AND CCSFS

No Action launch vehicle flight and test operations at KSC and CCSFS are listed in Table 3. These operations are organized in the launch, landing, and static fire event categories and then by facility (KSC or CCSFS), launch complex, and by vehicle or program name, followed by the annual number of daytime (0700-2200) and nighttime (2200-0700) operations. These represent a maximum scenario of the launch, landing, and static fire test events that have undergone review and approval, but have not occurred yet (i.e., they are not part of the baseline).

Table 3. No Action Launch, Landing, and Static Fire Test Operations at KSC and CCSFS

Event	Facility	Complex	Vehicle/Program	Day	Night	Total
Launch	KSC	LC-39A	SpaceX Falcon 9	0	36	36
		LC-39A	SpaceX Falcon Heavy	0	5	5
		LC-39B	NASA Space Launch System	0.6	0.4	1
		LC-48N	NASA SCLV	32.5	19.5	52
		LC-48S	NASA SCLV	32.5	19.5	52
	CCSFS	SLC-16	Relativity Terran R	18	6	24
		SLC-36	Blue Origin New Glenn Launch	10	2	12
		SLC-40	SpaceX Falcon 9 Launch	0	70	70
		SLC-41	ULA Atlas V 551 (5 SRBs)	6.25	3.75	10
		SLC-41	ULA Vulcan VC6S	13	7	20
		SLC-46	Liquid Propellant Vehicle	7.5	4.5	12
		SLC-46	Solid Propellant Vehicle	7.5	4.5	12
			Total	**127.8**	**178.2**	**306**
Landing	CCSFS	LZ-1/2	SpaceX Falcon Booster	0	54	54
		LZ-1/2	SpaceX Falcon Heavy Booster	0	10	10
			Total	**0**	**64**	**64**
Static Fire	KSC	LC-39A	SpaceX Falcon 9	0	36	36
		LC-39A	SpaceX Falcon Heavy	0	5	5
		LC-48N	NASA SCLV	32.5	19.5	52
		LC-48S	NASA SCLV	32.5	19.5	52
	CCSFS	SLC-11	Blue Origin BE-4 Engine Testing	108	0	108
		SLC-16	Relativity Terran R Static Fire	18	6	24
		SLC-16	Relativity Terran R Stage MDC Hot Fire	10	4	14
		SLC-36	Blue Origin New Glenn Static Fire	10	2	12
		SLC-40	SpaceX Falcon 9 Static Fire	0	70	70
			Total	**211**	**162**	**373**

4.2 No Action: Rocket Noise Exposure: DNL Contours

Figure 14 shows the DNL contours for the No Action operations in Table 3, including DNL 65-85 dBA in 5 dB increments; these contours represent the cumulative subsonic noise environment due to rocket noise. The DNL 65 dBA contour, which represents the significance threshold for noise sensitive areas, is entirely within the KSC and CCSFS properties. Additional details of the No Action DNL exposure, and comparison with the DNL exposure estimates for the other operational scenarios are provided in Section 8.

4.3 No Action: Sonic Boom Exposure: CDNL Contours

Figure 15 shows the CDNL contours for the No Action operations in Table 3, including the CDNL 60, 65, and 70 dBC contours. The CDNL 60 dBC contour, which represents the significance threshold for noise sensitive areas, extends beyond the KSC and CCSFS property lines into Merritt Island to the west and the City of Cape Canaveral, and parts of Cocoa and Cocoa Beach to the south. The primary reason these CDNL contours extend into residential areas is the high number of annual nighttime landing operations (Table 3) which include a 10-decibel penalty compared to daytime operations. Additional details of the No Action CDNL exposure, and comparison with the CDNL exposure estimates for the other operational scenarios are provided in Section 8, which summarizes the results.

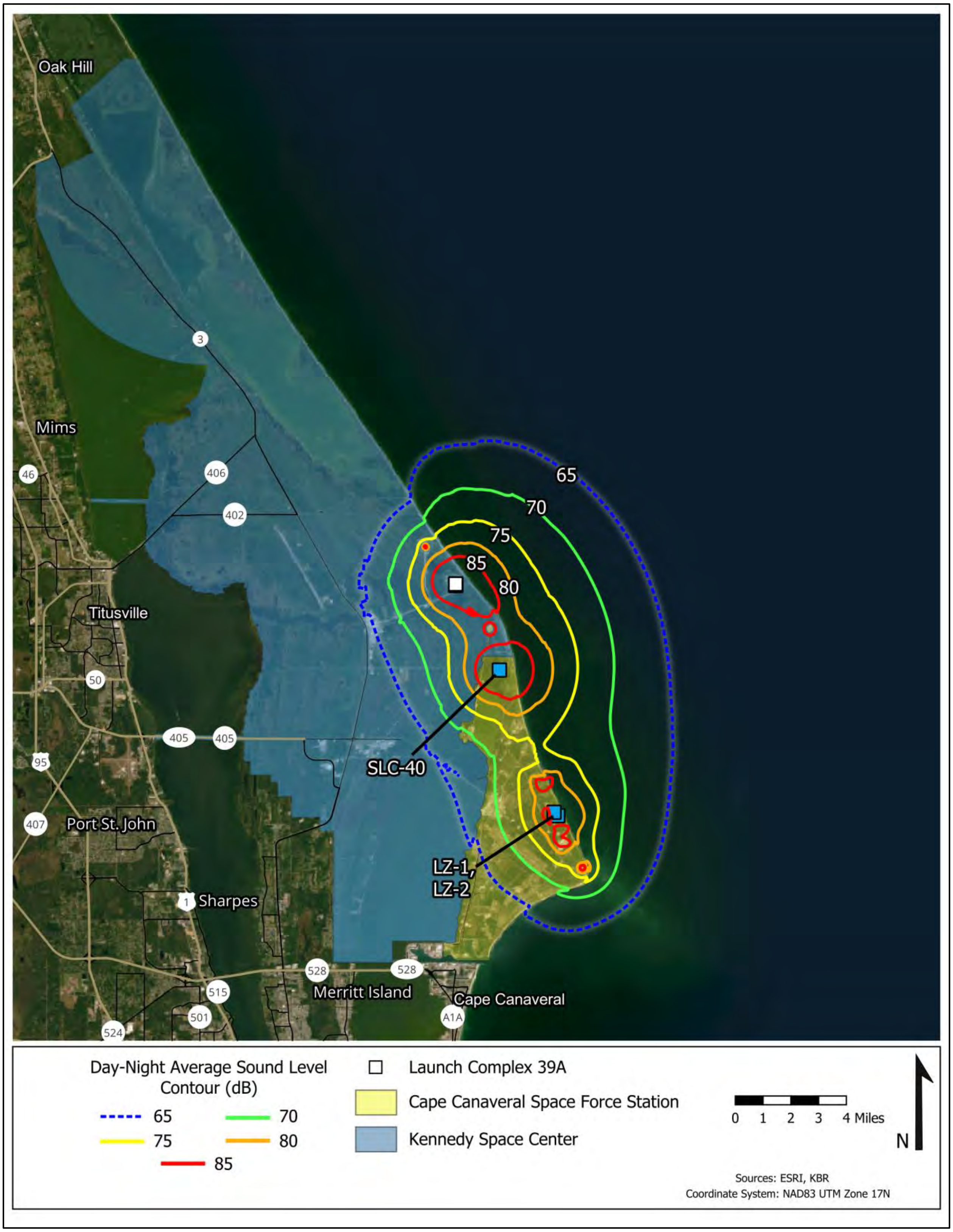

Figure 14. KSC and CCSFS No Action Rocket Noise Exposure: DNL Contours

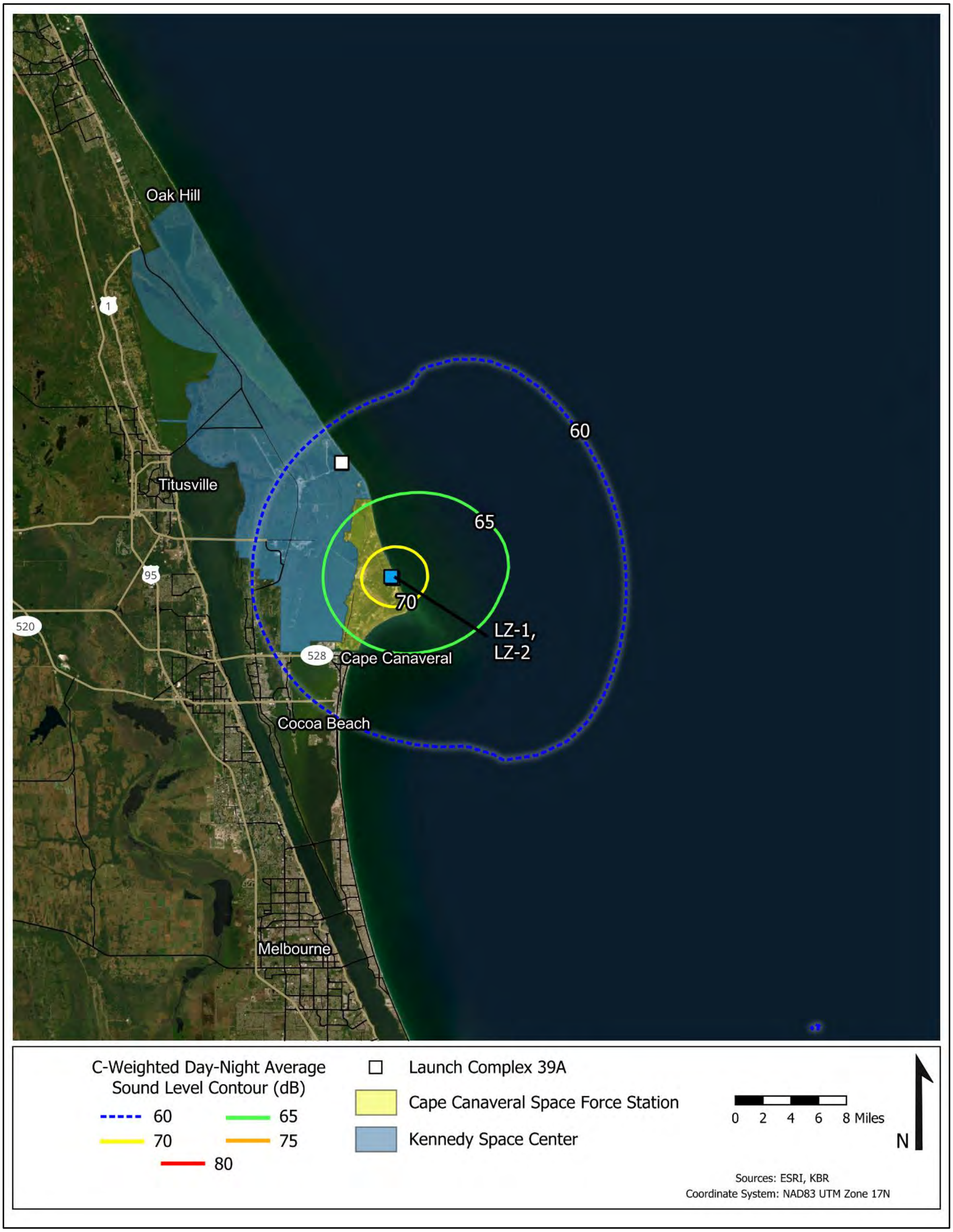

Figure 15. KSC and CCSFS No Action Sonic Boom Exposure: CDNL Contours

5 PROPOSED STARSHIP AND SUPER HEAVY BOOSTER FLIGHT AND TEST OPERATIONS AT LC-39A

5.1 PROPOSED ANNUAL OPERATIONS AT LC-39A

This section describes the noise modeling and assessment results for the proposed Starship operations at LC-39A only; whereas Section 6 describes the results for the Proposed Action, which includes the Starship operations presented here plus all the launch and landing operations associated with the No Action Scenario (Section 4). The proposed Starship flight and test operations at LC-39A that are expected to fulfill mission and test requirements at KSC are listed in Table 4. The number of annual daytime (7 a.m. (0700) to 10 p.m. (2200)) and nighttime (10 p.m. (2200) to 7 a.m. (0700)) operations are listed for each type of operation and associated vehicle. For each operation type, there are a total of 44 proposed annual operations and, in each case, 22 (50 percent) are modeled as daytime operations and 22 as nighttime operations.

Table 4. Proposed Annual Starship Operations at LC-39A

Operation Type	Annual Operations by Vehicle						Total Annual Operations
	Starship + Super Heavy Booster		Starship		Super Heavy Booster		
	Day	Night	Day	Night	Day	Night	
Orbital Launch	22	22	-	-	-	-	44
Starship Spacecraft Landing	-	-	22	22	-	-	44
Super Heavy (Booster) Landing	-	-	-	-	22	22	44
Starship Static Fire Test	-	-	22	22	-	-	44
Super Heavy (Booster) Static Fire Test	-	-	-	-	22	22	44

5.2 ROCKET NOISE EXPOSURE AT LC-39A

In this section, noise levels are estimated for the Starship proposed flight and test operations at LC-39A. The single event noise levels for each type of operation are assessed in the following sections: Starship Orbital Launch Noise Levels (Section 5.2.1), Descent/Landing Noise Levels (5.2.2), and Static Fire Test Noise Levels (5.2.3). The cumulative noise exposure from all operations combined are assessed using the DNL metric in Section 5.2.4 including the noise exposed population, acreage, and households within each DNL contour band (from 65 to 85 dB in 5 dB increments) and at the study points of interest (POIs) using guidelines approved by the FAA. Following this, in Section 5.2.5, is a supplemental noise metrics assessment at the same POIs including: Speech Interference (5.2.5.1), Classroom Learning Interference (5.2.5.2), Probability of Awakening (5.2.5.3), and Potential for Hearing Loss (5.2.5.4). The supplemental noise metrics assessment follows DoD guidelines for noise impact analysis[18]. Section 5 concludes with an assessment of the sonic boom exposures that would result from the proposed Starship flight operations at LC-39A.

5.2.1 Starship Orbital Launch Noise Levels at LC-39A

RNOISE was used to estimate the L_{Amax}, SEL, and L_{max} contours for Starship orbital launches at LC-39A using trajectory data, from liftoff to stage separation, provided by SpaceX in file 'Starship_Bottom_Up_Ascent_Nominal_80_12_r2.ASC'. The L_{Amax} contours indicate the A-weighted maximum sound level at each location over the duration of the launch where engine thrust varies according to the ascent thrust profile provided. For orbital launches, the Starship launch vehicle is comprised of the Starship spacecraft (vehicle with payload) and the Super Heavy Booster.

RNOISE computations were done using a radial grid consisting of 128 azimuths and 500 intervals out to 500,000 feet from the launch pad. Land areas were modeled using a single ground impedance value representing soft ground cover in the vicinity of LC-39A and offshore water areas modeled as acoustically hard. Ground effect (i.e., the difference in sound pressure level in the presence of ground compared with free field conditions) is based on a weighted average over the propagation path. As will be shown in the resulting noise contour maps (Figures 16 through 21), the shape of the innermost contours is approximately circular. The shape of the outermost contours is due to rocket noise directivity and the difference between acoustically hard water and acoustically soft ground. The launch pad location at LC-39A is indicated in the map legends as are the boundaries of Cape Canaveral Space Force Station and Kennedy Space Center. All the maps depicting noise contours for operations at LC-39A also show the nearby cities including Titusville, Cape Canaveral, and Cocoa Beach, FL. Throughout this report, two different map scales are used as appropriate to show the extent of the noise contours.

The L_{Amax} 90 dB through 140 dB contours shown on Figures 16 and 17 represent the A-weighted maximum levels estimated for a Starship orbital launch at LC-39A. Figure 17 shows these contours using a zoomed in map scale to better show the extent of the noise exposure relative to the local towns and cities in the close vicinity of LC-39A. The higher L_{Amax} contours (100 – 140 dB) are located within about 8 miles of LC-39A; the 100 dB contour is located mostly within the KSC and CCSFS properties. In all cases following, where noise exposures are reported to be off KSC and/or off CCSFS properties, this refers to contours that extend to the north, south, and west into populated areas, rather than to contours that extend east over the Atlantic Ocean. The 90 dB contour extends west of the Indian River into Titusville. If a Starship orbital launch occurs during the day, when background levels are in the 50 dB to 60 dB range, residents of Titusville may notice launch noise levels above 70 dB. If the same launch occurs during the night, when background levels are lower than during the day (e.g., below 40 dB to 50 dB range), these residents may notice launch noise levels that exceed 60 dB. A prevailing on-shore or off-shore breeze may also strongly influence noise levels in nearby communities.

Estimated SEL contours of 90 dB through 150 dB, in 10 dB increments, are shown on Figures 18 and 19 for Starship orbital launch at LC-39A with Figure 19 showing a zoomed in map scale. As mentioned previously, SEL is an integrated metric and is expected to be greater than the L_{Amax} because the launch event is up to several minutes in duration whereas the maximum sound level (L_{Amax}) occurs instantaneously. On Figure 18, the 100 dB SEL contour is estimated to extend to the west side of Titusville.

Starship orbital launch events are the loudest single events of all the flight and test operations assessed in this modeling study. Accordingly, orbital launch single event noise levels are related to guidelines in Section 2.1.3 for hearing conservation and potential for structural damage. These guidelines are also used later in the report to assess noise from the other Starship flight and test operations.

An estimate of the areas, in the vicinity of Starship orbital launches, where a hearing conservation program should apply was made using KSC's permissible daily noise exposure limit of 108 dBA (slow response) for a duration of 2 minutes or less[15]. Figure 17 shows that noise levels (L_{Amax}) are less than KSC's 108 dBA upper noise limit guideline at distances greater than approximately 5 miles from the launch pad. Starship orbital launch noise events will last a few minutes at most, at a single location, with the highest noise levels occurring for less than a minute such that KSC's 108 dBA daily noise exposure limit is not expected to be exceeded.

The potential for structural damage due to Starship orbital launch events is assessed using two different criteria as described in Section 2.1.3. The first criteria indicates that, based on Maximum Unweighted Sound Level (L_{max}), approximately one damage claim will result per 100 households exposed at 120 dB and one damage claim will result per 1,000 households exposed at 111 dB[16]. The L_{max} 110 dB through 150 dB contours estimated for Starship orbital launch events are shown on Figures 20 and 21 (zoomed in) including the L_{max} 111 dB and 120 dB contours used for damage claim assessment. Starship orbital launch events are estimated to generate L_{max} of 120 dB approximately 10 miles from the launch pad (Figure 20); the 120 dB contour would extend west to the Indian River and north to Wilson, but remain mostly on KSC and CCSFS properties. The 111 dB contour would extend approximately 22 miles from the launch pad into residential areas west of Titusville, south along the coast between Cocoa Beach and Satellite Beach, and north to Oak Hill; for residences located between the 111 dB and 120 dB contours, between one and ten damage claims per 1,000 households would be expected based on assessment using this criteria. The second, less conservative criteria, is based on a study that concludes that structural damage becomes improbable below 140 dB L_{max}. No glass or plaster damage is expected below 140 dB and no damage is expected below 134 dB[18]. Figure 21 shows that the 140 dB and 130 dB, and thus the 134 dB contour (not shown but located about halfway between the 140 dB and 130 dB contours, are all located within KSC and CCSFS properties. No structural damage is expected to occur to residences located off KSC and CCSFS properties based on assessment using this criteria.

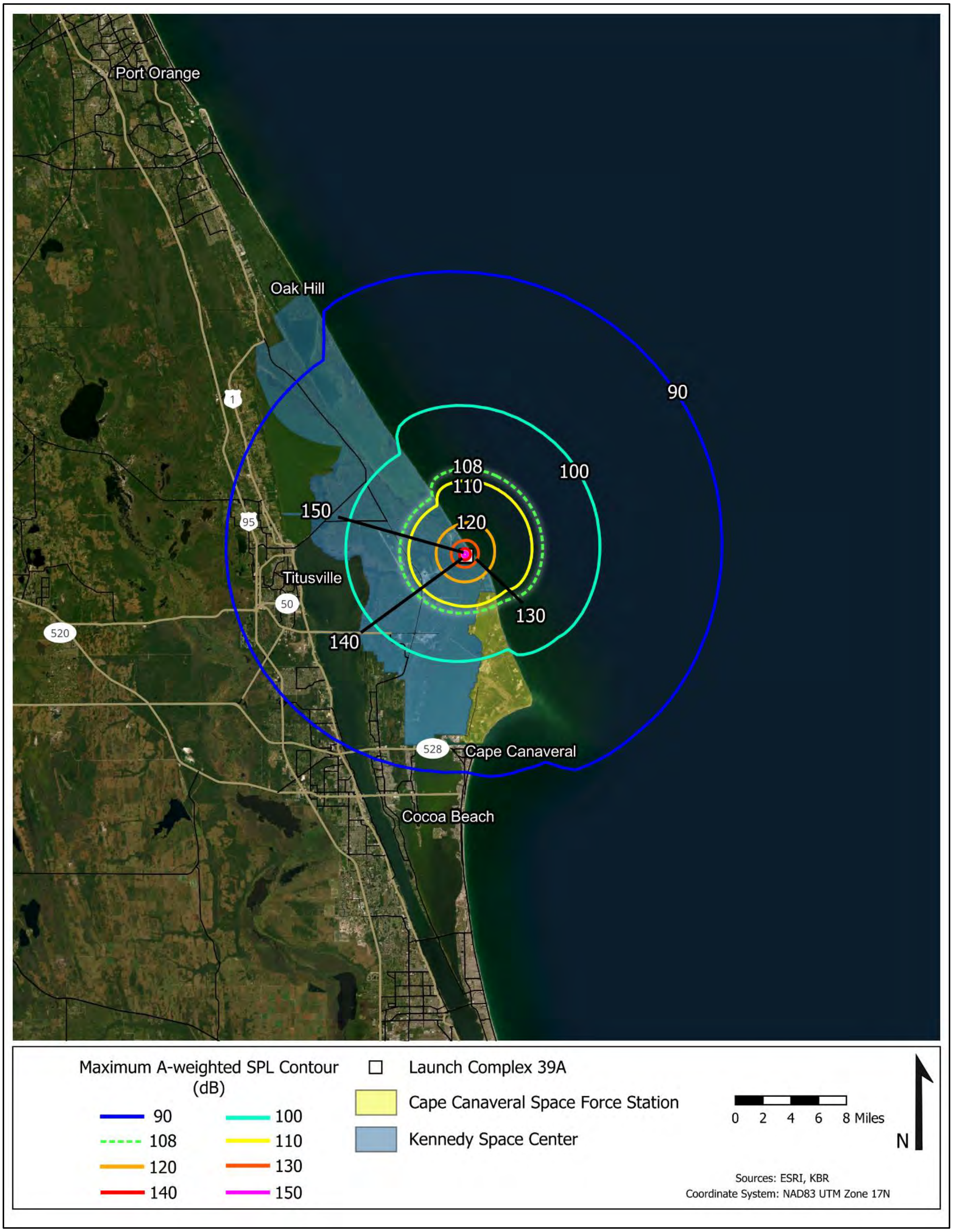

Figure 16. Starship Orbital Launch from LC-39A: Maximum A-Weighted Sound Levels

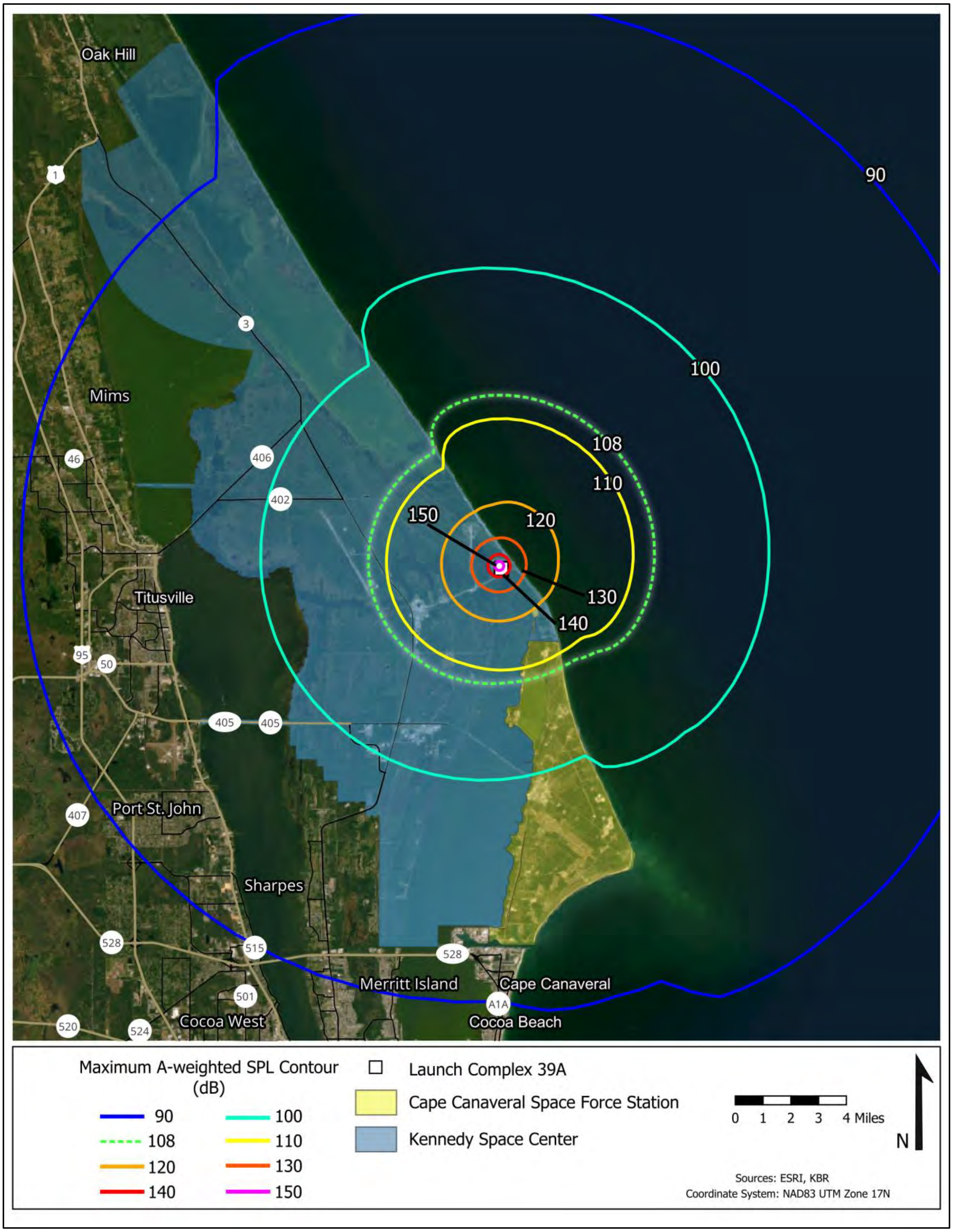

Figure 17. Starship Orbital Launch from LC-39A: Maximum A-Weighted Sound Levels (Zoom In)

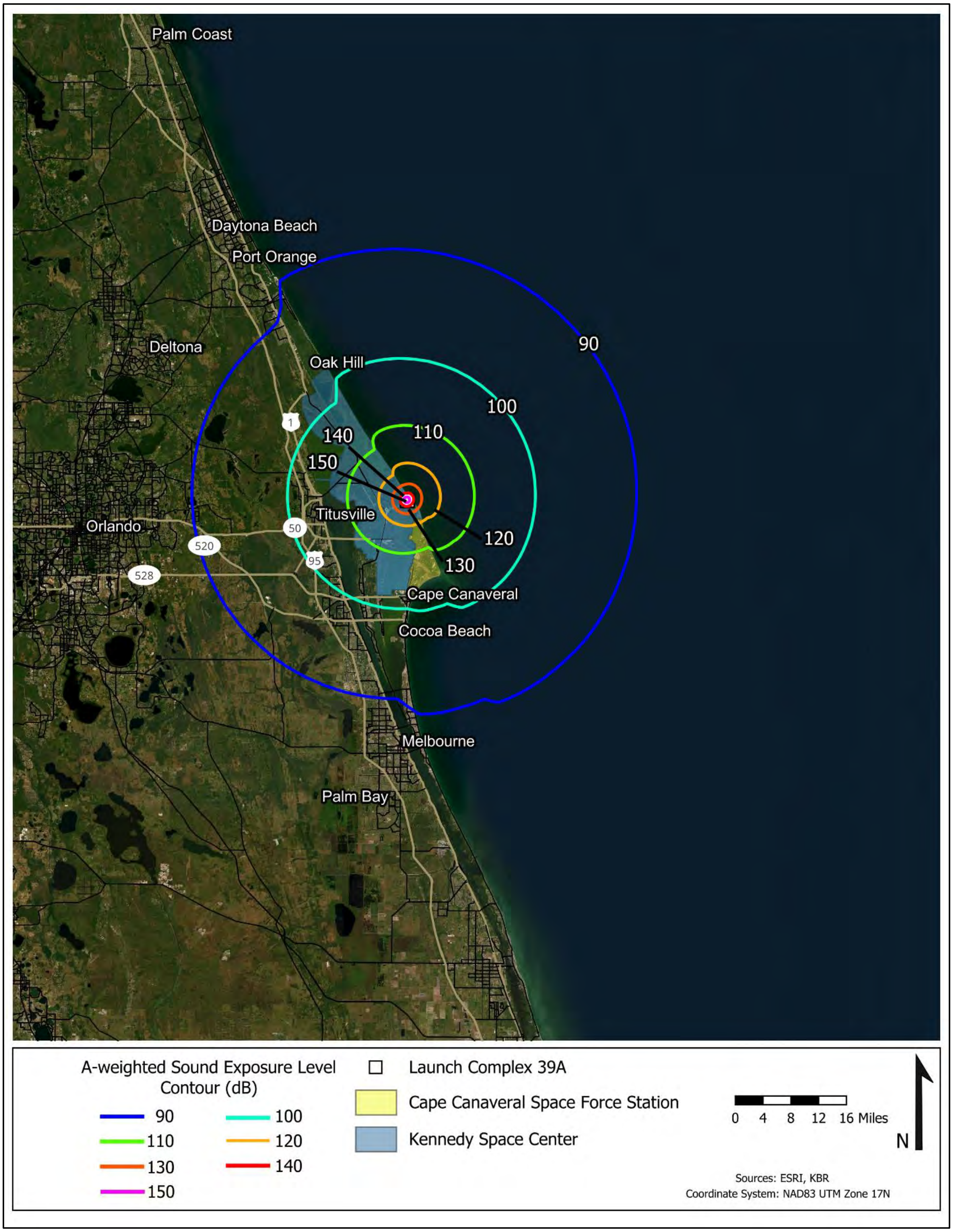

Figure 18. Starship Orbital Launch from LC-39A: Sound Exposure Levels

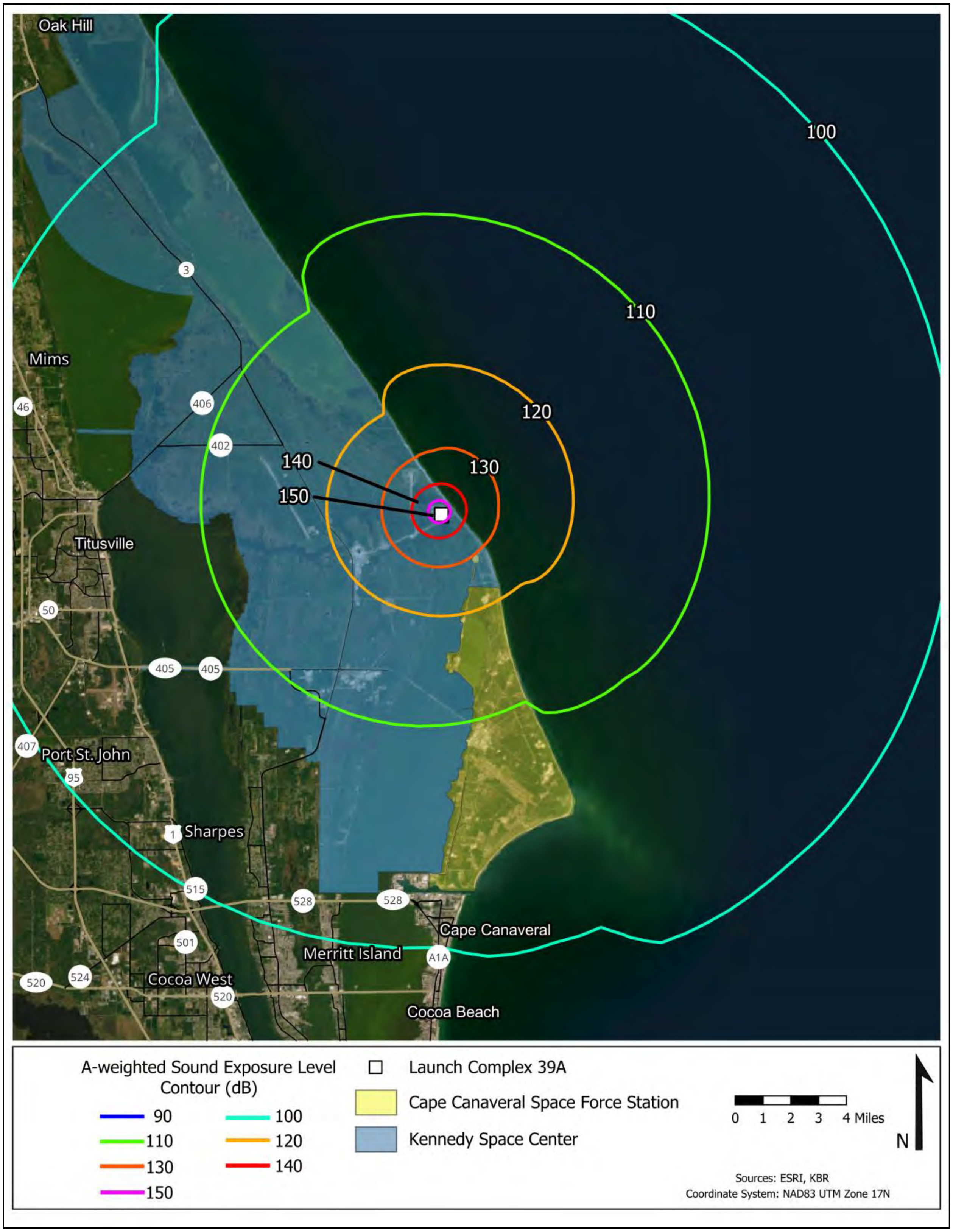

Figure 19. Starship Orbital Launch from LC-39A: Sound Exposure Levels (Zoom In)

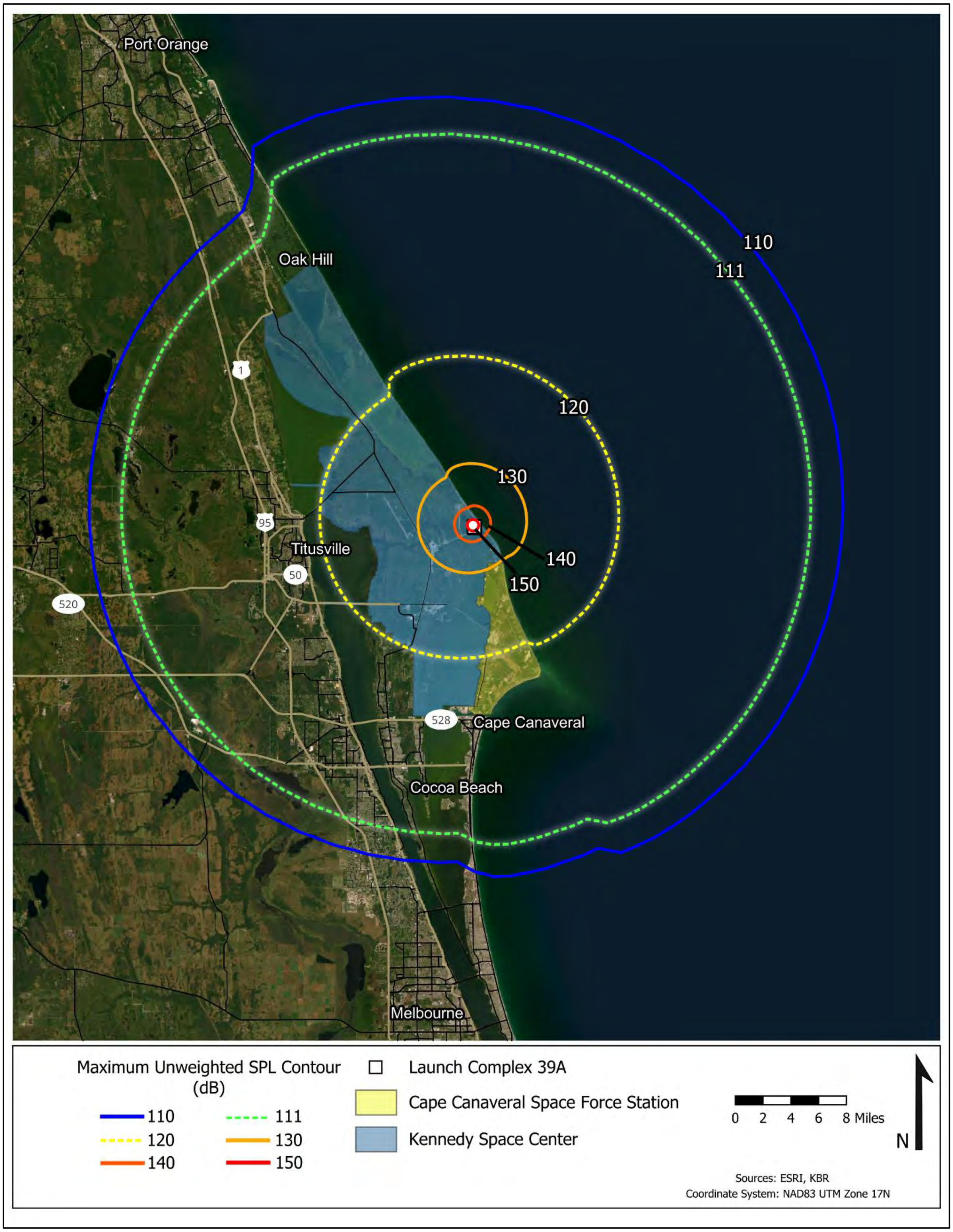

Figure 20. Starship Orbital Launch from LC-39A: Maximum Unweighted Sound Levels

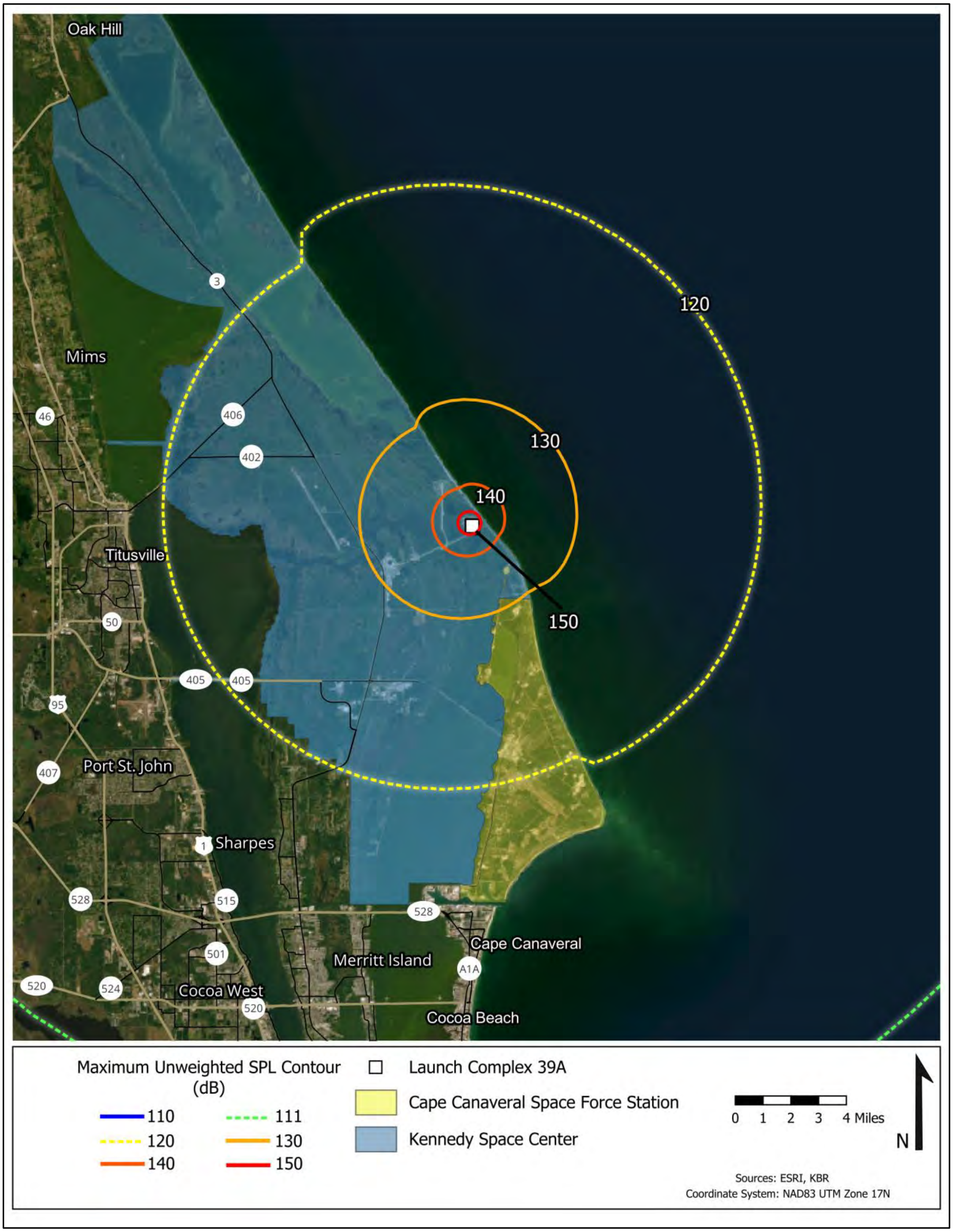

Figure 21. Starship Orbital Launch from LC-39A: Maximum Unweighted Sound Levels (Zoom In)

5.2.2 Descent/Landing Noise Levels at LC-39A

5.2.2.1 Starship Spacecraft Landings

RNOISE was used to estimate the L_{Amax}, SEL, and L_{max} contours for Starship spacecraft descent/landings at LC-39A. L_{Amax} contours indicate the maximum A-weighted sound level at each location over the duration of the landing where engine thrust varies according to the descent/landing thrust schedule provided.

RNOISE computations were performed as noted previously in Section 5.2.1. The L_{Amax}, SEL, and L_{max} contours for a Starship spacecraft landing at LC-39A are shown on Figures 22 through 24, respectively. The landing site location at LC-39A is indicated in the map legends as are the boundaries of Cape Canaveral Space Force Station and Kennedy Space Center. On Figure 22 the 90 dB L_{Amax} contour is about 5 miles from the LC-39A landing site and lies entirely within the CCSFS and KSC properties. The 108 dB L_{Amax} contour, which can be used as a threshold limit for hearing conservation, is located approximately 1.5 miles from the landing pad. Compared with the Starship orbital launch noise levels reported in Section 5.2.1, Starship spacecraft descent/landing noise levels are considerably lower due to the much lower total engine thrust used for landing operations. On Figure 23, the SEL 90 and 100 dBA contours are estimated to remain entirely on the CCSFS and KSC properties. The L_{max} 111 dB and 120 dB contours, shown on Figure 24 and used as the more conservative measure to assess the potential for structural damage, are entirely within the KSC and CCSFS properties. Similarly, the L_{max} 130 dB and 140 dB contours, along with the 134 dB contour (not shown) are entirely within the KSC and CCSFS properties. No structural damage is expected to occur to residences located off KSC and CCSFS properties based on assessment using either criteria.

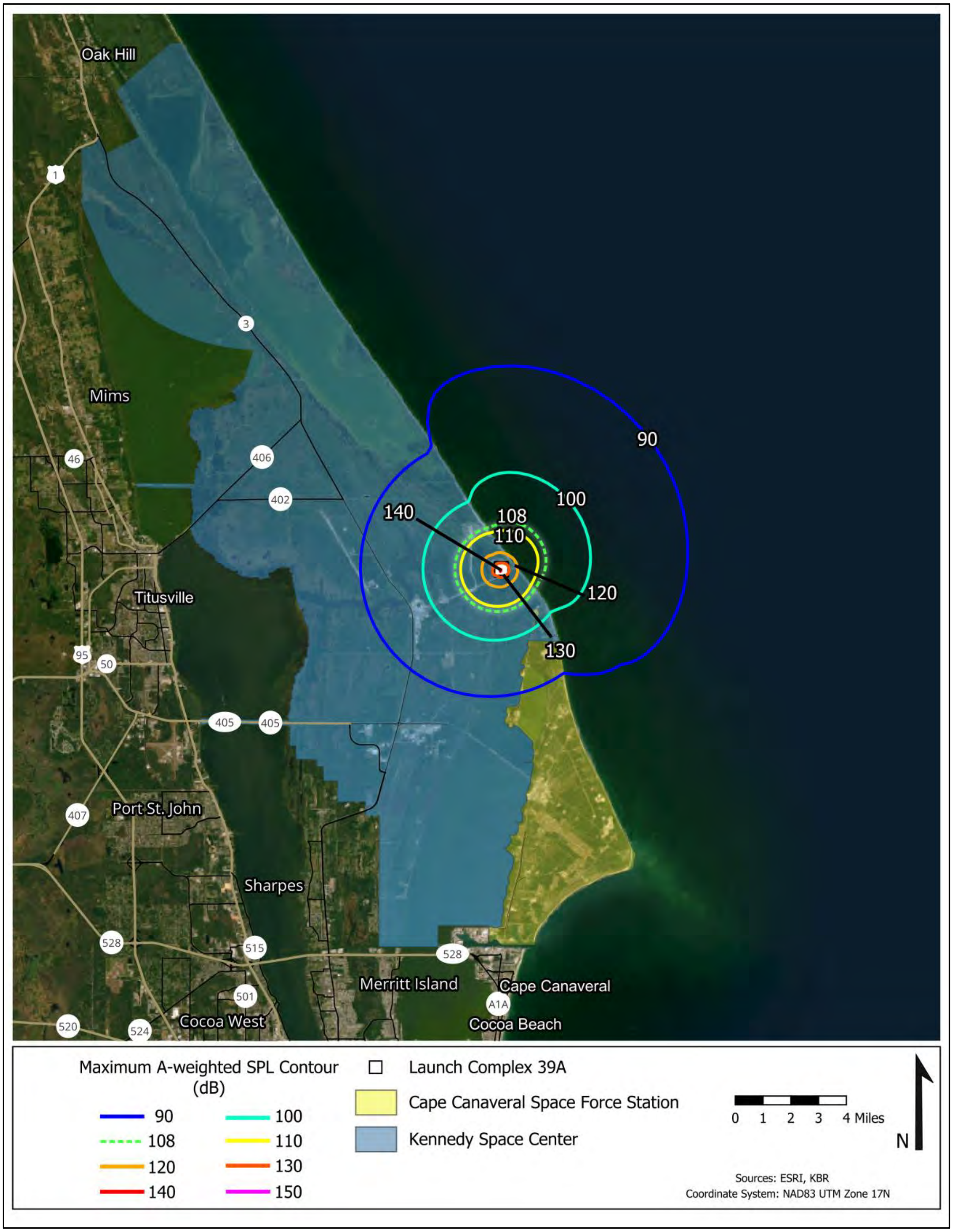

Figure 22. Starship Spacecraft Landing at LC-39A: Maximum A-Weighted Sound Levels

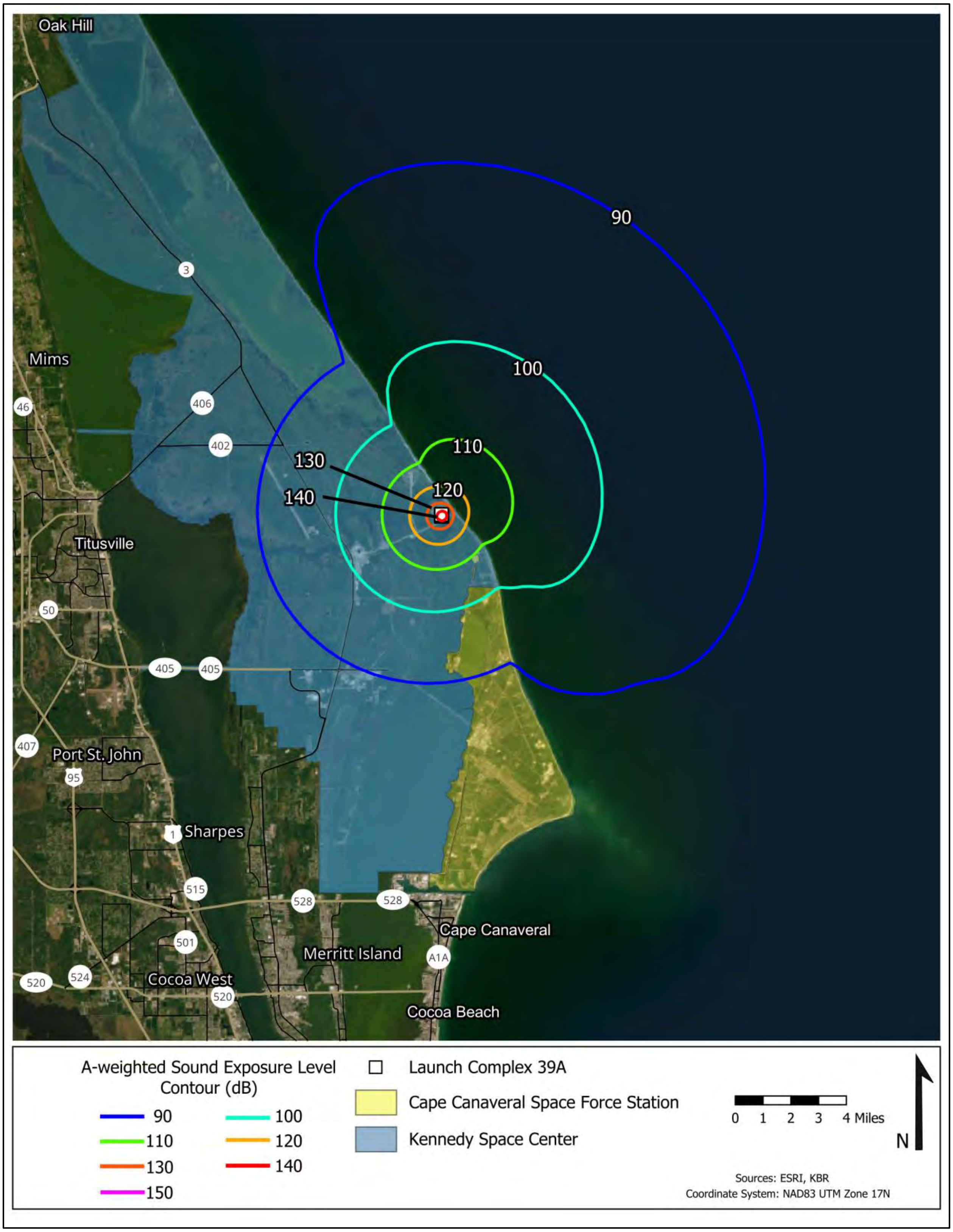

Figure 23. Starship Spacecraft Landing at LC-39A: Sound Exposure Levels

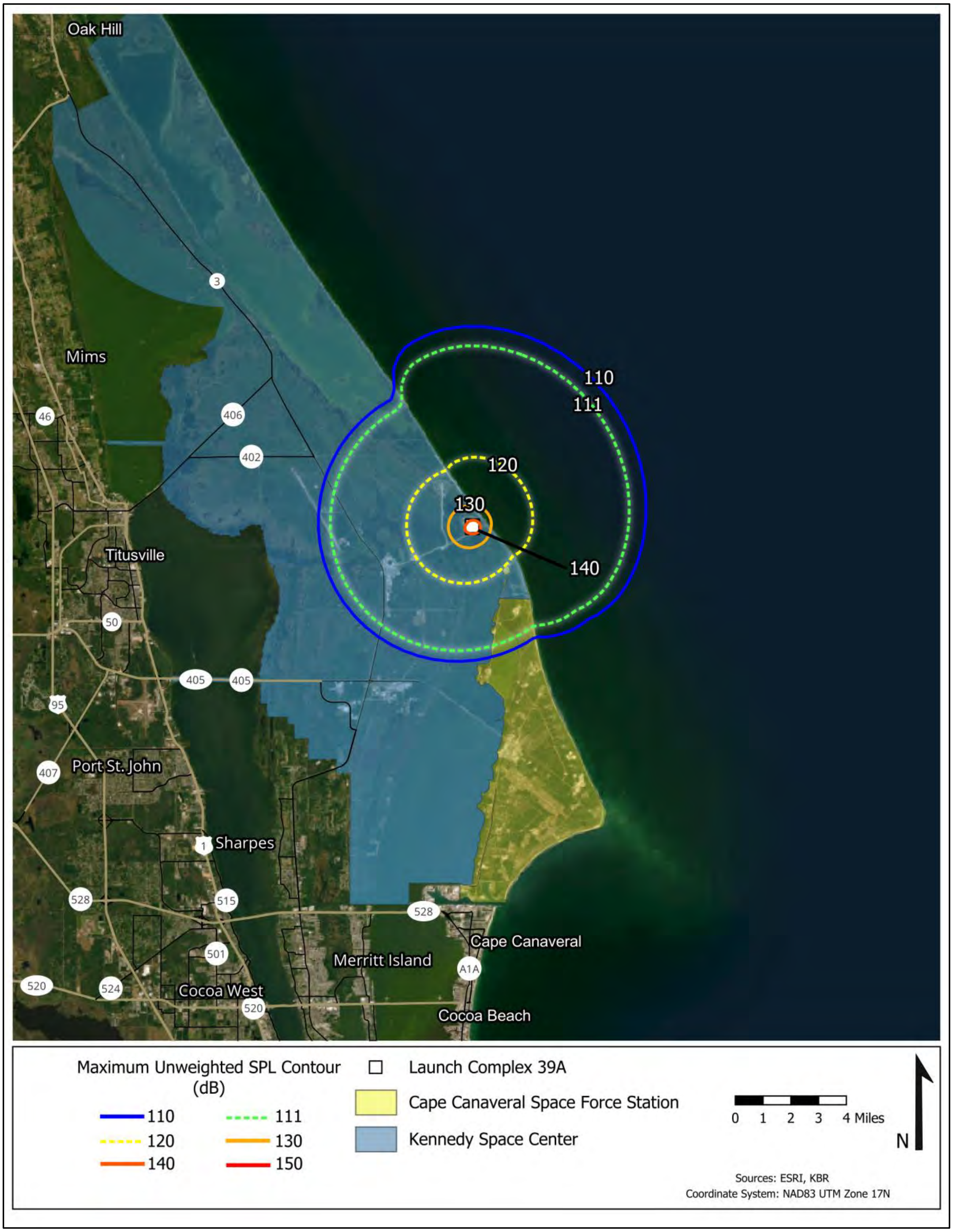

Figure 24. Starship Spacecraft Landing at LC-39A: Maximum Unweighted Sound Levels

5.2.2.2 Super Heavy (Booster) Landings

RNOISE was used to estimate the L_{Amax}, SEL, and L_{max} contours for Super Heavy descent/landings at LC-39A. The nominal booster reentry and landing trajectory (descending from an approximate 80-degree heading) was provided by SpaceX in file 'Starship_Bottom_Up_Flyback_Nominal_80_12_r2.ASC' and two additional landing trajectories were provided which represent the northern bounding trajectory (40-degrees) and the southern bounding trajectory (115-degrees). The L_{Amax} contours for each case indicate the maximum A-weighted sound level at each location over the duration of the landing where engine thrust varies according to the reentry/descent thrust schedule provided.

RNOISE computations were performed as noted previously in Section 5.2.1. The L_{Amax}, SEL, and L_{max} contours for each of the three Super Heavy landings at LC-39A are shown sequentially in Figures 25 through 33. The landing site location at LC-39A is indicated in the map legends as are the boundaries of Cape Canaveral Space Force Station and Kennedy Space Center. On Figure 25 the 90 dB L_{Amax} contour is about 9 miles from the LC-39A landing site and lies almost entirely within the CCSFS and KSC properties. The 108 dB L_{Amax} contour, which can be used as a threshold limit for hearing conservation, is located approximately 2.5 miles from the landing pad. Compared with the Starship orbital launch noise levels reported in Section 5.2.1, Super Heavy descent/landing noise levels are considerably lower due to the much lower total engine thrust used for landing operations. On Figure 28, the SEL 90 dB and 100 dB contours are estimated to remain almost entirely on the CCSFS and KSC properties. The L_{max} 111 dB and 120 dB contours, as well as the 130 dB and 140 dB contours shown on Figure 31, and thus the 134 dB contour (not shown), used to assess the potential for structural damage, are located almost entirely on the KSC and CCSFS properties. No structural damage is expected to occur to residences located off KSC and CCSFS properties based on assessment using either criteria.

Note that on the three figures shown for each metric, the noise contours associated with the nominal (80-degree), 40-degree, and 115-degree booster landing trajectories change location although the changes are not easily observed; more so when examining the larger sound exposure level contours (Figures 28 through 30) for comparison. The reason the location of the contours (noise exposure) does not change much is because the booster thrust on landings occurs within about the final 5,000 feet of altitude, relatively close to the ground, on each of the three trajectory headings. As will be shown in Section 5.3, sonic boom exposures on the ground, from each of the three booster landing trajectories, are more spatially separated than the subsonic (rocket) noise contours just presented, since sonic boom is generated at much higher altitudes where the trajectories would have more separation.

The next section presents single event noise levels for proposed Starship spacecraft and Super Heavy (Booster) static fire tests at LC-39A.

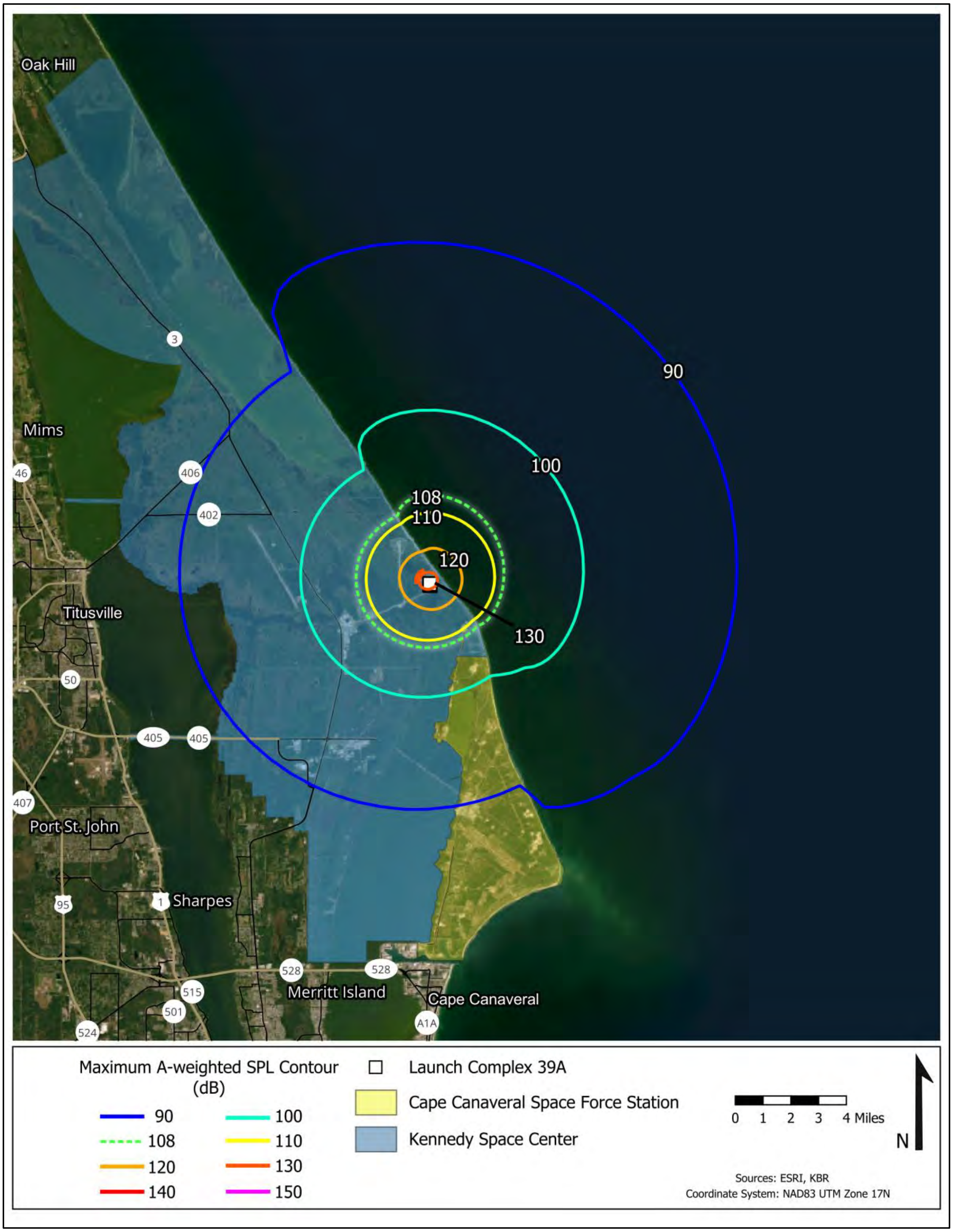

Figure 25. Super Heavy Landing at LC-39A (Nominal): Maximum A-Weighted Sound Levels

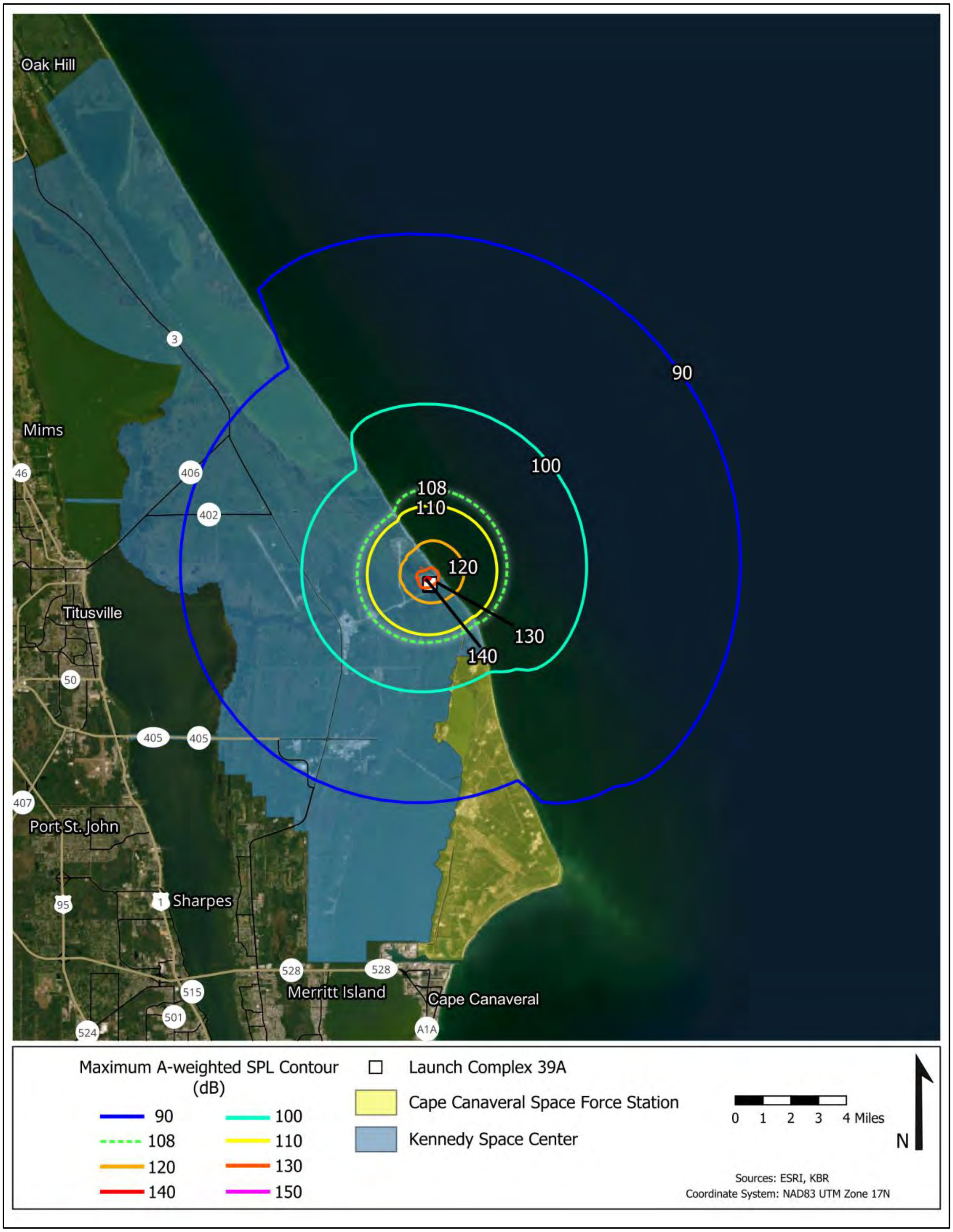

Figure 26. Super Heavy Landing at LC-39A (40-Degrees): Maximum A-Weighted Sound Levels

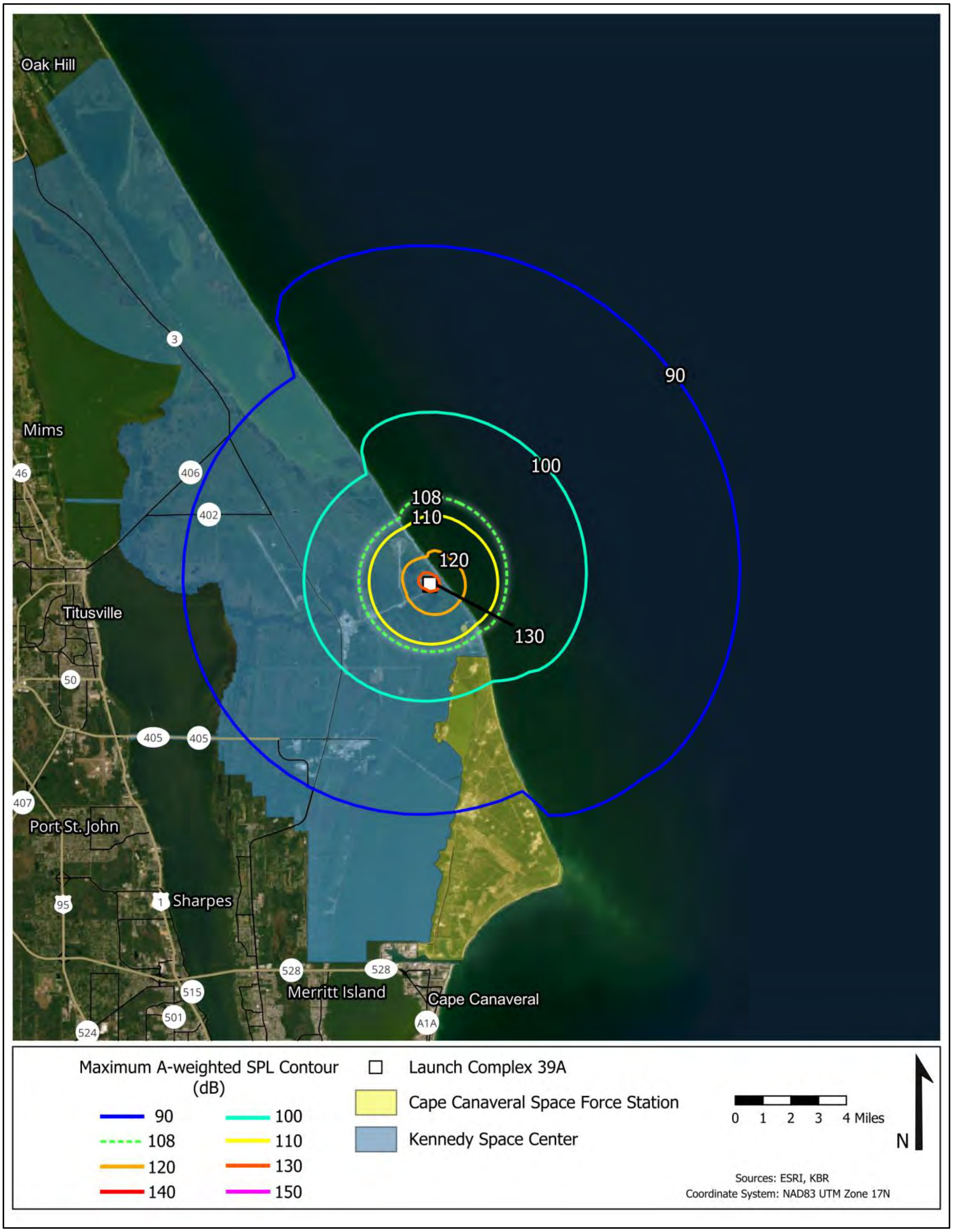

Figure 27. Super Heavy Landing at LC-39A (115-Degrees): Maximum A-Weighted Sound Levels

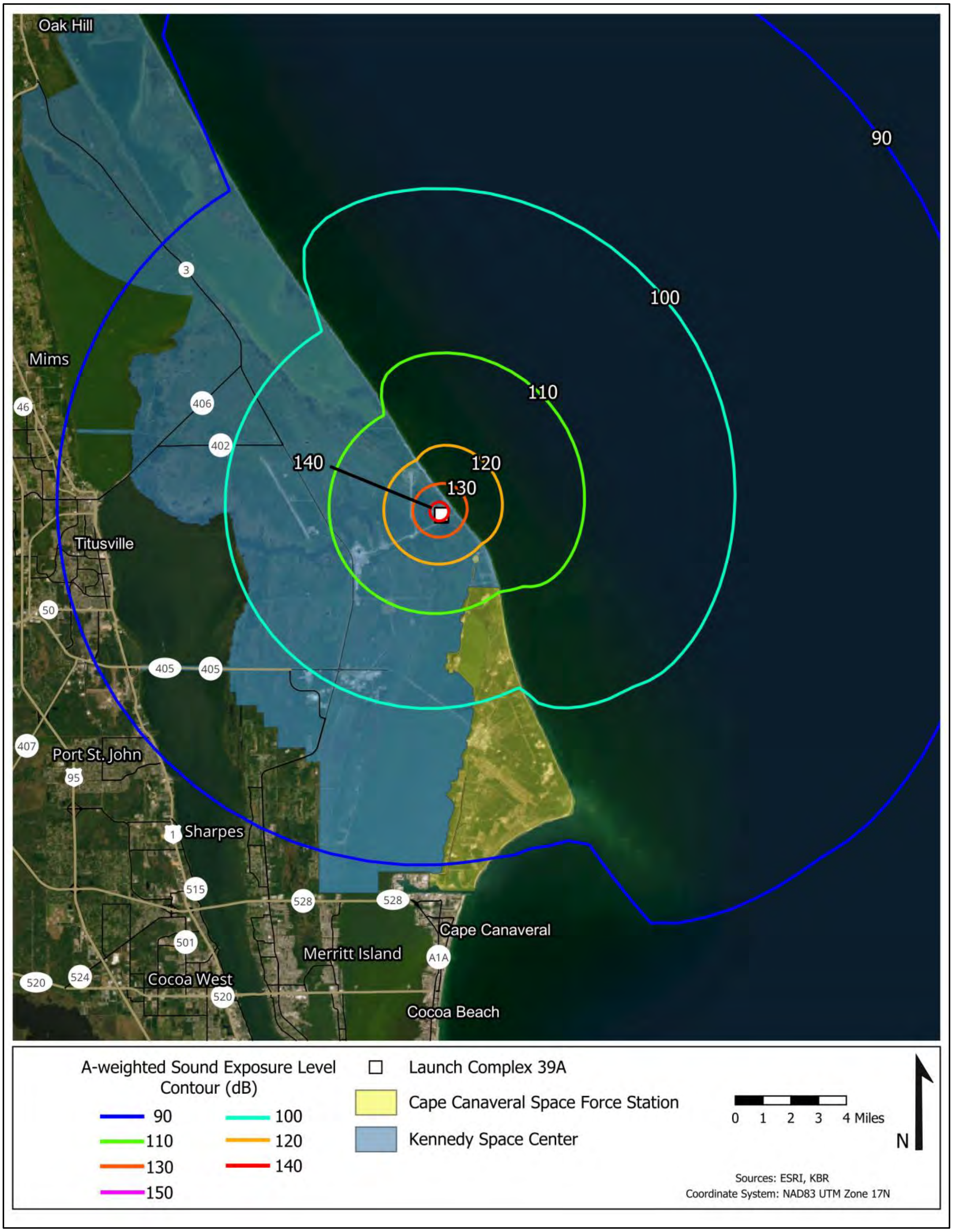

Figure 28. Super Heavy Landing at LC-39A (Nominal): Sound Exposure Levels

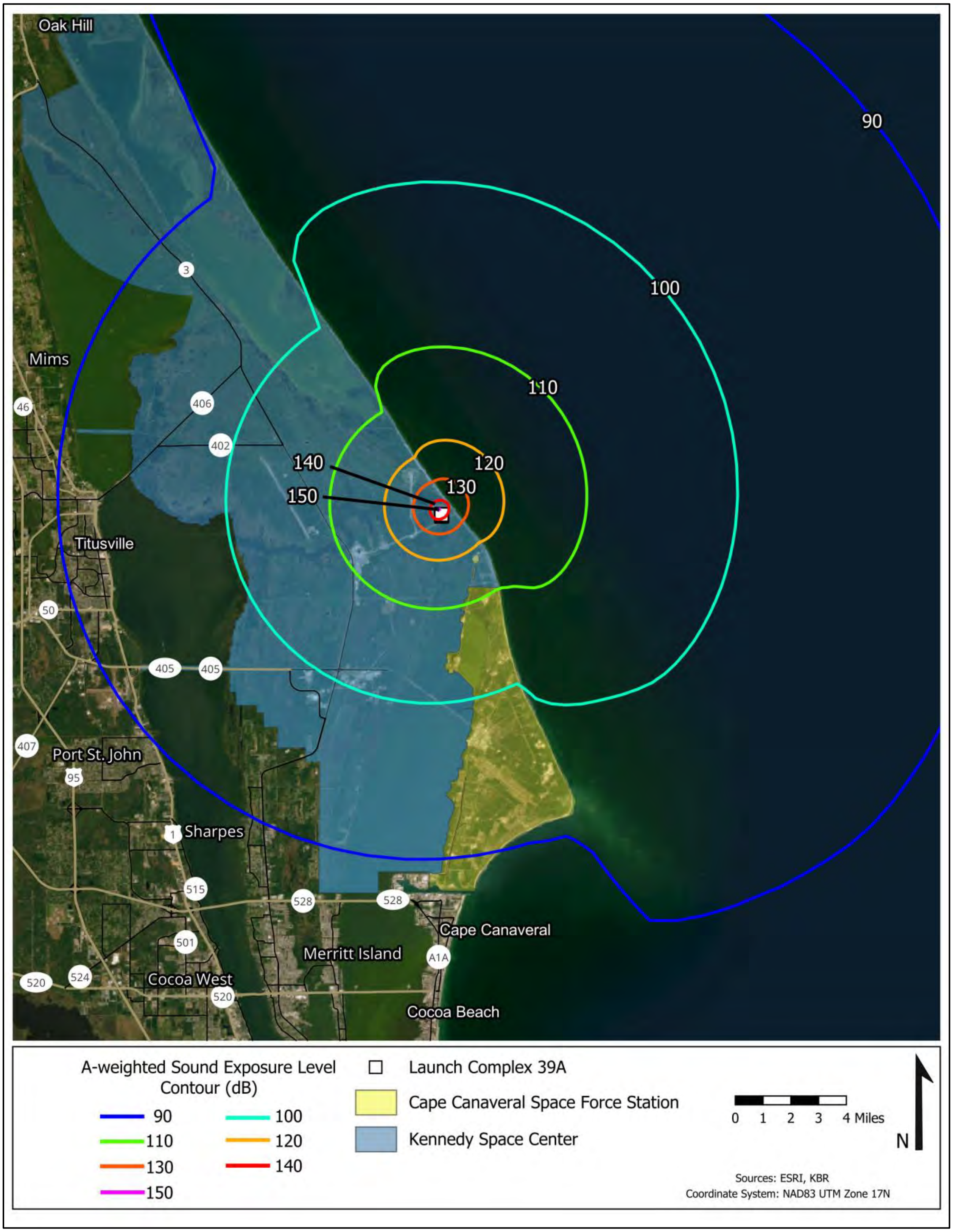

Figure 29. Super Heavy Landing at LC-39A (40-Degrees): Sound Exposure Levels

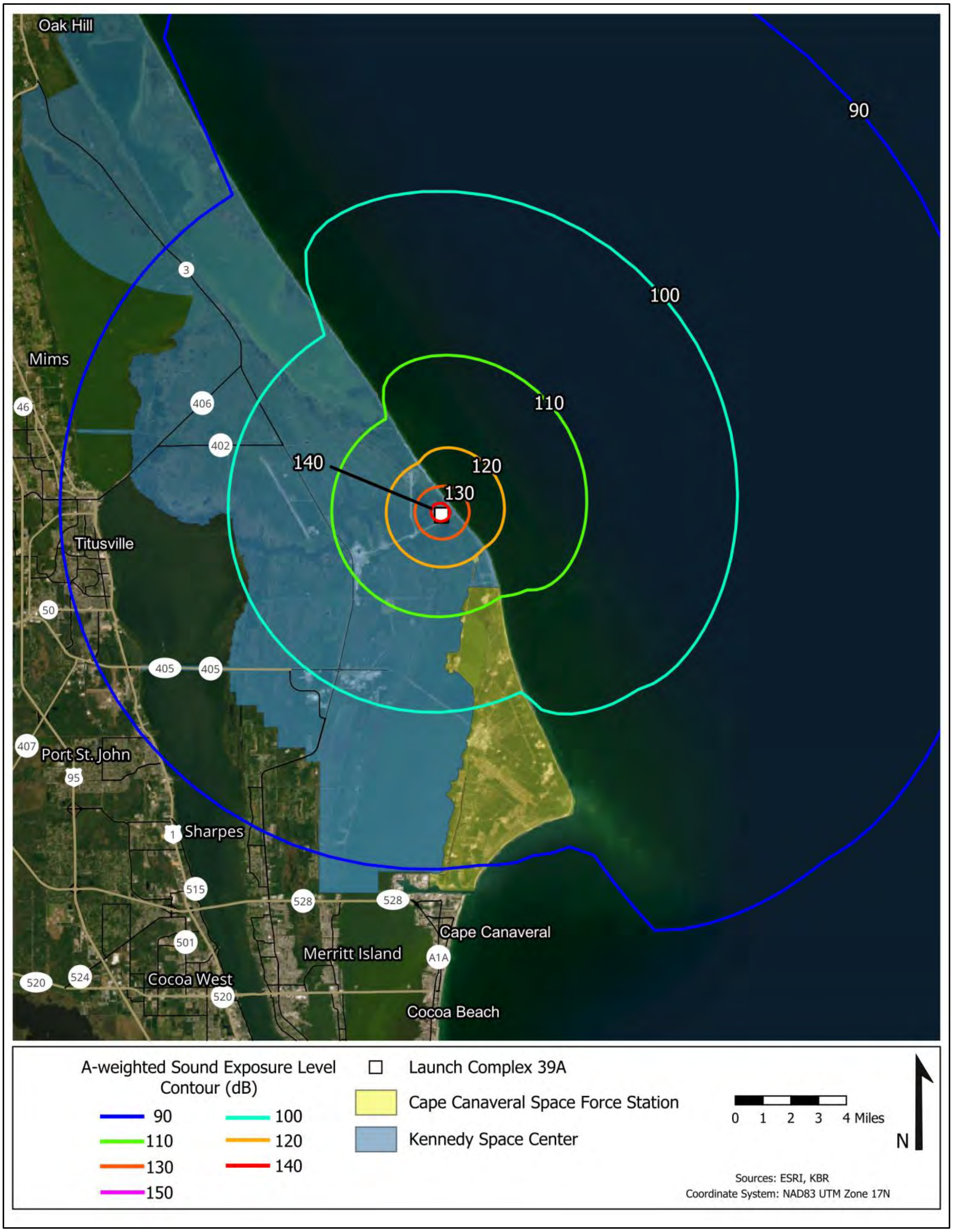

Figure 30. Super Heavy Landing at LC-39A (115-Degrees): Sound Exposure Levels

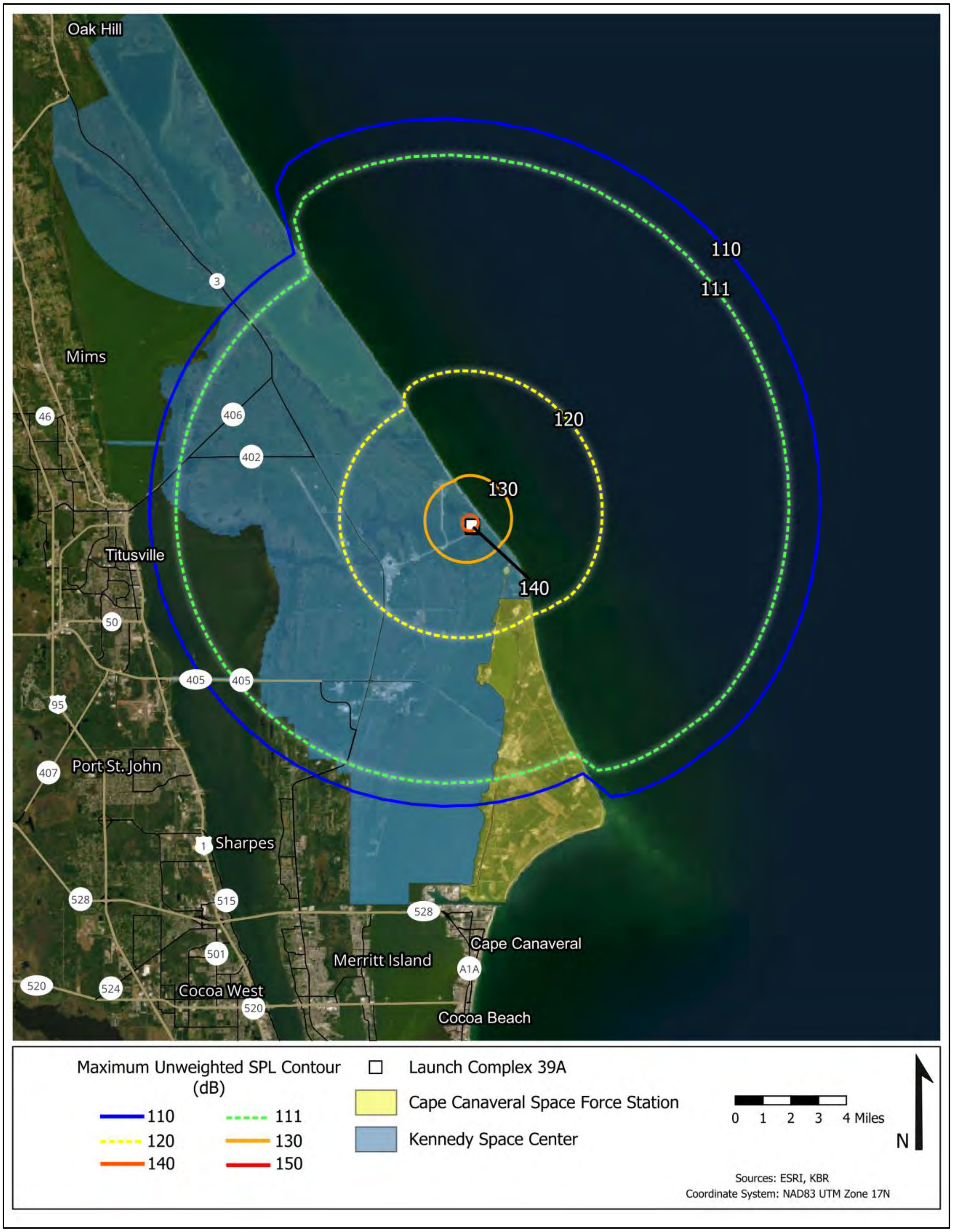

Figure 31. Super Heavy Landing at LC-39A (Nominal): Maximum Unweighted Sound Levels

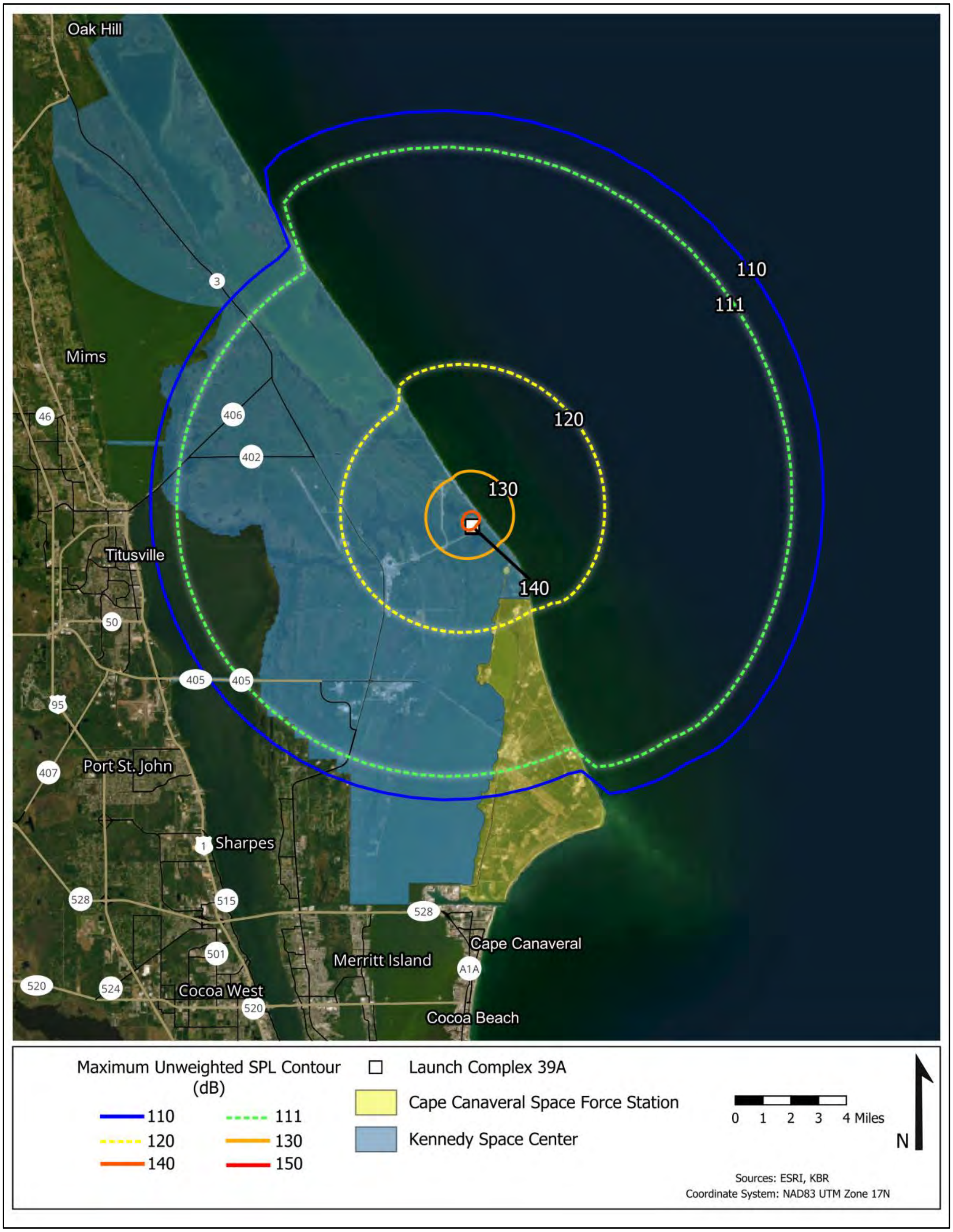

Figure 32. Super Heavy Landing at LC-39A (40-Degrees): Maximum Unweighted Sound Levels

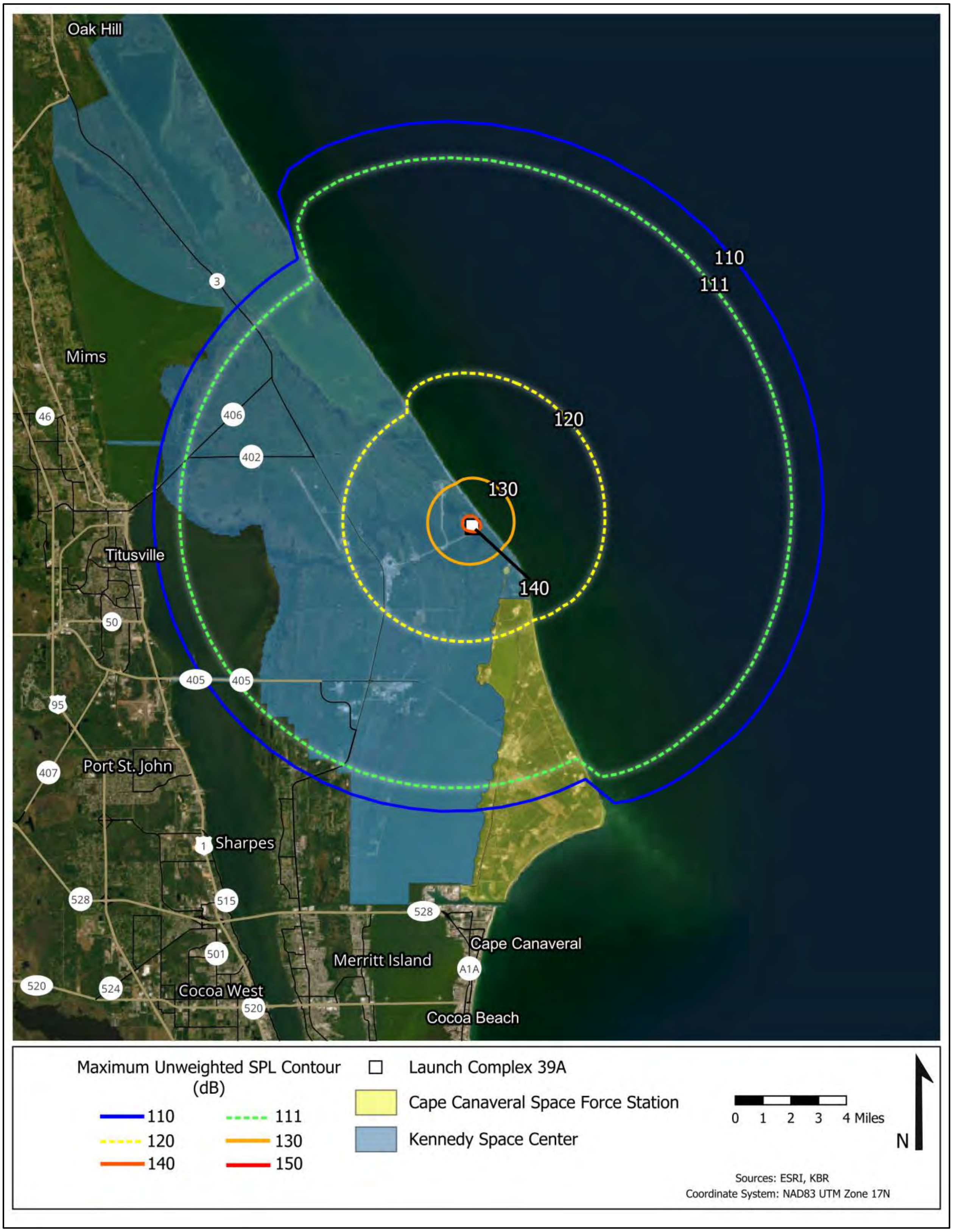

Figure 33. Super Heavy Landing at LC-39A (115-Degrees): Maximum Unweighted Sound Levels

5.2.3 Static Fire Test Noise Levels at LC-39A

5.2.3.1 Starship Spacecraft Static Fire Tests

Starship spacecraft static fire tests are planned to occur at LC-39A where nine engines, that each generate 3.11 MN of thrust at sea level, will be fired for 15 seconds per test. RNOISE computations were performed as noted previously in Section 5.2.1. The L_{Amax}, SEL, and L_{max} contours for a Starship spacecraft static fire test at LC-39A are shown in Figures 34 through 36, respectively.

The L_{Amax} 90 dB contour (Figure 34) extends about 3 miles west of the LC-39A test site while the SEL 90 dB contour (Figure 35) extends about 6 miles west of the test site. Residents of Titusville, the City of Cape Canaveral, and other nearby communities may hear Starship spacecraft static test events above 60 dB, depending on wind conditions (onshore or offshore) at the time of the test and if the test occurs during daytime or nighttime hours. The L_{Amax} 108 dB contour, which is shown on Figure 34 and used as a threshold limit for hearing conservation, is located about 1 mile west of the static test site.

The L_{max} 111 dB and 120 dB contours, as well as the 130 dB and 140 dB contours shown on Figure 36, and thus the 134 dB contour (not shown), used to assess the potential for structural damage, are located almost entirely on the KSC and CCSFS properties (only the 111 dB contour extends just west of these properties over the Indian River). No structural damage is expected to occur to residences located off KSC and CCSFS properties based on assessment using either criteria.

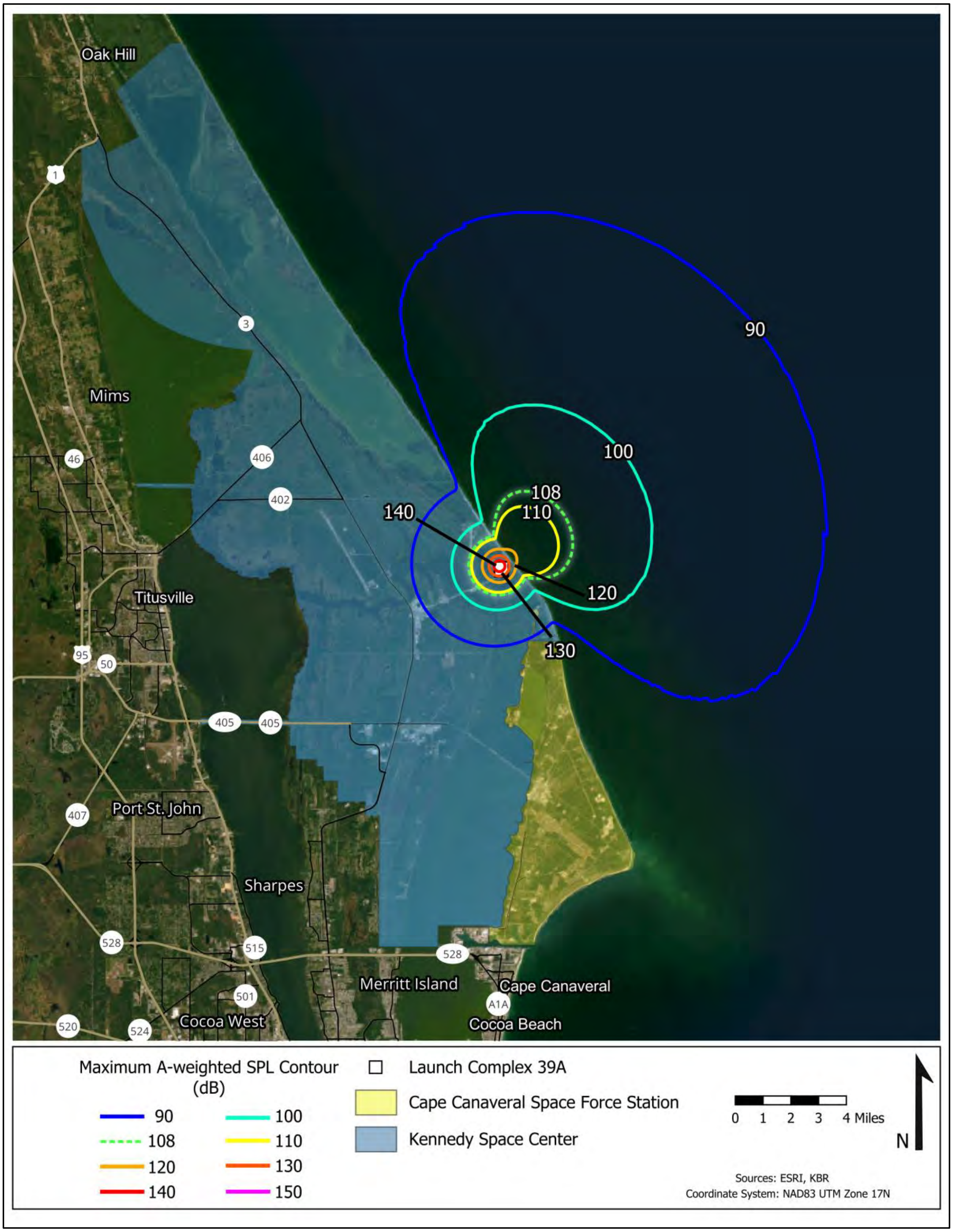

Figure 34. Starship Spacecraft Static Fire Test at LC-39A: Maximum A-Weighted Sound Levels

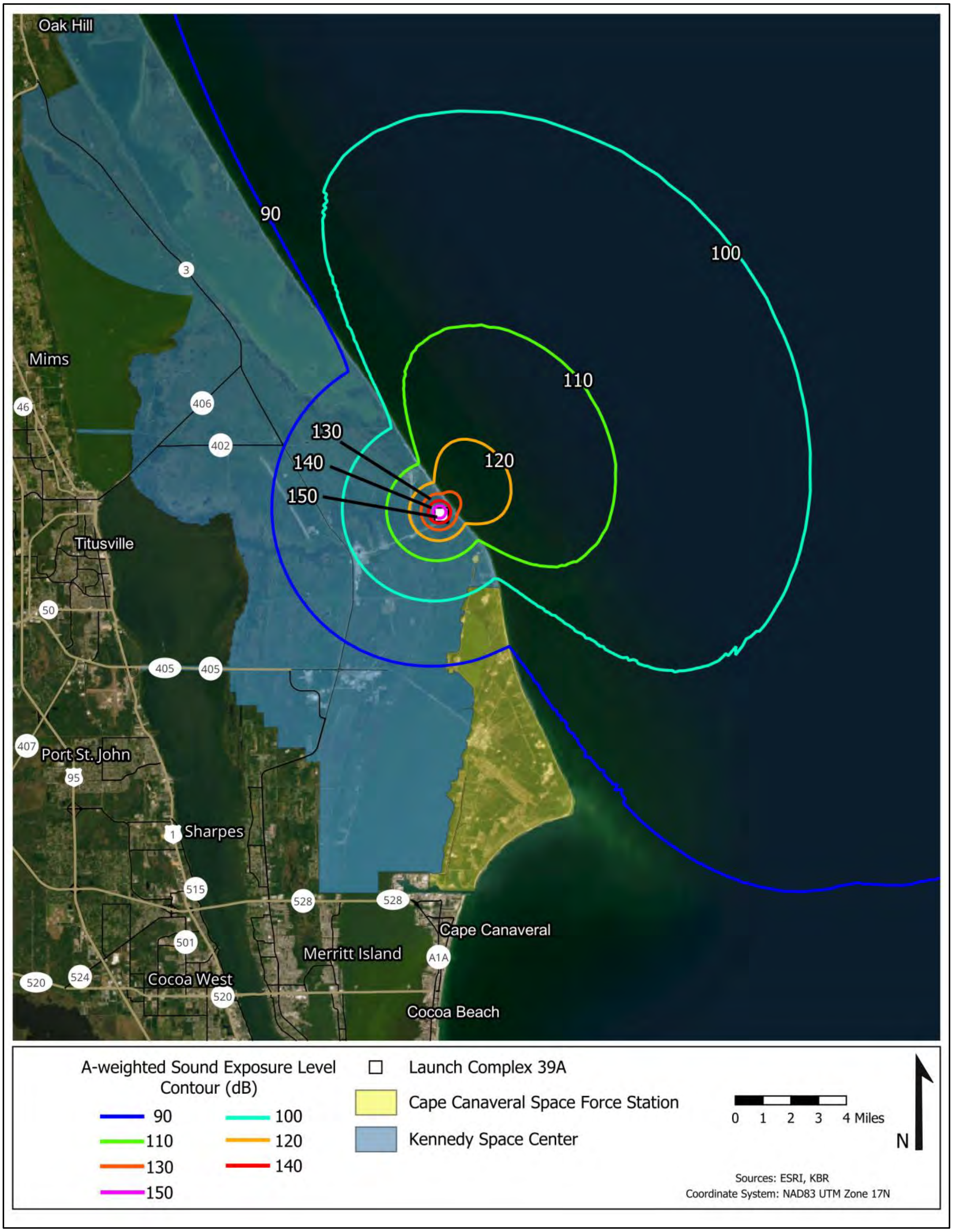

Figure 35. Starship Spacecraft Static Fire Test at LC-39A: Sound Exposure Levels

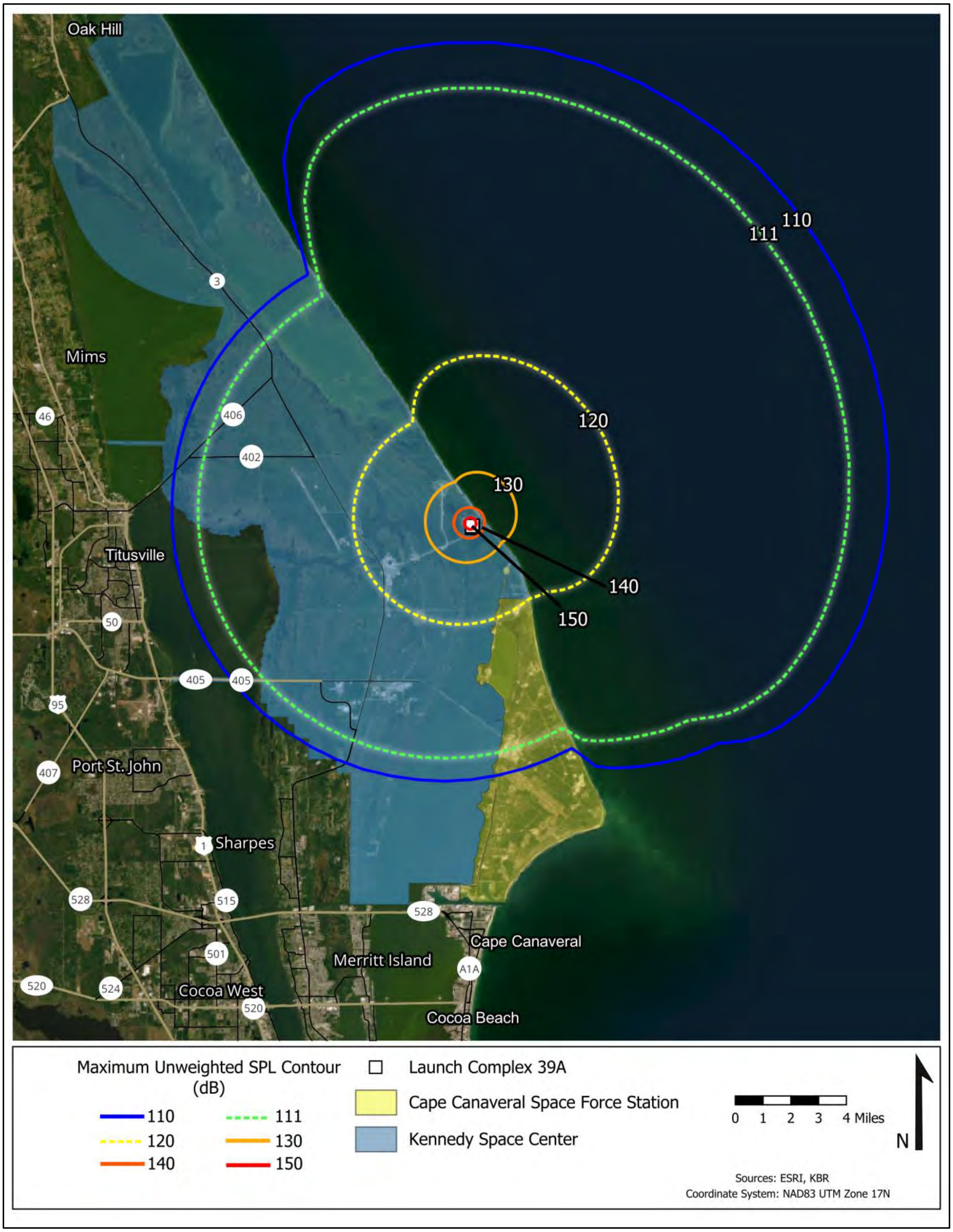

Figure 36. Starship Spacecraft Static Fire Test at LC-39A: Maximum Unweighted Sound Levels

5.2.3.2 Super Heavy Static Fire Tests

Super Heavy static fire tests are planned to occur at LC-39A where thirty-five engines, that each generate 2.94 MN of thrust at sea level, will be fired for 15 seconds per test. RNOISE computations were performed as noted previously in Section 5.2.1. The L_{Amax}, SEL, and L_{max} contours for a booster static fire test at LC-39A are shown in Figures 37 through 39, respectively.

The L_{Amax} 90 dB contour (Figure 37) extends about 4.5 miles west of the LC-39A test site while the SEL 90 dB contour (Figure 38) extends about 8 miles west of the test site. Residents of Titusville, the City of Cape Canaveral, and other nearby communities may hear booster static test events above 60 dB, depending on wind conditions (onshore or offshore) at the time of the test and if the test occurs during daytime or nighttime hours. The L_{Amax} 108 dB contour, which is shown on Figure 37 and used as a threshold limit for hearing conservation, is located about 1.5 miles west of the static test site.

The L_{max} 111 dB and 120 dB contours, shown on Figure 39 are used as the more conservative measure to assess the potential for structural damage as described in Section 2.1.3. While the 120 dB contour is located almost entirely within the KSC and CCSFS properties, the 111 dB contour extends west of Titusville. The potential for structural damage is assessed using the potential for structural damage claims where approximately one damage claim will result per 1,000 households exposed at 111 dB[16]. Residences located within the L_{max} 111 dB contour therefore have a low probability of structural damage occurring (1 in 1,000 residences up to 1 in several hundred residences). No structural damage is expected to occur to residences located off KSC and CCSFS properties based on the less conservative criteria using the L_{max} 134 dB and 140 dB contours which are entirely within KSC and CCSFS properties.

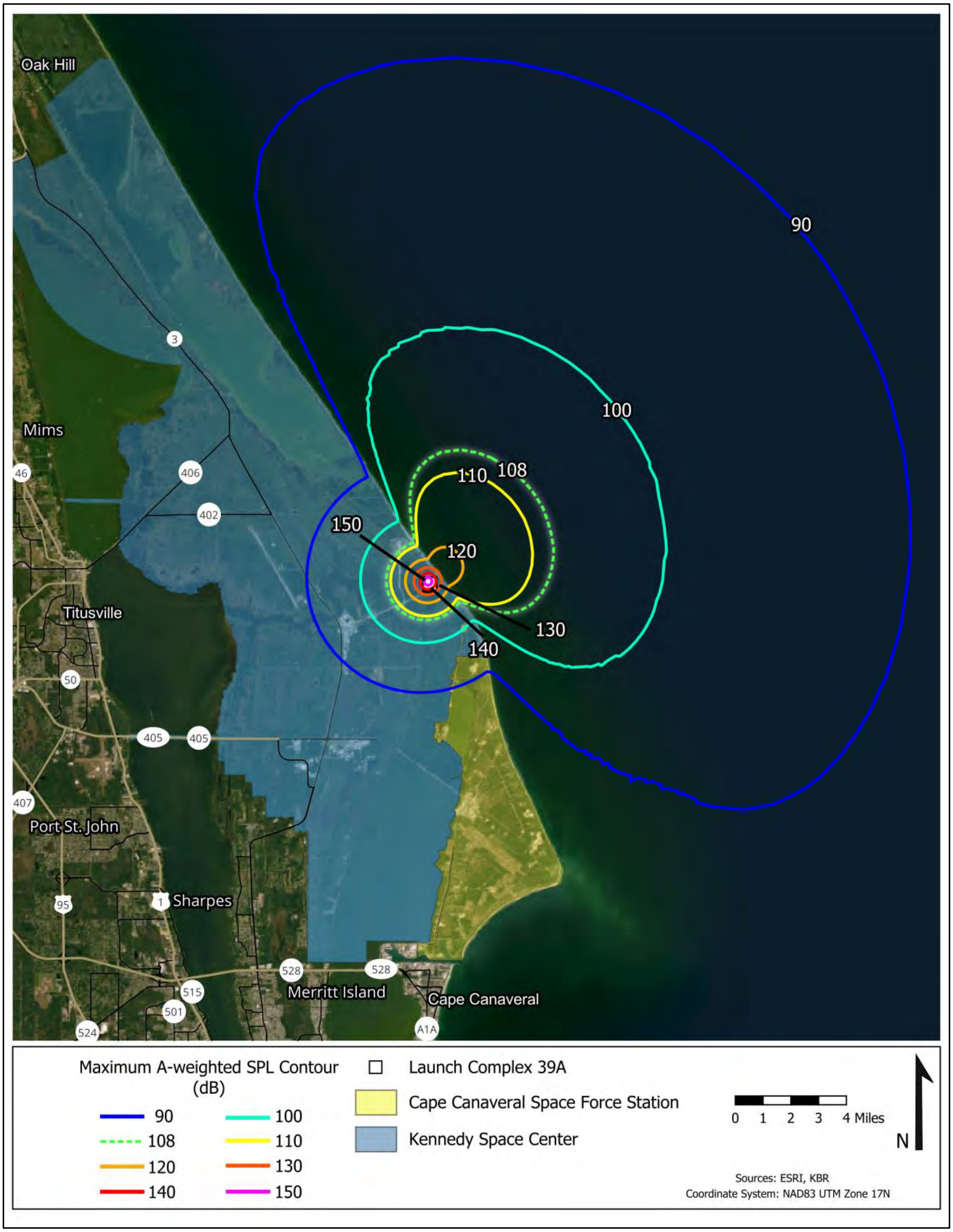

Figure 37. Super Heavy Static Fire Test at LC-39A: Maximum A-Weighted Sound Levels

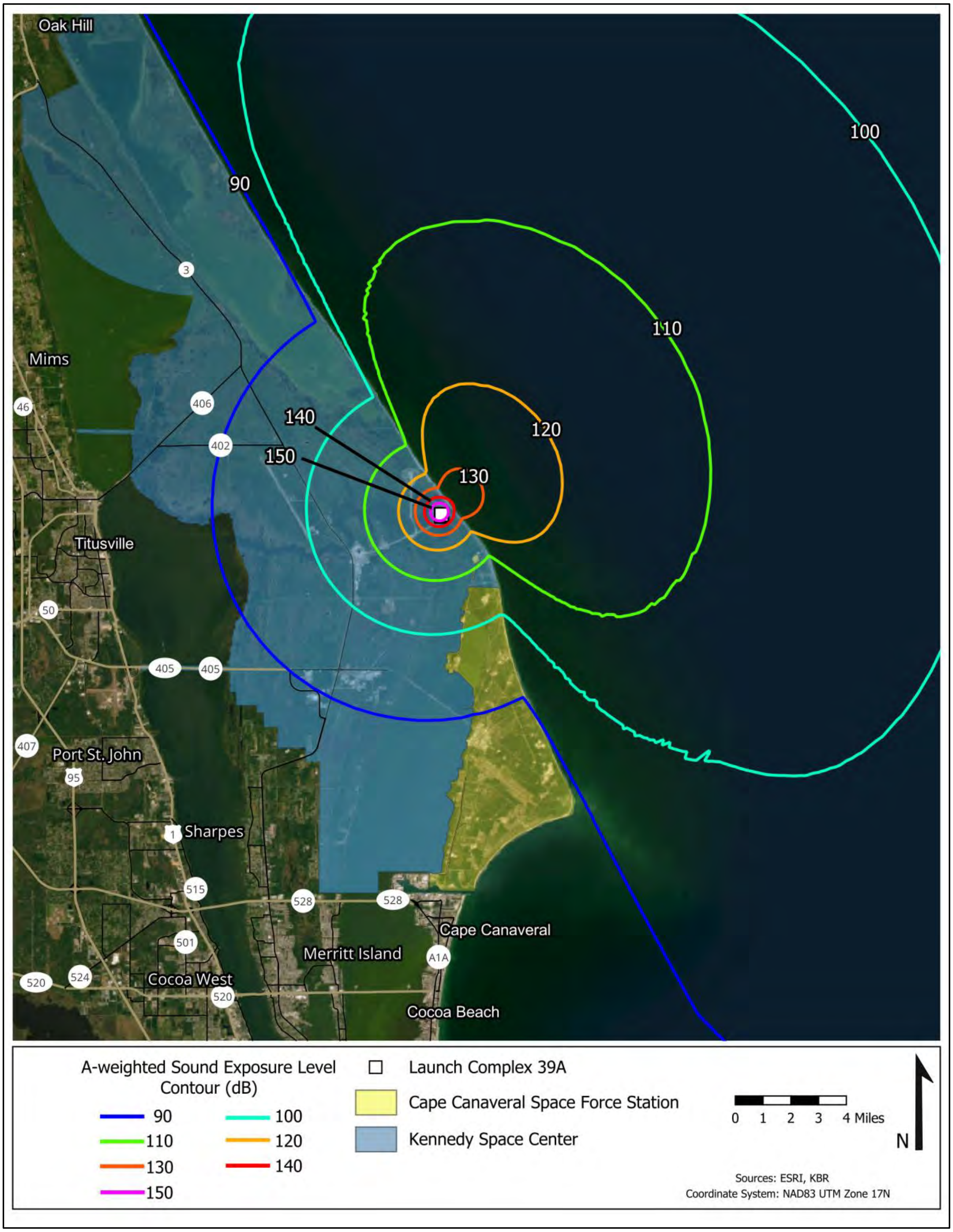

Figure 38. Super Heavy Static Fire Test at LC-39A: Sound Exposure Levels

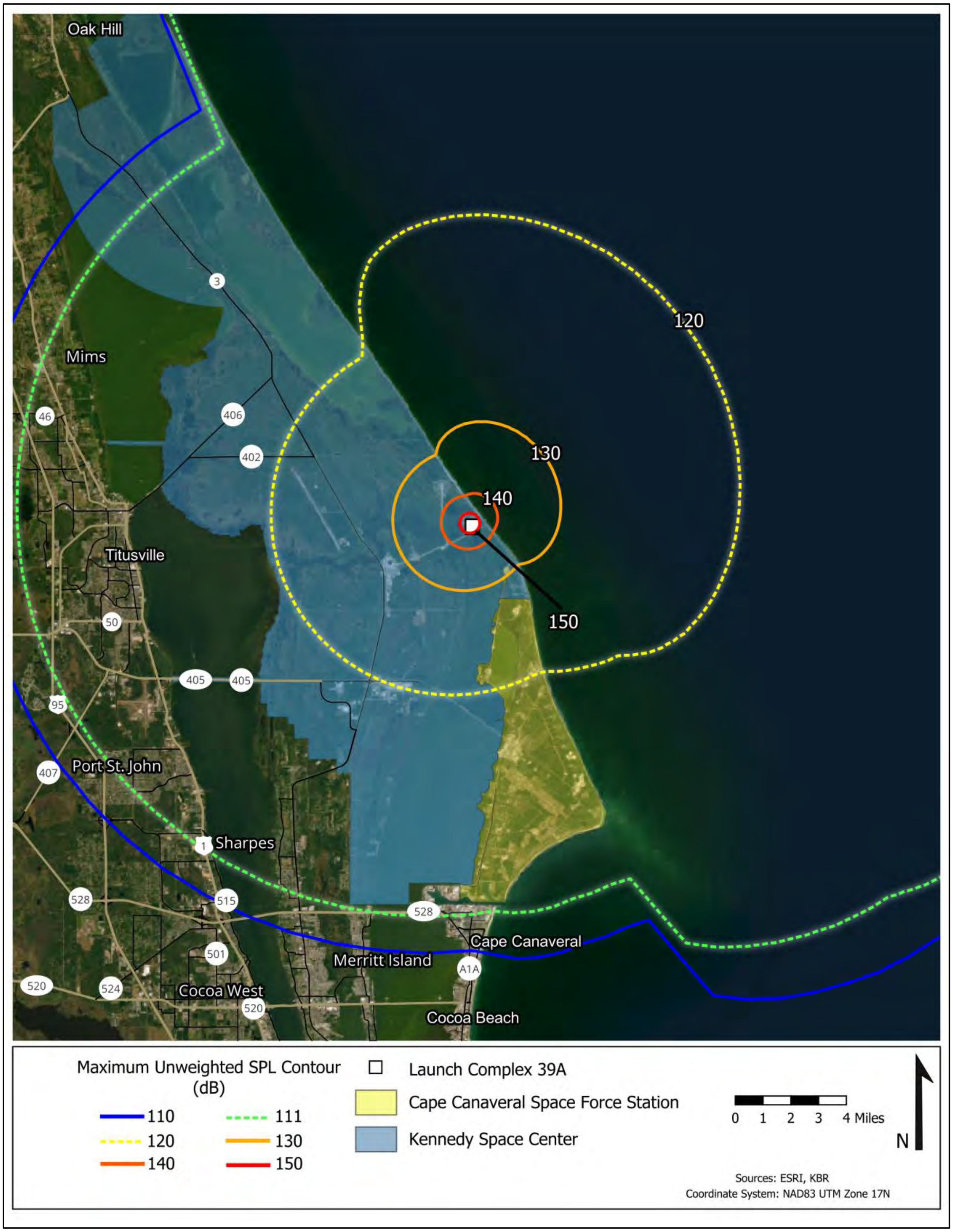

Figure 39. Super Booster Static Fire Test at LC-39A: Maximum Unweighted Sound Levels

5.2.4 Cumulative Noise Levels for All Starship Operations at LC-39A

5.2.4.1 Day-Night Average Sound Level (DNL) Contours

Cumulative noise levels were estimated, using DNL, for projected annual launch, landing, and static fire test operations at LC-39A that are expected to fulfill Starship mission and test requirements at KSC. For orbital launches, the Super Heavy Booster total thrust would be 103 MN (about 23 MM lbf). Starship landings would use a maximum total thrust of 770 Klbf and Super Heavy Booster landings would use a maximum total thrust of 3.5 MM lbf. Static fire tests would be conducted by both vehicles for 15 seconds per test; the booster would use 35 engines, each with a thrust of 2.94 MN, and the Starship would use 9 engines, each with a thrust of 3.11 MN. Forty-four annual operations of each type of event would be conducted with a 50% daytime and 50% nighttime split as described previously in Section 5.1 and summarized here as follows:

<u>Projected Starship Operations at LC-39A</u>

- 44 Starship orbital launches
- 44 Starship spacecraft landings
- 44 Super Heavy Booster landings
- 44 Starship spacecraft static fire tests (15 seconds each)
- 44 Super Heavy Booster static fire tests (15 seconds each)

The estimated DNL contours in the vicinity of LC-39A for the combined annual operations are shown in Figure 40. Results indicate that when cumulative noise is assessed for all projected Starship operations (combined) at LC-39A, the 65 DNL contour is estimated to be entirely within the CCSFS and KSC properties.

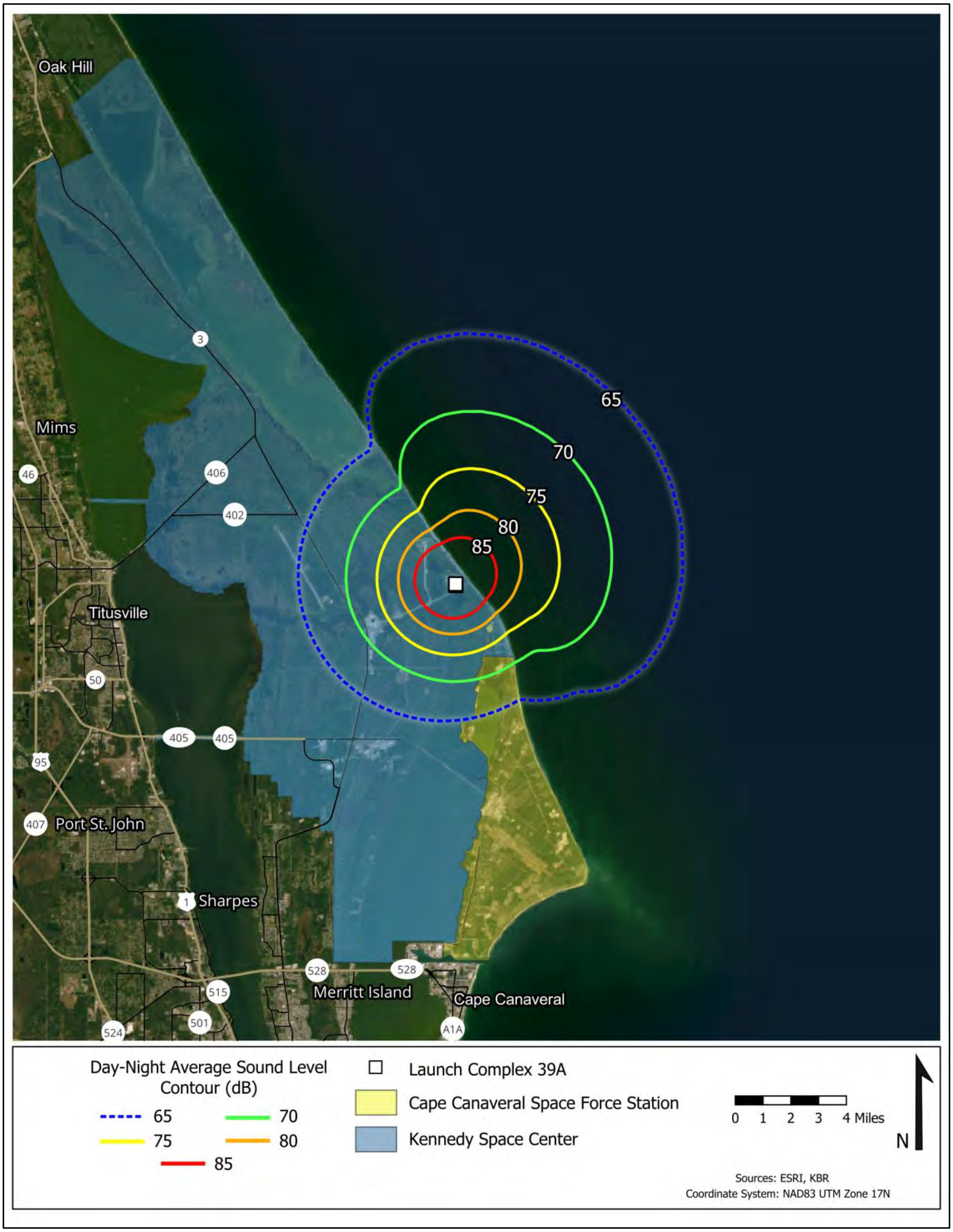

Figure 40. Starship Combined Operations at LC-39A: DNL Contours

5.2.4.2 DNL Exposure at Noise Sensitive Receptors

The twenty-four noise sensitive receptors or points of interest (POIs) assessed in this study are listed in Table 5 and Figure 41 shows their locations relative to LC-39A. For each POI, Table 5 includes the POI number identifier (ID) which is shown on the map in Figure 41, POI name, location, type of POI (e.g., residential, school, place of worship, or wildlife conservation area),and the estimated DNL for proposed Starship operations at LC-39A. DNL values range from 44.7 dB, at Fern Meadows to 84 dB at Titusville Beach (nearest POI location to LC-39A). Three POIs are exposed to DNL 65 dB or greater, which is the FAA threshold for land use compatibility (the DNL values for these three POIs are highlighted in Table 5); all three of these POIs (3, 4, and 23) are located on KSC property.

Table 5. Proposed Starship Operations at LC-39A: DNL Exposure at POIs

POI ID	POI Name	Location	Type	DNL(dB)
1	Cape Canaveral Space Force Station (CCSFS)	Cape Canaveral	CCSFS Representative	58.3
2	SpaceX Operations Area	Merritt Island	SpaceX Facility	63.5
3	Titusville Beach	Titusville	Recreational (Private)	84.0
4	Playalinda Beach	Titusville	Recreational Area	68.4
5	Kennedy Space Center Visitor Complex	Merritt Island	KSC Representative	60.0
6	KSC Child Development Center	Merritt Island	School	60.5
7	Merrit Island National Wildlife Refuge Visitor Center	Merritt Island	Wildlife Conservation Area	59.7
8	Pine Island Conservation Area/Pine Island Estates	Merritt Island	Wildlife Conservation Area/Residential Area	55.6
9	Kings Park Estates - Courtenay	Courtenay	Residential	53.6
10	Jetty Park Campground	Cape Canaveral	Recreational Area	50.8
11	Rockledge High School	Rockledge	School	45.5
12	Merritt Island	Merritt Island	Residential	46.5
13	Oak Park Elementary School	Titusville	School	51.1
14	Titusville High School	Titusville	School	54.1
15	Summerwood Villas	Titusville	Residential	53.0
16	Atlantis Elementary School	Port St. John	School	51.3
17	Fairglen Elementary School	Cocoa	School	50.3
18	Lewis Carroll Elementary School	Merritt Island	School	49.2
19	Cocoa	Cocoa	Residential	47.8
20	Cocoa Beach	Cocoa Beach	Residential	46.1
21	Pinegrove Estates	MIMS	Residential	50.1
22	Fern Meadows	West Cocoa	Residential	44.7
23	KSC Office Outside BDA	KSC	Office	72.4
24	The Rock Church	Fontaine Grant	Place of Worship	46.9

Notes: POI = Point of Interest; ID = Identification; Day Night Average Sound Level; dB = decibel.

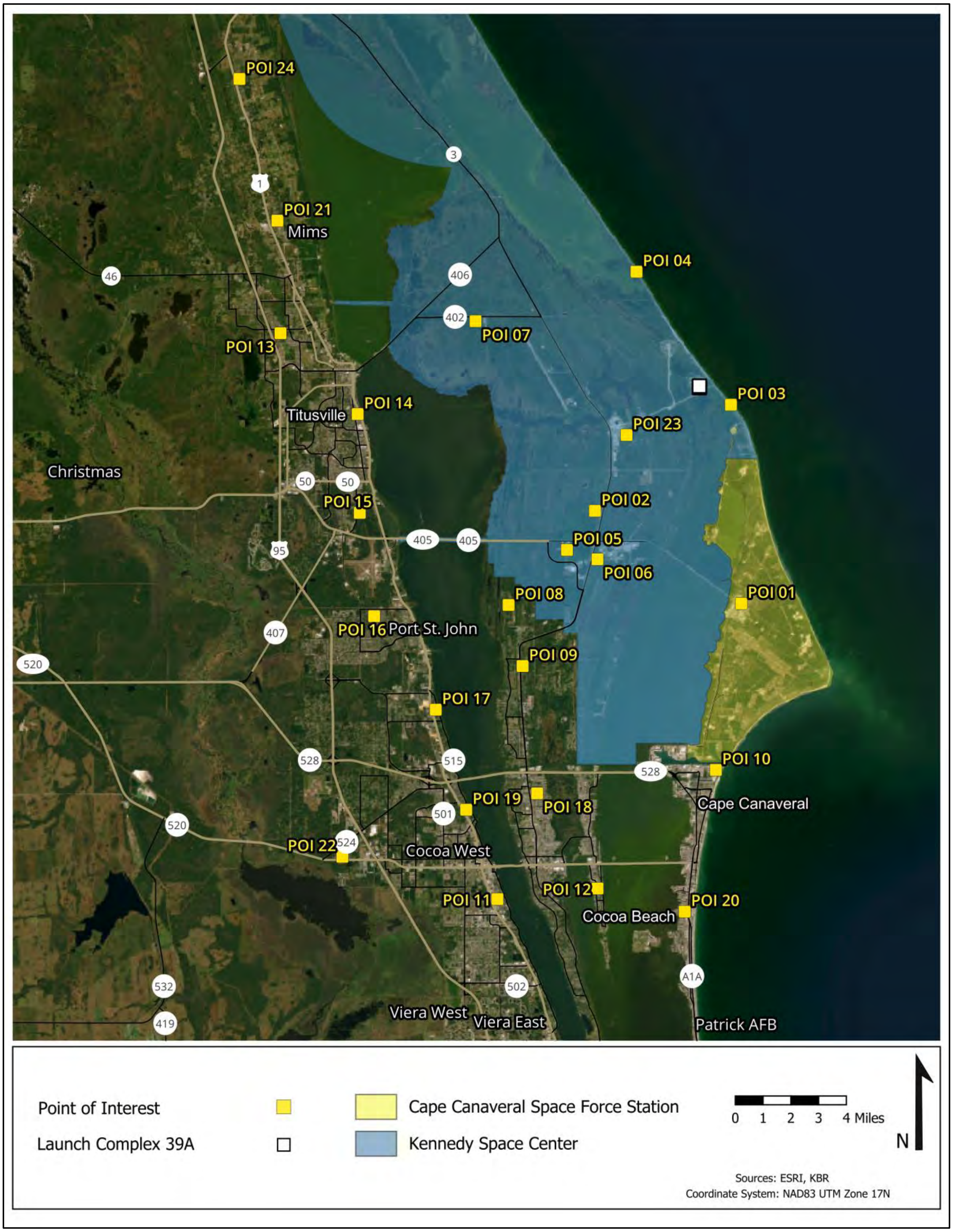

Figure 41. Points of Interest (POIs) In the Vicinity of LC-39A

5.2.4.3 Acreage, Housing, and Population Within DNL Contours

Table 6 shows the total acreage within each DNL contour band, resulting in a total of 25,383 acres that would be exposed to DNL 65 dB or greater due to noise from the proposed Starship operations at LC-39A. This acreage excludes water bodies and is comprised of 12,646 acres exposed to DNL 65 to 70 dB, 5,850 acres exposed to DNL 70 to 75 dB, 3,403 acres exposed to DNL 75 to 80 dB, 1,578 acres exposed to DNL 80 to 85 dB, and 1,906 acres exposed to DNL greater than 85 dB.

Table 6. Proposed Starship Operations at LC-39A: DNL Exposure Acreage

DNL Band (dB)	Acreage
	Total
65-70	12,646
70-75	5,850
75-80	3,403
80-85	1,578
85+	1,906
Total	**25,383**

Note: DNL = Day-Night Average Sound Level; dB = decibel.

Geographic Information System (GIS) analysis was used to estimate the population and households within each DNL contour band. If a block group was partially within a DNL contour band the number of households and population were scaled based upon the proportion of the block group area within each DNL contour band. Table 7 lists estimated total households and population that would be exposed to each DNL contour band under the proposed Starship operations at LC-39A. Since the DNL 65 dBA contour is entirely within the KSC and CCSFS properties, there are no houses or people exposed to DNL greater than 65 dBA.

Table 7. Proposed Starship Operations at LC-39A: DNL Exposure (Households and Population)

DNL Band (dB)	Households	Population
65-70	0	0
70-75	0	0
75-80	0	0
80-85	0	0
85+	0	0
Totals	**0**	**0**

Note: DNL = Day-Night Average Sound Level; dB = decibel.

5.2.5 Supplemental Metrics Assessment for Rocket Noise Events at LC-39A

A supplemental metrics assessment was conducted for the twenty-four POIs in this study to further characterize the noise exposures due to proposed Starship operations at LC-39A. Descriptions of each supplemental metric evaluated are provided in Section 2.3. The following sections report results for these metrics including the potential for Speech Interference (Section 5.2.5.1), Classroom Learning Interference (5.2.5.2), Residential Sleep Disturbance (5.2.5.3), Potential for Hearing Loss (5.2.5.4), and Potential for Structural Damage (5.2.5.5). In most cases, this report provides a supplemental metrics assessment for all these metrics at each noise sensitive receptor. For example, residences are often located close to schools, such that determining percent awakenings at a school location, which would not normally apply, could be applied to nearby residences. This method of assessment, which is becoming more common, provides additional useful information at some of the noise sensitive receptors, but not in every case.

5.2.5.1 Speech Interference

This study assesses the potential for Starship noise events to interfere with speech communication, or non-school speech, at all POIs during the acoustic daytime (7 a.m. (0700) to 10 p.m. (2200)). Table 8 presents the number of potential speech interference events based upon the number of Starship noise events per average hour during the daytime period for both windows open and windows closed cases. The number of events that could interfere with speech per average daytime hour is low at all POIs due to the infrequency of Starship noise events. The highest number of speech interfering events per daytime hour (0.02), that would potentially be experienced at 11 of the 24 POIs, is equal to 9 speech interfering events per month or nearly 110 speech interfering events per year which is equal to the number of proposed daytime Starship operations per year. The other 13 POIs would experience fewer speech interference events (0.004 speech interfering events per average daytime hour = 22 events per year, 0.008 speech interfering events per average daytime hour = 44 events per year, and 0.016 speech interfering events per average daytime hour = 88 events per year).

Table 8. Proposed Starship Operations at LC-39A: Speech Interference Events per Daytime Hour

POI ID	POI Name	Location	Windows Open[1]	Windows Closed[2]
1	Cape Canaveral Space Force Station (CCSFS)	Cape Canaveral	0.020	0.016
2	SpaceX Operations Area	Merritt Island	0.020	0.020
3	Titusville Beach	Titusville	0.020	0.020
4	Playalinda Beach	Titusville	0.020	0.020
5	Kennedy Space Center Visitor Complex	Merritt Island	0.020	0.016
6	KSC Child Development Center	Merritt Island	0.020	0.016
7	Merrit Island National Wildlife Refuge Visitor Center	Merritt Island	0.020	0.016
8	Pine Island Conservation Area/Pine Island Estates	Merritt Island	0.020	0.012

POI ID	POI Name	Location	Windows Open[1]	Windows Closed[2]
9	Kings Park Estates - Courtenay	Courtenay	0.020	0.008
10	Jetty Park Campground	Cape Canaveral	0.016	0.008
11	Rockledge High School	Rockledge	0.008	0.004
12	Merritt Island	Merritt Island	0.008	0.008
13	Oak Park Elementary School	Titusville	0.016	0.008
14	Titusville High School	Titusville	0.020	0.008
15	Summerwood Villas	Titusville	0.016	0.008
16	Atlantis Elementary School	Port St. John	0.016	0.008
17	Fairglen Elementary School	Cocoa	0.016	0.008
18	Lewis Carroll Elementary School	Merritt Island	0.016	0.008
19	Cocoa	Cocoa	0.012	0.008
20	Cocoa Beach	Cocoa Beach	0.008	0.008
21	Pinegrove Estates	MIMS	0.016	0.008
22	Fern Meadows	West Cocoa	0.008	0.004
23	KSC Office Outside BDA	KSC	0.020	0.020
24	The Rock Church	Fontaine Grant	0.008	0.008

Notes: [1]Assumes 15 dB Noise Level Reduction; [2] Assumes 15 dB Noise Level Reduction; POI = Point of Interest; ID = Identification;

5.2.5.2 Classroom Learning Interference

Table 9 presents the analysis of classroom learning interference for the POIs that are schools (POI IDs 6, 11, 13, 14, 16, 17, and 18) that would experience noise from proposed Starship operations. The school screening threshold of a 60 dB L_{eq}(8hr) exterior level equates to an interior noise level of 45 dB L_{eq}(8hr) with windows open and represents the threshold at which studies have found classroom learning is affected[14,16]. None of the seven schools listed in Table 9 are exposed to exterior L_{eq}(8hr) levels greater than 60 dB, therefore no further analysis is warranted for the proposed Starship operations.

Table 9. Proposed Starship Operations at LC-39A: Classroom Learning Interference

POI ID	POI Name	City/Community	L_{eq}(8hr) (dB)
6	KSC Child Development Center	Merritt Island	57.9
11	Rockledge High School	Rockledge	42.9
13	Oak Park Elementary School	Titusville	48.5
14	Titusville High School	Titusville	51.5
16	Atlantis Elementary School	Port St. John	48.7
17	Fairglen Elementary School	Cocoa	47.7
18	Lewis Carroll Elementary School	Merritt Island	46.6

Notes: POI = Point of Interest; ID = Identification;
LAeq,8 = 8-Hour Energy Average Sound Level ; dB = decibel.

5.2.5.3 Residential Sleep Disturbance

The potential for residential sleep disturbance is assessed at each POI as percent awakenings (PA) for a proposed Starship nighttime launch. Estimating PA involves taking the outdoor SEL at each POI, computing the indoor SEL (assuming a 15 dB building noise reduction for windows open and 25 dB building noise reduction for windows closed) and using the FICAN updated (1997) recommended dose -response curve[22], interpreted to be the "maximum percent awakened" for a given residential population. Table 10 presents the estimated PA with windows open as ranging from 27 percent at the Titusville Beach POI (nearest to the launch pad) to 10 percent at the POIs representing Fern Meadows, Cocoa Beach, Merritt Island, and Rockledge High School. These percentages represent the percentage of the population that would be awakened at least once per night due to proposed Starship launches. Although PA has been estimated at all 24 study POIs, only about 7 POIs were listed as residential areas in Table 5; POIs 1 through 6 are well within the CCSFS and KSC properties. Super Heavy Booster landing SELs are approximately 10 dB lower than launch SELs (PA would decrease by about 4 percent at all POIs and, as a result, most residential area POIs would have a PA of less than 10 percent). All the other operations (Starship spacecraft landings and Starship spacecraft and Booster static fire tests) generate SELs that are lower than launch SELs by more than 20 dB (PA would decrease by about 8 percent at all POIs and, as a result, most residential area POIs would have a PA of less than 5 percent). People sleeping in transient lodgings (e.g. hotels) that have never experienced the noise source as well as people sleeping in locations with no structural noise attenuation (e.g., camping in a tent) would be expected to have a higher probability of being awakened.

Table 10. Proposed Starship Launch at LC-39A: Estimated Percent Awakenings

POI ID #	Receptor Name	Starship Launch SEL (dB)	PA (Windows Open)	PA (Windows Closed)
1	Cape Canaveral Space Force Station (CCSFS)	109.2	15	11
2	SpaceX Operations Area	114.3	17	13
3	Titusville Beach	134.5	27	22
4	Playalinda Beach	119.0	19	15
5	Kennedy Space Center Visitor Complex	110.8	16	12
6	KSC Child Development Center	111.3	16	12
7	Merritt Island National Wildlife Refuge Visitor Center	110.6	16	12
8	Pine Island Conservation Area/Pine Island Estates	106.5	14	10
9	Kings Park Estates - Courtenay	104.5	13	9
10	Jetty Park Campground	101.7	12	8
11	Rockledge High School	96.5	10	7
12	Merritt Island	97.5	10	7
13	Oak Park Elementary School	102.1	12	9
14	Titusville High School	105.0	13	10
15	Summerwood Villas	103.9	13	9
16	Atlantis Elementary School	102.3	12	9
17	Fairglen Elementary School	101.3	12	8

POI ID #	Receptor Name	Starship Launch SEL (dB)	PA (Windows Open)	PA (Windows Closed)
18	Lewis Carroll Elementary School	100.2	11	8
19	Cocoa	98.8	11	8
20	Cocoa Beach	97.1	10	7
21	Pinegrove Estates	101.1	12	8
22	Fern Meadows	95.7	10	7
23	KSC Office Outside BDA	123.1	21	17
24	The Rock Church	97.9	11	7

Notes: POI = Point of Interest; ID = Identification; PA = Percent Awakening; dB = decibel.

5.2.5.4 Potential for Hearing Loss

The potential for hearing loss in the residential areas off KSC and CCSFS properties is low enough to be considered improbable; the highest noise levels experienced in these populated areas from the loudest proposed Starship event (orbital launch, see Figure 17) do not exceed any criteria thresholds for hearing loss including NASA's 108 dBA upper noise limit guideline for hearing conservation[15].

5.2.5.5 Potential for Structural Damage

The potential for structural damage due to Starship orbital launch events is assessed using the potential for structural damage claims. An applicable study of structural damage claims from rocket static firing tests indicates that, based on Maximum Unweighted Sound Level (L_{max}), approximately one damage claim will result per 100 households exposed at 120 dB and one damage claim will result per 1,000 households exposed at 111 dB[16]. The L_{max} 111 dB and 120 dB contours estimated for Starship orbital launch events are shown on Figure 20. Starship orbital launch events are estimated to generate L_{max} of 120 dB approximately 10 miles from the launch pad; the 120 dB contour would extend west to the Indian River, but not into Titusville, and north of Wilson. The 111 dB contour would extend approximately 22 miles from the launch pad to areas west of Titusville, south along the coast between Cocoa Beach and Satellite Beach, and north to Oak Hill. The second structural damage assessment using the 134 dB and 140 dB criteria levels does not indicate any potential for structural damage.

Table 11 shows the L_{max} values estimated at each of the study POIs for a proposed Starship launch at LC-39A. The level at each POI is compared with the 111 dB and 120 dB thresholds and a checkmark in either of the two rightmost columns in the table indicates the potential for damage claims to occur with the probability per household shown. Note that not all the POIs listed have existing residential or other structure types, however, this assessment was done for all POIs since there may be other structures nearby, in the vicinity of the listed POI.

Table 11. Proposed Starship Launch at LC-39A: Assessment of Potential for Structural Damage

POI ID #	Receptor Name	Starship Launch Lmax (dB)	@ 111 dB Damage Claim % (1/1,000)	@ 120 dB Damage Claim % (1/100)
1	Cape Canaveral Space Force Station (CCSFS)	121.5	√	√
2	SpaceX Operations Area	125.5	√	√
3	Titusville Beach	137.6	√	√
4	Playalinda Beach	128.9	√	√
5	Kennedy Space Center Visitor Complex	122.9	√	√
6	KSC Child Development Center	123.2	√	√
7	Merritt Island National Wildlife Refuge Visitor Center	123.0	√	√
8	Pine Island Conservation Area/Pine Island Estates	119.8	√	
9	Kings Park Estates - Courtenay	118.3	√	
10	Jetty Park Campground	116.0	√	
11	Rockledge High School	112.5	√	
12	Merritt Island	113.2	√	
13	Oak Park Elementary School	116.8	√	
14	Titusville High School	118.9	√	
15	Summerwood Villas	118.0	√	
16	Atlantis Elementary School	116.8	√	
17	Fairglen Elementary School	115.9	√	
18	Lewis Carroll Elementary School	115.1	√	
19	Cocoa	114.2	√	
20	Cocoa Beach	112.8	√	
21	Pinegrove Estates	116.1	√	
22	Fern Meadows	112.1	√	
23	KSC Office Outside BDA	131.7	√	√
24	The Rock Church	113.9	√	

Notes: POI = Point of Interest; ID = Identification; % = Percentage;
Lmax = Maximum Unweighted Sound Level; dB = decibel.
The second structural damage assessment using the 134 dB and 140 dB criteria levels does not indicate any potential for structural damage.

5.3 Sonic Boom Exposure At LC-39A

Sonic boom exposure footprints were computed for the Starship launch (Section 5.3.1) and, after stage 1 separation, for Starship spacecraft reentry from low Earth orbit and landing at LC-39A (Section 5.3.2), and the Super Heavy Booster descent and landing at LC-39A (Section 5.3.3).

5.3.1 Sonic Boom From Starship Launch at LC-39A

The sonic boom from a Starship launch at LC-39A would occur over the Atlantic Ocean after the vehicle pitches over during ascent. The sonic boom analysis uses the same trajectory that was used in the launch noise analysis (Section 5.2.1.), though primarily the ascent part of the trajectory is supersonic above approximately 23,000 feet altitude until Stage 1 apogee. The vehicle is a cylinder, with tapered nose cone. During launch, the Starship ascends to an altitude of about 450Kft reaching hypersonic speeds above Mach 12. Sonic boom would be generated while the vehicle is supersonic and pitching over (starting at about t=91 seconds at 77Kft altitude, Mach 2.7, and a flight path angle of 38 degrees).

The boom footprint for Starship launch was computed using PCBoom.[3,4] Figure 42 shows the sonic boom footprint, in the form of overpressure contours, pounds per square foot (psf). The ground track of the Starship launch trajectory is also shown in Figure 42. The ascent phase of the launch generates a broad forward-facing crescent region; crescent shaped overpressure contours (primarily 1 psf through 6 psf) are shown along and to the side of the trajectory. Overpressure levels within the boom carpet are generally less than 6 psf but reach 10 psf to 15 psf at several small focal regions on the eastern edge of the footprint. The entire boom footprint would be located offshore approximately 35 miles from the LC-39A launch site, making it unlikely that people would be exposed to this noise event.

5.3.2 Starship Spacecraft Reentry/Landing Sonic Boom at LC-39A

The proposed operations indicate that Starship launches at LC-39A would result in the same number of Starship spacecraft (stage 2 vehicle) recoveries at LC-39A via landing operations. The Starship spacecraft landing trajectory for LC-39A is the same as the one used in the landing noise analysis (Section 5.2.2), though a higher altitude part of the trajectory is used in the sonic boom analysis. The reentry/decent portion of the landing is supersonic from the apogee (or deorbit point) until it passes through an altitude just below 75,000 feet. Most of the Starship spacecraft descent is unpowered with landing thrust applied during approximately the last 1,800 feet of altitude.

The Starship spacecraft landing sonic boom is generated above 75,000 feet altitude as the vehicle follows a reentry/descent flight path from west to east like past Space Shuttle landings at KSC. The sonic boom footprints for this landing were computed using PCBoom.[3,4] Figure 43 shows the sonic boom footprint, in the form of overpressure contours, pounds per square foot (psf) for the Starship spacecraft landing at LC-39A. The ground track of the trajectory, as the vehicle approaches the landing site at LC-39A from the west, is also shown in Figure 43. The part of the reentry provided starts at hypersonic speeds above Mach

15 and slows to supersonic speeds until it passes through an altitude of about 75,000 feet, after which vehicle speeds are subsonic until landing.

Overpressure contours on Figure 43 ranging from 1 psf to 1.7 psf are shown along and to the side of the trajectory. Near the landing site there is an oval shaped boom footprint region generated with levels from 1 psf to 1.7 psf (the estimated maximum overpressure level is 1.72 psf). The 1 psf contour is estimated to be about 30 miles west of the landing site, extending well beyond Titusville.

In general, booms in the 0.2 to 0.3 psf range could be heard by someone who is expecting it and listening for it, but usually would not be noticed. Booms of 0.5 psf are more likely to be noticed, and booms of 1.0 psf and above are certain to be noticed. Therefore, people in the vicinity of the LC-39A landing site to areas west of Titusville are expected to notice booms from Starship spacecraft landings; those located on the KSC and CCSFS properties, within the 1.5 psf region, could possibly be startled. Announcements of upcoming Starship launches and landings serve to warn people about these noise events and are likely to help reduce adverse reactions to these noise events. The boom levels over land are not likely to cause property damage; while structures in good condition have been undamaged by overpressures of up to 11 psf, rare minor damage may result from boom levels with peak overpressures between 2 and 5 psf[26].

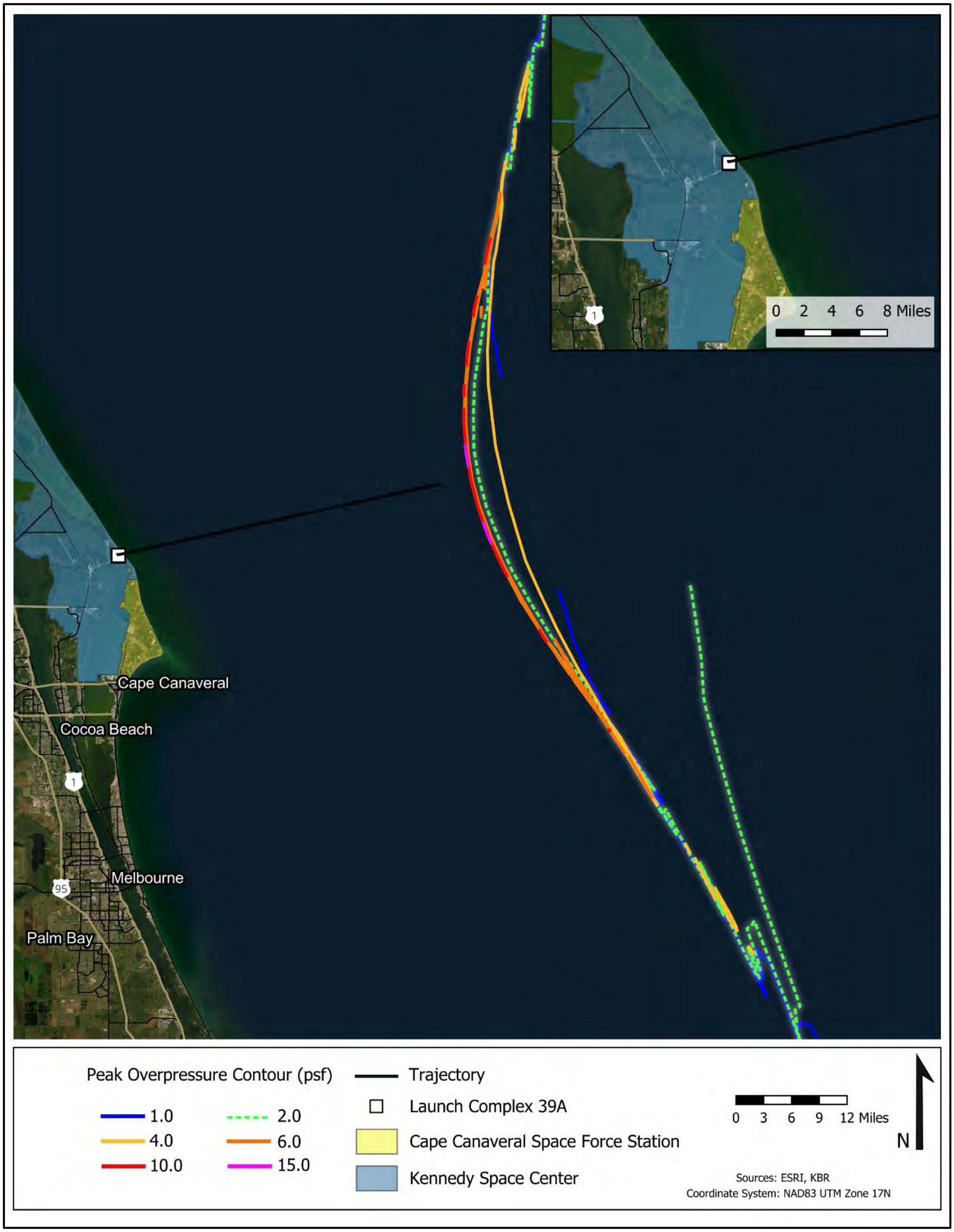

Figure 42. Sonic Boom from Starship Launch at LC-39A: psf Contours

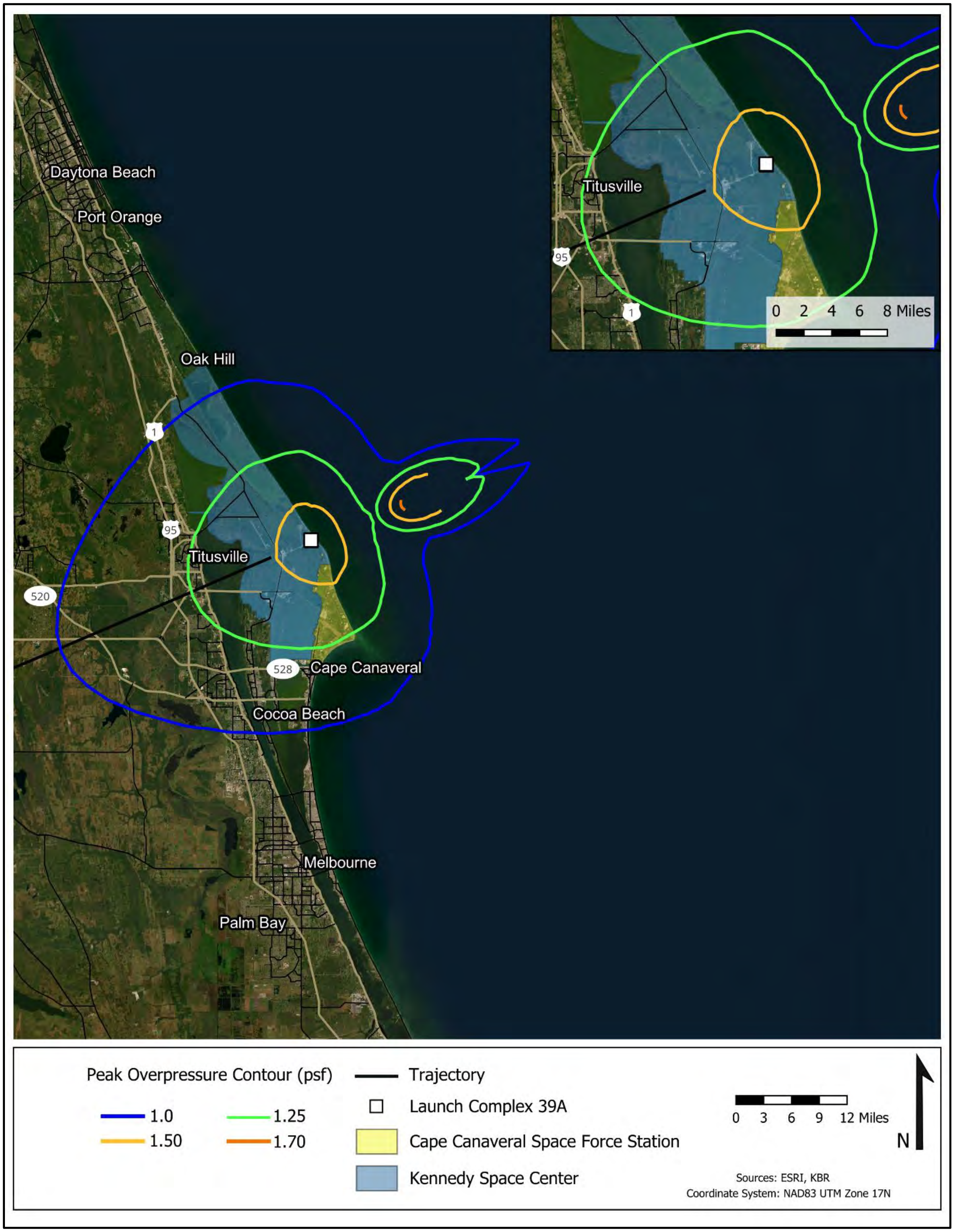

Figure 43. Sonic Boom from Starship Spacecraft Descent/Landing at LC-39A: psf Contours

5.3.3 Super Heavy Booster Descent/Landing Sonic Boom at LC-39A

The proposed operations indicate that Starship launches at LC-39A would result in the same number of Super Heavy Booster (stage 1) recoveries at LC-39A via landing operations. The Super Heavy landing trajectory for LC-39A is the same as the one used in the landing noise analysis (Section 5.2.2.2), though a higher altitude part of the trajectory is used in the sonic boom analysis. The decent portion of the booster landing at LC-39A is supersonic until it passes through an altitude just below 9,000 feet. Most of the booster descent is unpowered. As described in Section 5.2.2.2, three Booster landing trajectories were analyzed, including the nominal trajectory from a heading of 80-degrees (projected to be used 80 percent of the time), north bounding trajectory from 40-degrees (10 percent use), and south bounding trajectory from 115-degrees (10 percent use).

The sonic boom footprints at LC-39A were computed using PCBoom.[3,4] The vehicle is a cylinder generally aligned with the velocity vector, descending engines first. The landing trajectory kinematics includes the effect of atmospheric drag and the retro burn in each case.

As Figure 44 shows that for descent on the nominal trajectory, there is a broad forward-facing crescent region generated as the vehicle descends below 200,000 feet at a heading of approximately 260 degrees. After the burn finishes there is a roughly oval boom footprint region that ends when vehicle speed becomes subsonic. Levels within this oval footprint range from 6 psf to 20 psf close to the landing site.

- Boom levels at the LC-39A landing pad would be 20 (+) psf.
- Boom levels on CCSFS and KSC properties would range from 4 to 10 psf in areas away from the landing pad.
- Residents outside of the CCSFS and KSC properties would experience lower boom levels ranging from 1 psf to 2 psf except the northern half of Cape Canaveral and parts of Merritt Island could experience booms up to up to 4 psf.
- The highest boom levels offshore are between 10 psf and 20 psf just east of LC-39A.

Similar sonic boom levels are expected from landings using the 40-degree north bounding trajectory (Figure 45) and the 115-degree south bounding trajectory (Figure 46) although the exposures, away from the landing pad, would be in different areas depending on the landing trajectory used. Super Heavy landing booms would likely be noticed by residents of Titusville, Merritt Island, Cocoa and Cocoa Beach to the south, and Oak Hill to the north; lower level booms (below 1 psf) could be heard by people even farther away from the landing site. Residents of Merritt Island, the City of Cape Canaveral, and those working or visiting CCSFS or KSC are likely to experience booms greater than 2 psf and could possibly be startled. Announcements of upcoming Starship launches and landings serve to warn people about these noise events and are likely to help reduce adverse reactions to these noise events. The boom levels over land are not likely to cause property damage in residential areas; rare minor damage may result from boom levels with peak overpressures between 2 and 5 psf[26]. For all Starship operations discussed for LC-39A, the location of maximum overpressure will vary with weather conditions, so it is unlikely that any given location will experience the maximum estimated level more than once over multiple events.

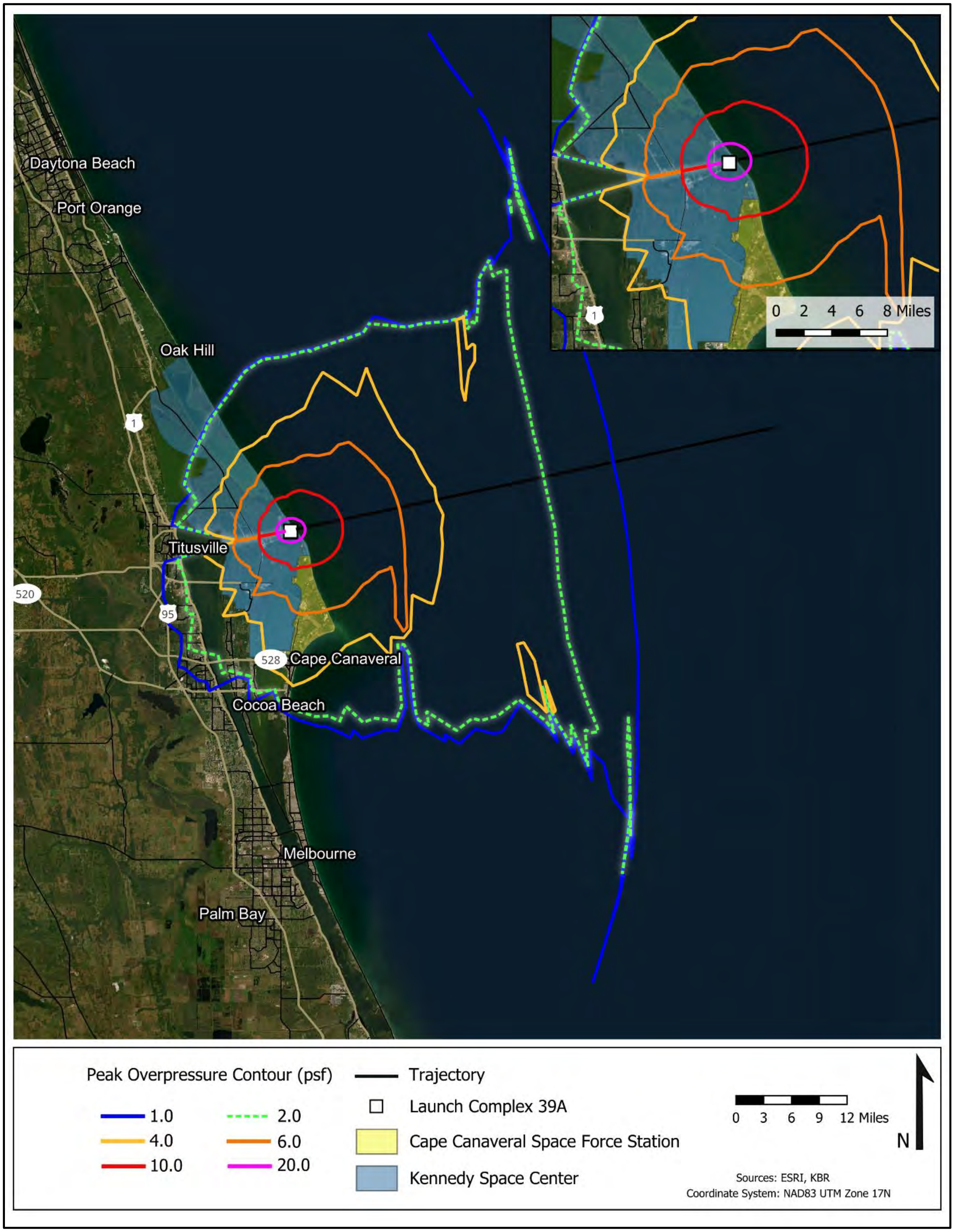

Figure 44. Sonic Boom from Super Heavy Descent (Nominal) at LC-39A: psf Contours

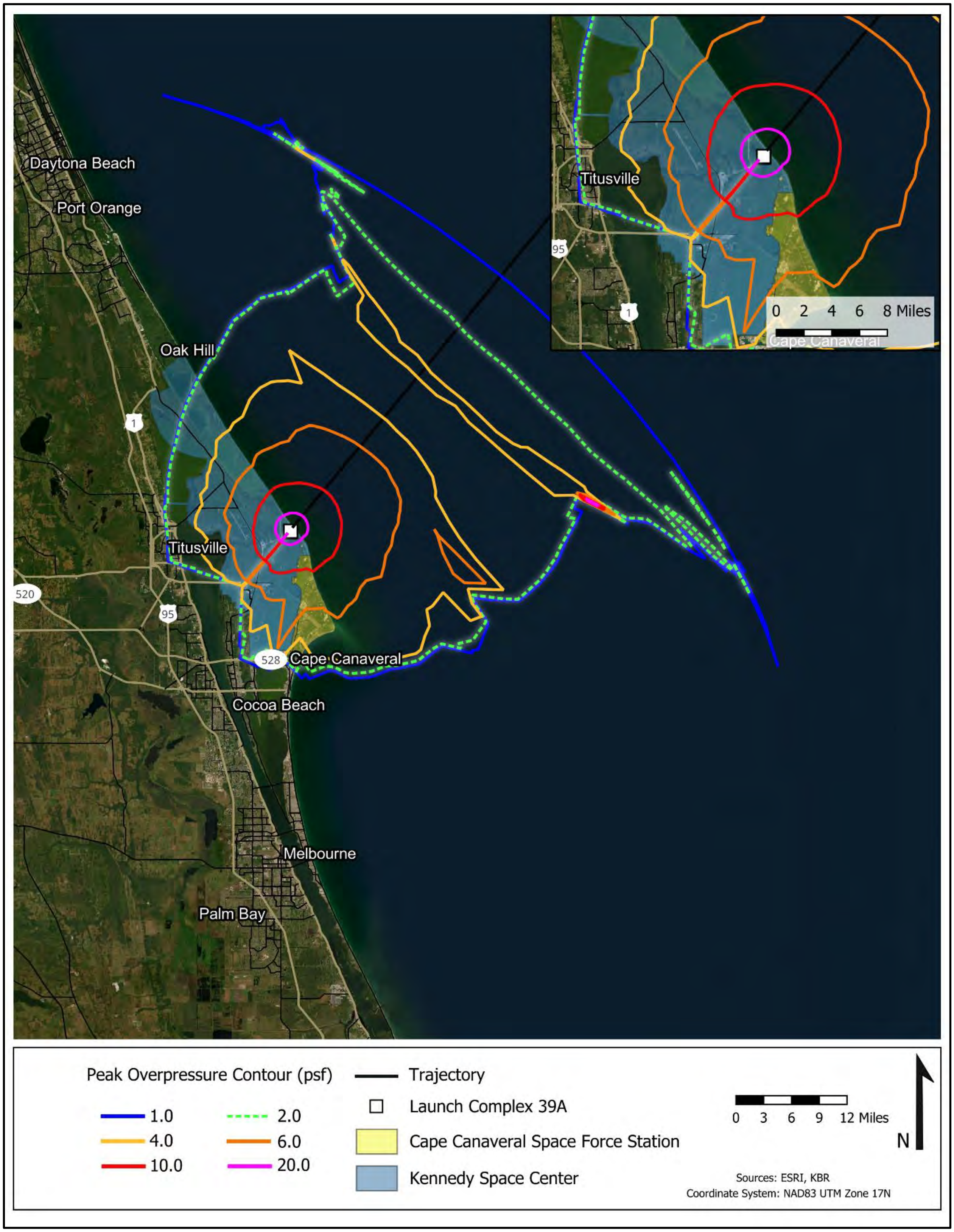

Figure 45. Sonic Boom from Super Heavy Descent (40-Degrees) at LC-39A: psf Contours

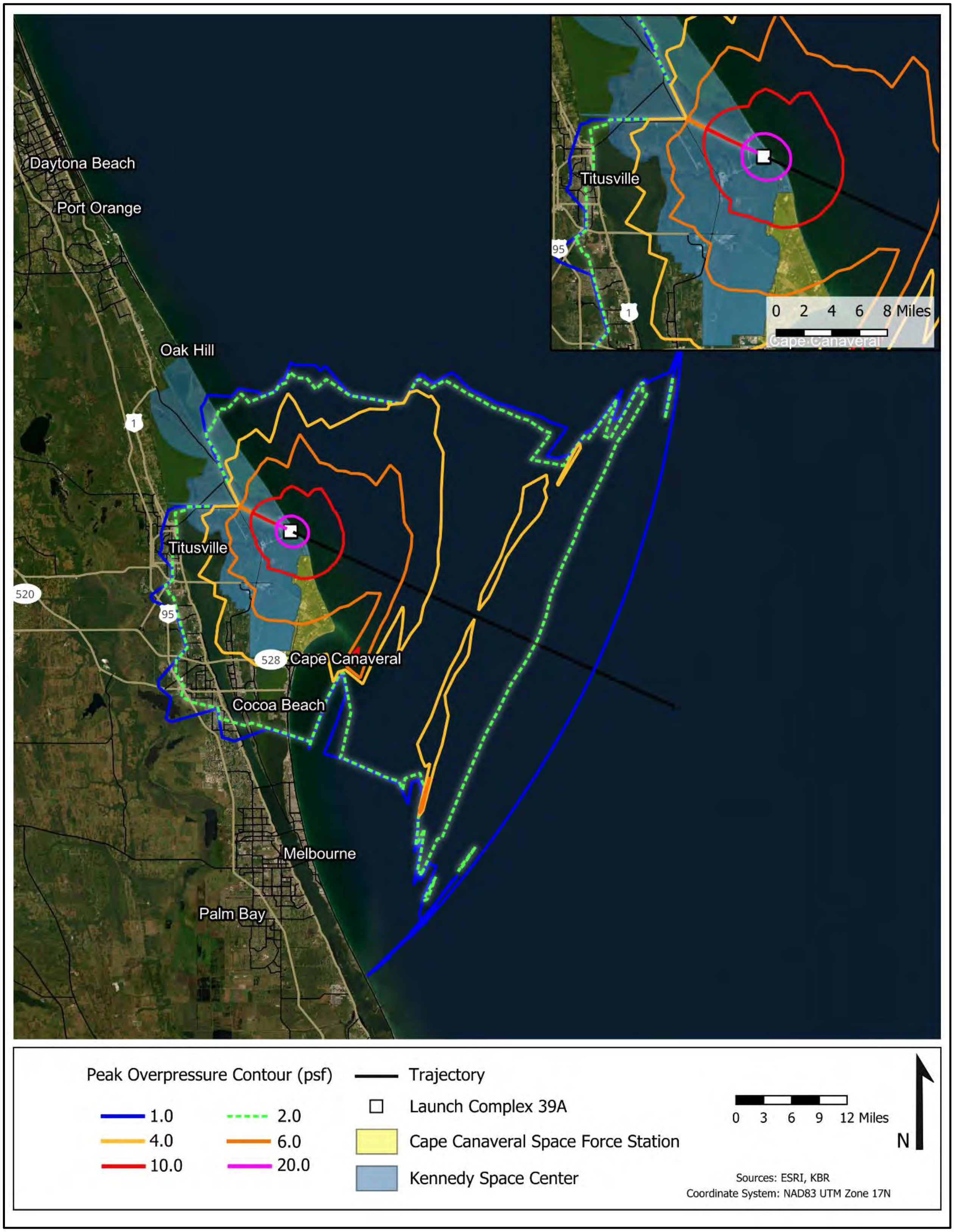

Figure 46. Sonic Boom from Super Heavy Descent (115-Degrees) at LC-39A: psf Contours

5.3.4 Cumulative Sonic Boom Levels at LC-39A

Cumulative sonic boom levels were estimated, using C-weighted Day-Night Average Sound Level (CDNL), for projected annual Starship and Booster landing operations at LC-39A. CDNL is DNL computed with C-weighting (more emphasis is placed on low frequencies below 1,000 hertz). The CDNL metric is used as a cumulative measure of noise events having lower frequency content and higher levels (e.g., sonic booms, large caliber weapons, and blast noise events). Cumulative sonic boom levels would include the CDNL exposure due to all annual Starship spacecraft landings and Super Heavy Booster landings combined.

The estimated CDNL results are shown as contours on Figure 47 and as levels at the study points of interest (Table 11). CDNL exposure is also presented as the number of acres (Table 12) and population and housing (Table 13) within each 5 dB contour band from CDNL 60 dBC to 80 dBC; where CDNL 60 dB is the FAA's significance threshold for noise sensitive land uses.

Figure 47 shows that most of the areas exposed to CDNL 60 dB or above are on KSC and CCSFS property. Other areas outside of KSC and CCSFS property that are exposed to CDNL 60 dB or above include parts of Merritt Island, Cape Canaveral, Cocoa, Cocoa Beach, and a small area south of Titusville near Port St. John and Sharpes. Table 12 shows that the CDNL values from Starship landing operations exceed the CDNL 60 dBC threshold at fourteen of the twenty-four POIs. About half of these CDNL exposures above 60 dB are at POIs located within KSC or CCSFS properties. Section 5.3.4.2 includes more details about the CDNL estimates at the POIs and Section 5.3.4.3 describes the CDNL exposed acreage, housing, and population that would result from the proposed annual Starship and Booster landing operations at LC-39A.

Though the cumulative sonic boom levels estimated would include the CDNL exposure due to all annual Starship spacecraft landings and Super Heavy Booster landings combined, the single event levels and CDNL values for the Super Heavy Booster landings in these areas are much higher than Starship spacecraft landing single event levels and CDNL values, by more than 10 dB in most cases. The Starship spacecraft landing boom levels therefore do not contribute much to the combined CDNL result (i.e., the Super Heavy Booster landing CDNL values dominate the cumulative sonic boom exposure from all landings).

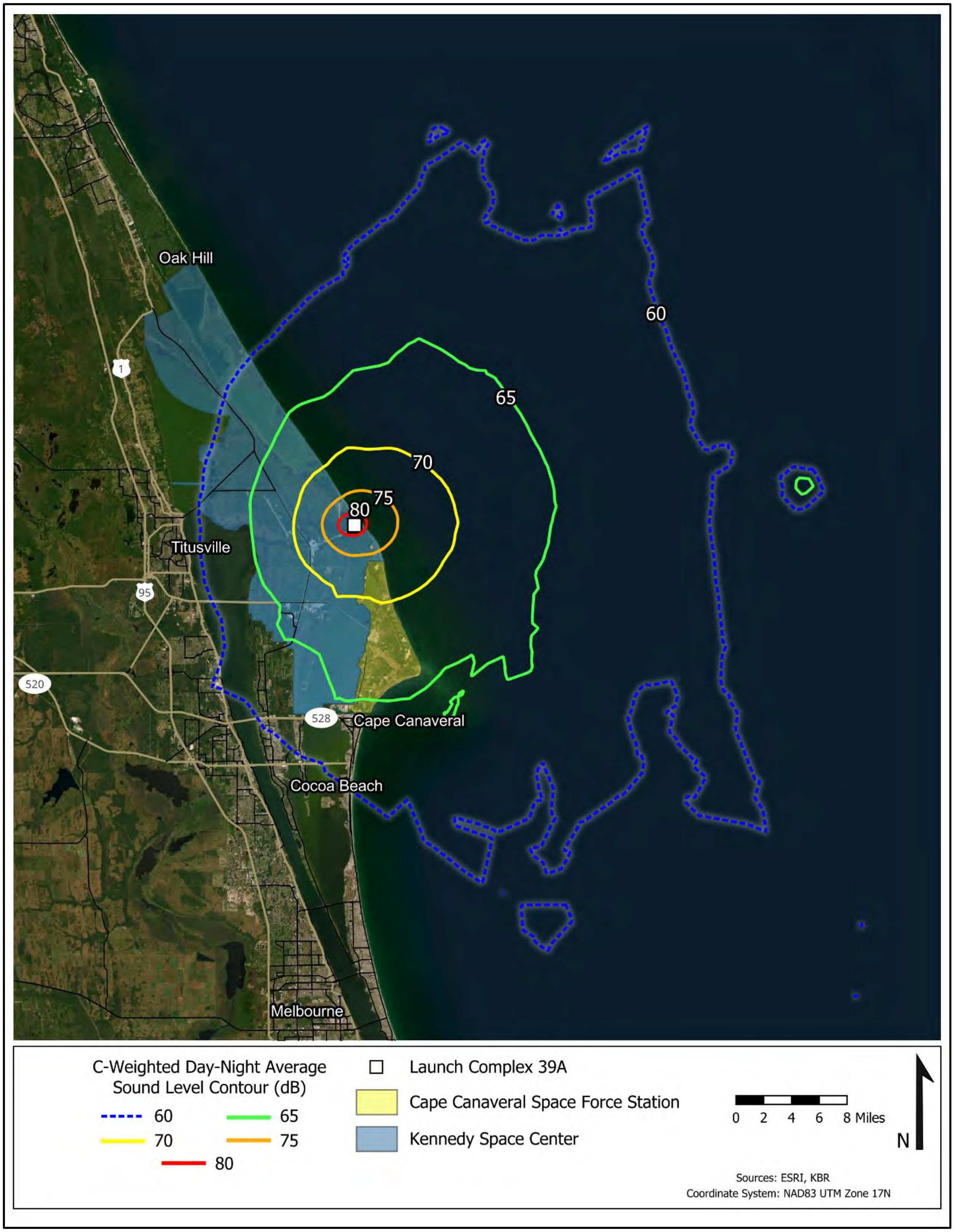

Figure 47. Cumulative Sonic Boom Exposure (All Starship Operations) at LC-39A: CDNL Contours

5.3.4.2 CDNL Exposure at Points of Interest

The twenty-four POIs assessed in this study are listed in Table 12 and Figure 41 shows their locations relative to LC-39A. For each POI, Table 12 includes the POI number identifier (ID) which is shown on the map in Figure 41, POI name, location, type of POI (residential, school, place of worship, etc.) and the estimated CDNL due to proposed Starship operations at LC-39A. CDNL values range from 50.8 dBC, at The Rock Church, to 78.1 dBC at Titusville Beach (nearest POI to LC-39A). Fourteen POIs are exposed to CDNL 60 dB or greater (highlighted cells in the table), where CDNL 60 dB is the FAA threshold for land use compatibility. POIs 1-7 and 23 are located on CCSFS or KSC property while the other POIs (above CDNL 60 dB) are in Merritt Island (8 and 18), Courtenay (9), Cape Canaveral (10), Cocoa (17), and Cocoa Beach (20).

Table 12. Proposed Starship Operations at LC-39A: CDNL Exposure at POIs

POI ID	POI Name	Location	Type	CDNL(dB)
1	Cape Canaveral Space Force Station (CCSFS)	Cape Canaveral	CCSFS Representative	68.1
2	SpaceX Operations Area	Merritt Island	SpaceX Facility	67.9
3	Titusville Beach	Titusville	Recreational (Private)	78.1
4	Playalinda Beach	Titusville	Recreational Area	70.1
5	Kennedy Space Center Visitor Complex	Merritt Island	KSC Representative	65.7
6	KSC Child Development Center	Merritt Island	School	67.1
7	Merritt Island National Wildlife Refuge Visitor Center	Merritt Island	Wildlife Conservation Area	64.1
8	Pine Island Conservation Area/Pine Island Estates	Merritt Island	Wildlife Conservation Area/Residential Area	62.7
9	Kings Park Estates - Courtenay	Courtenay	Residential	62.4
10	Jetty Park Campground	Cape Canaveral	Recreational Area	64.3
11	Rockledge High School	Rockledge	School	53.8
12	Merritt Island	Merritt Island	Residential	56.2
13	Oak Park Elementary School	Titusville	School	52.3
14	Titusville High School	Titusville	School	57.1
15	Summerwood Villas	Titusville	Residential	56.8
16	Atlantis Elementary School	Port St. John	School	55.8
17	Fairglen Elementary School	Cocoa	School	60.2
18	Lewis Carroll Elementary School	Merritt Island	School	60.5
19	Cocoa	Cocoa	Residential	55.6
20	Cocoa Beach	Cocoa Beach	Residential	60.0
21	Pinegrove Estates	MIMS	Residential	51.8
22	Fern Meadows	West Cocoa	Residential	51.4
23	KSC Office Outside BDA	KSC	Office	72.6
24	The Rock Church	Fontaine Grant	Place of Worship	50.8

Notes: POI = Point of Interest; ID = Identification; CDNL = C-weighted Day-Night Average Sound Level; dBC = decibel (C-weighted).

5.3.4.3 Acreage, Housing, and Population Within CDNL Contours

Table 13 shows the acreage within each CDNL contour band, resulting in a total of 108,059 acres exposed to DNL 60 dB or greater due to noise from proposed Starship operations at LC-39A. This total acreage excludes water bodies and is comprised of 45,345 acres exposed to CDNL 60 to 65 dB, 43,035 acres exposed to CDNL 65 to 70 dB, 14,947 acres exposed to CDNL 70 to 75 dB, 3,669 acres exposed to CDNL 75 to 80 dB, and 1,063 acres exposed to CDNL greater than 80 dB.

Table 13. Proposed Starship Operations at LC-39A: CDNL Exposure Acreage

CDNL Band (dBC)	Acreage
	Total
60-65	45,345
65-70	43,035
70-75	14,947
75-80	3,669
80+	1,063
Total	**108,059**

Note: CDNL = C-weighted Day-Night Average Sound Level; dBC = decibel (C-weighted).

Geographic Information System (GIS) analysis was used to estimate the population and households within each CDNL contour band. If a block group was partially within a CDNL contour band the number of households and population were scaled based upon the proportion of the block group area within each CDNL contour band. Table 14 lists estimated households and population outside of CCSFS and KSC properties that would be exposed to each CDNL contour band due to the Proposed Starship operations at LC-39A. Currently, 22,726 households and 34,957 people would be within the CDNL 60 to 65 dB contour band which includes parts of Titusville, Merritt Island, Cape Canaveral, Cocoa and Cocoa Beach.

Table 14. Proposed Starship Operations at LC-39A: CDNL Exposure (Households and Population)

CDNL Band (dBC)	Households	Population
60-65	22,726	34,957
65-70	0	0
70-75	0	0
75-80	0	0
80+	0	0
Totals	**22,726**	**34,957**

Note: CDNL = C-weighted Day-Night Average Sound Level; dBC = decibel (C-weighted).

5.3.5 Supplemental Metrics Assessment for Sonic Boom Exposure at LC-39A

The Supplemental metrics for assessing sonic boom exposures, described in Section 2.3, are used here to further characterize the noise environment from Starship supersonic flight operations. The following sections provide assessments of two supplemental metrics, Residential Sleep Disturbance (Section 5.3.5.1) and the Potential for Structural Damage (Section 5.3.5.2), two impacts that could occur from sonic booms generated by the proposed Starship spacecraft and Super Heavy landing operations at LC-39A, along with a discussion of the unlikely Potential for Hearing Loss in Section 5.3.5.3.

As with all the supplemental analysis presented in this report, these assessments use the 24 study POIs to describe the noise exposures from Starship operations, but in a general sense, where the assessment would be applicable to all areas with the same level of noise exposure. The Environmental Impact Statement (EIS), which this noise report supports, may include more in depth investigations of potential impact, such as determining the number of people exposed to noise events, focusing assessment on a known wildlife habitat, or evaluating potential damage to specific structures.

5.3.5.1 Residential Sleep Disturbance from Proposed Starship Sonic Boom Events

Half of all proposed Starship spacecraft and Booster landings are expected to be conducted at nighttime (i.e., 22 nighttime landings annually per vehicle). Nighttime landings and the sonic booms they generate are a new type of noise event that recently began occurring with SpaceX Falcon 9 and Falcon Heavy first stage recovery landings at Cape Canaveral. With the addition of proposed Starship operations at LC-39A, these types of events would become more regular and there is the potential that some residents in nearby communities could be awakened from sleep during these nighttime events. Some who may regularly sleep during the day may also be awakened by landing events that occur during daytime hours.

As reported by the Department of Defense (DOD) Noise working Group (DNWG)[25], direct empirical evidence of the ability of sonic booms to disturb sleep is very scarce. During the SST Program, only four studies were conducted on sleep awakenings from both simulated and actual sonic booms (Collins and Lampietro, 1973; Ludlow and Morgan, 1972; Lukas, Dobbs, and Kryter, 1971; and Lukas and Dobbs, 1972). A review of these studies combined their results to develop a preliminary dose-response relationship between sonic boom levels and awakenings (Pearsons et al., 1989) as follows:

% Awakened or Aroused = 2.32(CSEL) - 184.9

where CSEL is the C-weighted sound exposure level of an impulsive noise event such as a sonic boom. In this study, CSEL values were estimated from peak overpressure values (for N-wave boom signatures)[7] as shown in Table 15, and applying this dose-response relationship to the booster landing operations, that are expected to generate the highest sonic boom levels, yields the example results for the percent awakened shown in Table 15. Results shown in Table 15 reflect a booster landing on the nominal (80-degree) trajectory, and landings on other trajectories would yield different results. Since most of the acoustic energy in a sonic boom occurs at low frequencies (below 100 Hz), typical houses of good construction are not expected to provide noise reductions (NR) for sonic boom that are as high as those for subsonic noise (i.e., typically in the 15 to 25 dB range with windows open and windows closed, respectively). Table 15 shows the estimated percent awakened for 0 dB NR and 15 dB NR (provided as an example upper limit); for 0 dB NR, the percent awakened ranges from about 55-75 percent in residential areas whereas for 15 dB NR, the percent awakened ranges from about 20-40 percent. Note that whereas the residential sleep disturbance estimated for subsonic noise events (Section 5.2.5.3), which uses the FICAN (1997) dose-response curve, only reflects behavioral awakenings, this sonic boom dose-response curve reflects awakenings and sleep disturbance.

Table 15. Proposed Super Heavy Landing On Nominal Trajectory at LC-39A: % Awakened at POIs

POI ID	POI Name	Location	Type	Overpressure (psf)	% Awakened (0 dB Noise reduction)	% Awakened (15 dB Noise reduction)
1	Cape Canaveral Space Force Station (CCSFS)	Cape Canaveral	CCSFS Representative	6.53	88.6	53.8
2	SpaceX Operations Area	Merritt Island	SpaceX Facility	6.35	88.2	53.4
3	Titusville Beach	Titusville	Recreational (Private)	20.51	100%	76.7
4	Playalinda Beach	Titusville	Recreational Area	8.16	93.0	58.2
5	Kennedy Space Center Visitor Complex	Merritt Island	KSC Representative	4.74	82.1	47.3
6	KSC Child Development Center	Merritt Island	School	6.09	87.2	52.4
7	Merrit Island National Wildlife Refuge Visitor Center	Merritt Island	Wildlife Conservation Area	4.02	78.9	44.1
8	Pine Island Conservation Area/Pine Island Estates	Merritt Island	Wildlife Conservation /Residential Area	3.81	77.7	42.9
9	Kings Park Estates - Courtenay	Courtenay	Residential	3.18	74.0	39.2
10	Jetty Park Campground	Cape Canaveral	Recreational Area	4.48	81.0	46.2
11	Rockledge High School	Rockledge	School		-	
12	Merritt Island	Merritt Island	Residential	1.24	55.2	20.4
13	Oak Park Elementary School	Titusville	School	-	-	-
14	Titusville High School	Titusville	School	-	-	-
15	Summerwood Villas	Titusville	Residential	1.80	62.6	27.8
16	Atlantis Elementary School	Port St. John	School	1.73	61.9	27.1
17	Fairglen Elementary School	Cocoa	School	2.58	69.8	35.0
18	Lewis Carroll Elementary School	Merritt Island	School	1.99	64.7	29.9
19	Cocoa	Cocoa	Residential	1.46	58.5	23.7
20	Cocoa Beach	Cocoa Beach	Residential	1.88	-	-
21	Pinegrove Estates	MIMS	Residential	-	-	-
22	Fern Meadows	West Cocoa	Residential	-	-	-
23	KSC Office Outside BDA	KSC	Office	11.06	99.3	64.5

POI ID	POI Name	Location	Type	Overpressure (psf)	% Awakened (0 dB Noise reduction)	% Awakened (15 dB Noise reduction)
24	The Rock Church	Fontaine Grant	Place of Worship	-	-	-

Notes: POI = Point of Interest; ID = Identification; psf = pounds per square foot; dBC = decibel (C-weighted); % = Percent. The POIs without noise values reported are located outside of the sonic boom footprint.

5.3.5.2 Potential for Structural Damage from Proposed Starship Sonic Boom Events

Proposed Starship landing operations also have the potential to cause damage to structures depending on the overpressure levels which are highest at the landing pad and, in general, are progressively lower with distance away from the landing pad. In this report, we assess the potential for structural damage using the proposed Super Heavy landing (which is expected to generate the highest sonic boom overpressures of all the Starship operations) as an example, as was done in the previous section to assess the potential for sleep disturbance. The overpressure values listed in Table 16 reflect a booster landing on the nominal (80-degree) trajectory, and results would differ for landings on other trajectories.

We assess the potential for structural damage based on data in the FAA's Hershey and Higgins 1976 report "*Statistical Model of Sonic Boom Structural Damage"*,[26] which is also supported in DAF's Haber and Nakaki 1989 report',[27] which describes damage probabilities for different structural components, for various sonic boom overpressure levels. We use 2 psf (pounds per square foot) and 4 psf primarily to assess the potential for structural damage, since areas off KSC and CCSFS properties are most likely to be exposed to booms, within this range of overpressure levels, from Super Heavy landing operations; 2 psf is also considered to be the low threshold level for glass breakage.

The peak overpressure levels (psf) estimated for a Super Heavy landing at LC-39A are highest at the POIs on KSC and CCSFS property (POI IDs 1-6 and 23) with the highest level occurring at Titusville Beach (closest to the landing pad at LC-39A). Off KSC and CCSFS property, levels are below 4 psf except at the Jetty Park Campground in Cape Canaveral (4.5 psf) and the Merritt Island National Wildlife Refuge Visitor Center (4.0). Overpressure levels at many of the other POIs, where data exists, are at 2 psf or lower; data were not available in several cases (for POIs located outside of the sonic boom footprint).

A summary of the structural damage potential, for overpressure levels of 2 and 4 psf, indicates:

2 psf

- Windows: The probability of window breakage at 2 psf is relatively low but not negligible. Studies have shown that the breakage probability for windows can range from about 1 in 10,000 to 1 in 1,000,000.
- Plaster and Bric-a-Brac: Items like plaster and small decorative objects (bric-a-brac) have a slightly higher probability of damage, but it is still quite low. For plaster, the probability can range from about 1 in 1,000 to 1 in 10,000.
- Structural Damage: Significant structural damage, such as to brick walls, is very unlikely at 2 psf. The probability is extremely low, often less than 1 in 1,000,000.

4 psf

- Windows: The probability of window breakage increases significantly at 4 psf. Studies suggest that the breakage probability for windows can range from about 1 in 100 to 1 in 1,000.
- Plaster and Bric-a-Brac: Items like plaster and small decorative objects have a higher probability of damage at 4 psf. For plaster, the probability can range from about 1 in 100 to 1 in 1,000.
- Structural Damage: While significant structural damage to well-built buildings is still relatively low, the probability increases. For example, brick walls might have a damage probability ranging from about 1 in 10,000 to 1 in 100,000.

Overall, while 4 psf sonic booms are more likely to cause damage compared to 2 psf, the extent of damage still depends on several factors, including the construction quality and maintenance of the structures.

Table 16. Proposed Super Heavy Landing On a Nominal Trajectory at LC-39A: Overpressure at POIs

POI ID	POI Name	Location	Peak Overpressure (psf)
1	Cape Canaveral Space Force Station (CCSFS)	Cape Canaveral	6.5
2	SpaceX Operations Area	Merritt Island	6.4
3	Titusville Beach	Titusville	20.5
4	Playalinda Beach	Titusville	8.2
5	Kennedy Space Center Visitor Complex	Merritt Island	4.7
6	KSC Child Development Center	Merritt Island	6.1
7	Merritt Island National Wildlife Refuge Visitor Center	Merritt Island	4.0
8	Pine Island Conservation Area/Pine Island Estates	Merritt Island	3.8
9	Kings Park Estates - Courtenay	Courtenay	3.2
10	Jetty Park Campground	Cape Canaveral	4.5
11	Rockledge High School	Rockledge	-
12	Merritt Island	Merritt Island	1.2
13	Oak Park Elementary School	Titusville	-
14	Titusville High School	Titusville	-
15	Summerwood Villas	Titusville	1.8
16	Atlantis Elementary School	Port St. John	1.7
17	Fairglen Elementary School	Cocoa	2.6
18	Lewis Carroll Elementary School	Merritt Island	2.0
19	Cocoa	Cocoa	1.5
20	Cocoa Beach	Cocoa Beach	1.9
21	Pinegrove Estates	MIMS	-
22	Fern Meadows	West Cocoa	-
23	KSC Office Outside BDA	KSC	11.1
24	The Rock Church	Fontaine Grant	-

Notes: POI = Point of Interest; ID = Identification; psf = pounds per square foot. The POIs without noise values reported are located outside of the sonic boom footprint.

5.3.5.3 Potential for Hearing Loss from Proposed Starship Sonic Boom Events

Sonic boom research summarized by the Defense Noise Working Group (DNWG) indicates that impulsive noise exposure produced by occasional overflights of supersonic aircraft poses no meaningful risk of hearing damage (including evidence that the high-frequency spectral content of sonic booms is inadequate to damage hearing). This is supported by several sonic boom field studies where researchers were exposed to high boom levels (e.g., in 1968 at Tonopah, Nevada, sonic booms with overpressures ranging from 50 to 144 psf caused no direct injury to exposed test subjects)[25].

6 PROPOSED ACTION SCENARIO

6.1 PROPOSED ACTION ANNUAL OPERATIONS

Proposed Action launch vehicle flight and test operations at KSC and CCSFS are listed in Table 17. These operations are organized in the launch, landing, and static fire event categories and then by facility (KSC or CCSFS), launch complex, and by vehicle or program name, followed by the annual number of daytime (0700-2200) and nighttime (2200-0700) operations. These represent the No Action operations (Table 3) plus the proposed Starship annual operations at LC-39A described in Section 5. For each Starship operation type, there are a total of 44 proposed annual operations and, in each case, 22 (50 percent) are modeled as daytime operations and 22 as nighttime operations.

Table 17. Proposed Action Launch, Landing, and Static Fire Test Operations at KSC and CCSFS

Event	Facility	Complex	Vehicle/Program	Day	Night	Total
Launch	KSC	LC-39A	Starship	22	22	44
		LC-39A	SpaceX Falcon 9	0	36	36
		LC-39A	SpaceX Falcon Heavy	0	5	5
		LC-39B	NASA Space Launch System	0.6	0.4	1
		LC-48N	NASA SCLV	32.5	19.5	52
		LC-48S	NASA SCLV	32.5	19.5	52
	CCSFS	SLC-16	Relativity Terran R	18	6	24
		SLC-36	Blue Origin New Glenn Launch	10	2	12
		SLC-40	SpaceX Falcon 9 Launch	0	70	70
		SLC-41	ULA Atlas V 551 (5 SRBs)	6.25	3.75	10
		SLC-41	ULA Vulcan VC6S	13	7	20
		SLC-46	Liquid Propellant Vehicle	7.5	4.5	12
		SLC-46	Solid Propellant Vehicle	7.5	4.5	12
			Total	**149.8**	**200.2**	**350**
Landing	KSC	LC-39A	Starship Spacecraft RTLS	22	22	44
		LC-39A	Super Heavy Booster RTLS	22	22	44
	CCSFS	LZ-1/2	SpaceX Falcon Booster	0	54	54
		LZ-1/2	SpaceX Falcon Heavy Booster	0	5	5

Event	Facility	Complex	Vehicle/Program	Day	Night	Total
			Total	**44**	**103**	**147**
Static Fire	KSC	LC-39A	Starship	22	22	44
		LC-39A	Super Heavy Booster	22	22	44
		LC-39A	SpaceX Falcon 9	0	36	36
		LC-39A	SpaceX Falcon Heavy	0	5	5
		LC-48N	NASA SCLV	32.5	19.5	52
		LC-48S	NASA SCLV	32.5	19.5	52
	CCSFS	SLC-11	Blue Origin BE-4 Engine Testing	108	0	108
		SLC-16	Relativity Terran R Static Fire	18	6	24
		SLC-16	Relativity Terran R Stage MDC Hot Fire	10	4	14
		SLC-20A	SCLV Static Fire	4.2	1.8	6
		SLC-20A	SCLV Acceptance Test	4.2	1.8	6
		SLC-20B	MCLV Static Fire	12.6	5.4	18
		SLC-20B	MCLV Acceptance Test	12.6	5.4	18
		SLC-36	Blue Origin New Glenn Static Fire	10	2	12
		SLC-40	SpaceX Falcon 9 Static Fire	0	70	70
			Total	**288.6**	**220.4**	**509**

6.2 PROPOSED ACTION: ROCKET NOISE EXPOSURE: DNL CONTOURS

The DNL contours for the Proposed Action operations in Table 17, including DNL 65-85 dBA in 5 dB increments are shown on Figure 48; these contours represent the cumulative subsonic noise environment due to rocket noise. The DNL 65 dBA contour, which represents the significance threshold for noise sensitive areas, is almost entirely within the KSC and CCSFS properties. Additional details of the Proposed Action DNL exposure, and comparison with the DNL exposure estimates for the other operational scenarios are provided in Section 8.

6.3 PROPOSED ACTION: SONIC BOOM EXPOSURE: DNL CONTOURS

Figure 49 shows the CDNL contours for the Proposed Action operations in Table 17, including the CDNL 60 through 80 dBC contours in 5 dB increments. The CDNL 60 dBC contour, which represents the significance threshold for noise sensitive areas, extends beyond the KSC and CCSFS property lines into parts of Titusville to the west, and the City of Cape Canaveral and parts of Cocoa and Cocoa Beach to the south. The primary reason these CDNL contours extend into residential areas is the overall high number of annual nighttime landing operations (Table 17) which include a 10-decibel penalty compared to daytime operations. Additional details of the Proposed Action CDNL exposure, and comparison with the CDNL exposure estimates for the other operational scenarios are provided in the noise exposure assessment summary in Section 8.

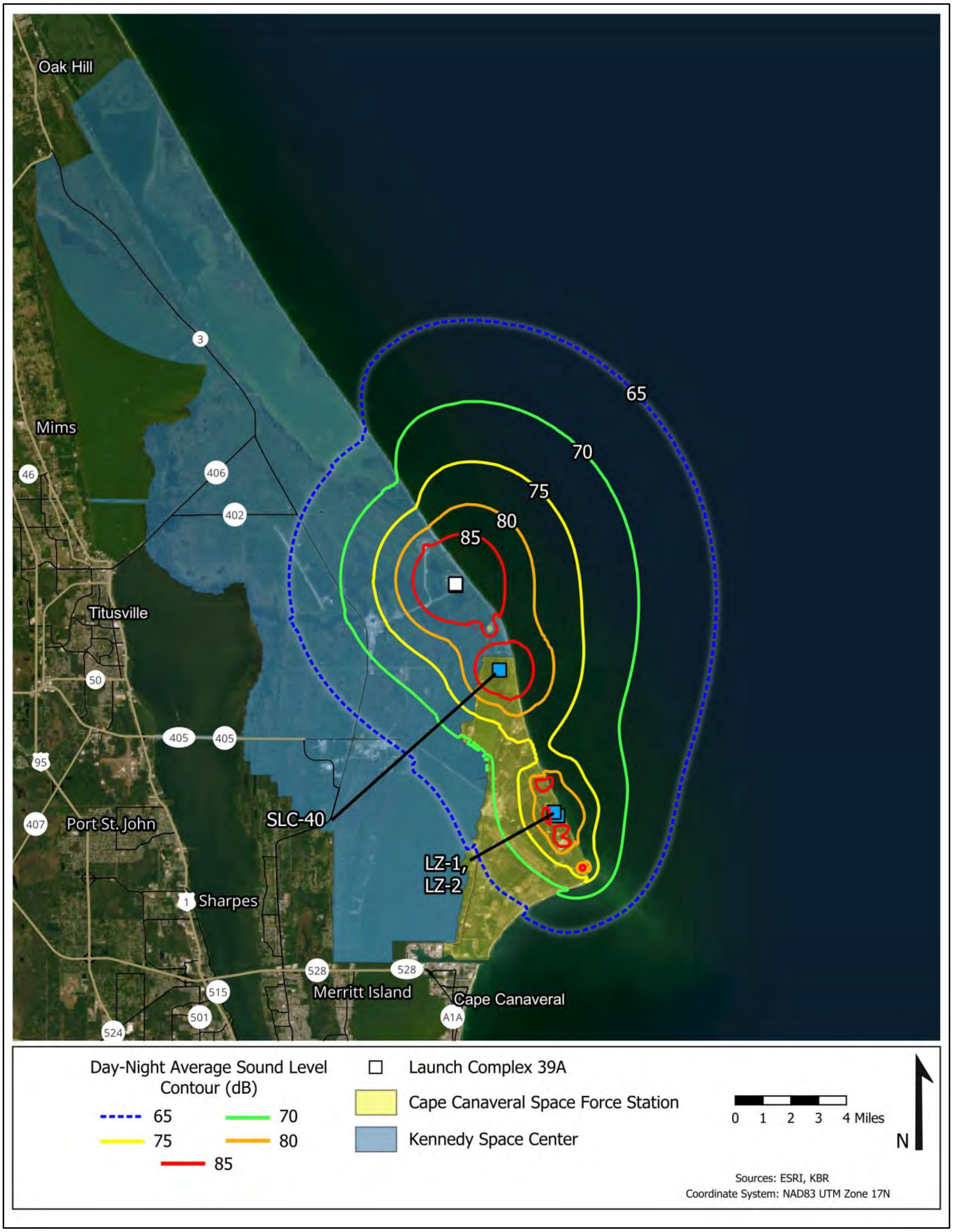

Figure 48. Proposed Action Rocket Noise Exposure: DNL Contours

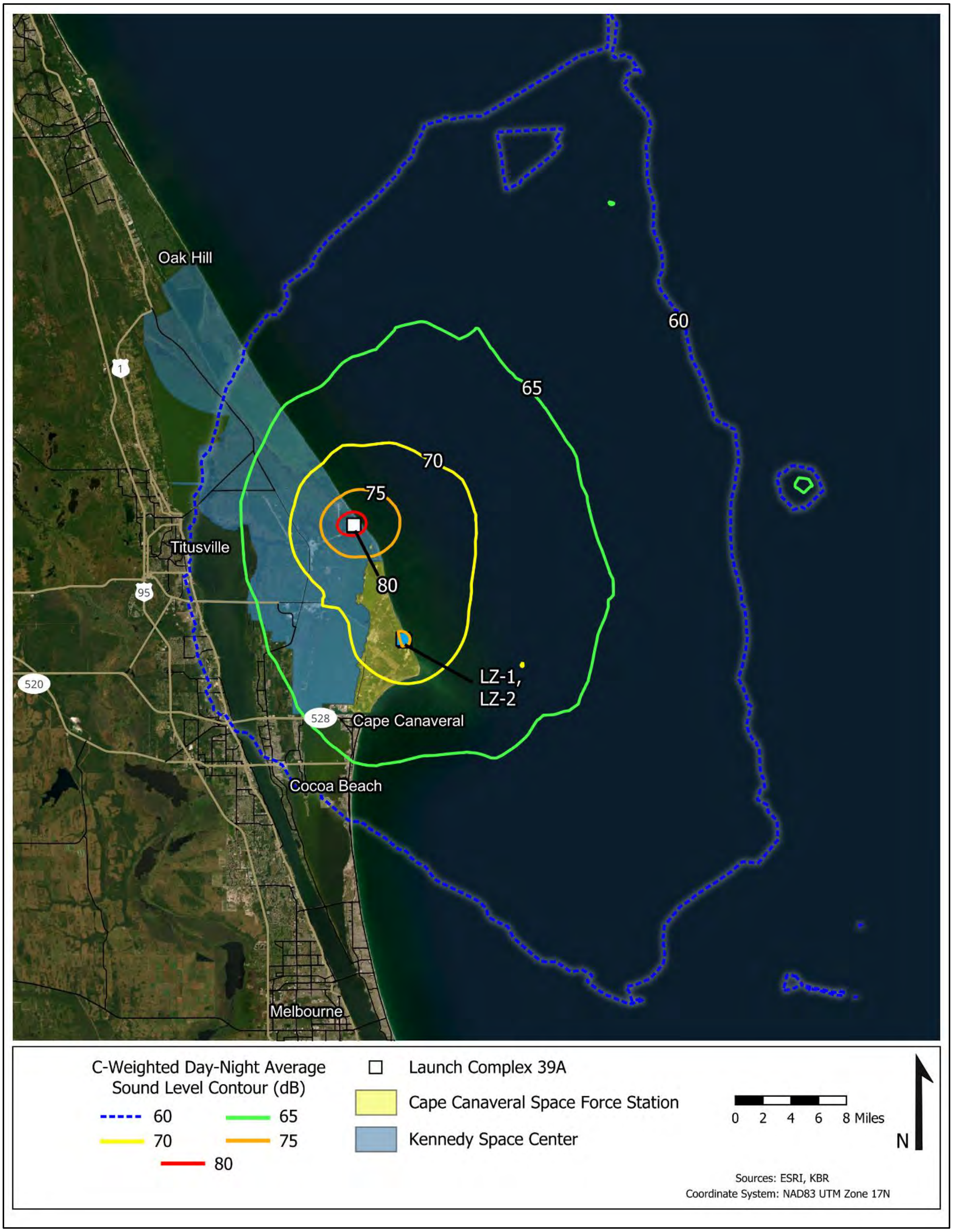

Figure 49. Proposed Action Sonic Boom Exposure: CDNL Contours

7 REASONABLY FORSEEABLE FUTURE ACTIONS SCENARIO

7.1 REASONABLY FORSEEABLE FUTURE ACTION OPERATIONS

The Reasonably Foreseeable Future Action operations at KSC and CCSFS are listed in Table 18 organized by the launch, landing, and static fire event categories and including the annual number of daytime (0700-2200) and nighttime (2200-0700) operations. These represent the Proposed Action operations (Table 17) plus the proposed Starship annual operations at SLC-37. For each Starship operation type at LC-39A, there are a total of 44 proposed annual operations and, in each case, 22 (50 percent) are modeled as daytime operations and 22 as nighttime operations. For each Starship operation type at SLC-37, there are a total of 76 proposed annual operations with the same 50/50 daytime/nighttime split.

Table 18. Reasonably Foreseeable Future Action Launch, Landing, and Test Operations at KSC and CCSFS

Event	Facility	Complex	Vehicle/Program	Day	Night	Total
Launch	KSC	LC-39A	Starship	22	22	44
		LC-39A	SpaceX Falcon 9	0	36	36
		LC-39A	SpaceX Falcon Heavy	0	5	5
		LC-39B	NASA Space Launch System	0.6	0.4	1
		LC-48N	NASA SCLV	32.5	19.5	52
		LC-48S	NASA SCLV	32.5	19.5	52
	CCSFS	SLC-14	Stoke Nova	5	5	10
		SLC-16	Relativity Terran R	18	6	24
		SLC-20A	SCLV	4.2	1.8	6
		SLC-20B	MCLV	12.6	5.4	18
		SLC-36	Blue Origin New Glenn Launch	10	2	12
		SLC-37	Starship	38	38	76
		SLC-40	SpaceX Falcon 9 Launch	0	70	70
		SLC-41	ULA Atlas V 551 (5 SRBs)	6.25	3.75	10
		SLC-41	ULA Vulcan VC6S	13	7	20
		SLC-46	Liquid Propellant Vehicle	7.5	4.5	12
		SLC-46	Solid Propellant Vehicle	7.5	4.5	12
			Total	**209.6**	**250.4**	**460**
Landing	KSC	LC-39A	Starship Spacecraft RTLS	22	22	44
		LC-39A	Super Heavy Booster RTLS	22	22	44
	CCSFS	LZ-1/2	SpaceX Falcon Booster	0	54	54
		LZ-1/2	SpaceX Falcon Heavy Booster	0	5	5
		SLC-37	Starship RTLS	38	38	76
		SLC-37	Super Heavy Booster RTLS	38	38	76
			Total	**120**	**179**	**299**
Static Fire	KSC	LC-39A	Starship	22	22	44
		LC-39A	Super Heavy Booster	22	22	44
		LC-39A	SpaceX Falcon 9	0	36	36
		LC-39A	SpaceX Falcon Heavy	0	5	5

Event	Facility	Complex	Vehicle/Program	Day	Night	Total
		LC-48N	NASA SCLV	32.5	19.5	52
		LC-48S	NASA SCLV	32.5	19.5	52
	CCSFS	SLC-11	Blue Origin BE-4 Engine Testing	108	0	108
		SLC-14	Stoke Nova	10	0	10
		SLC-16	Relativity Terran R Static Fire	18	6	24
		SLC-16	Relativity Terran R Stage MDC Hot Fire	10	4	14
		SLC-20A	SCLV Static Fire	4.2	1.8	6
		SLC-20A	SCLV Acceptance Test	4.2	1.8	6
		SLC-20B	MCLV Static Fire	12.6	5.4	18
		SLC-20B	MCLV Acceptance Test	12.6	5.4	18
		SLC-36	Blue Origin New Glenn Static Fire	10	2	12
		SLC-37	Starship	38	38	76
		SLC-37	Super Heavy Booster	38	38	76
		SLC-40	SpaceX Falcon 9 Static Fire	0	70	70
			Total	**374.6**	**296.4**	**671**

7.2 Reasonably Forseeable Future Actions: Rocket Noise Exposure: DNL Contours

The DNL contours for the Reasonably Foreseeable Future Action operations in Table 18, are shown on Figure 50 including the DNL 65-85 dBA contours in 5 dB increments; these contours represent the cumulative subsonic noise environment, due to rocket noise, for all proposed actions combined. The DNL 65 dBA contour, which represents the significance threshold for noise sensitive areas, is still almost entirely within the KSC and CCSFS properties (with some off-station exposure over the Banana River). Additional details of the Reasonably Foreseeable Future Actions DNL exposure, and comparison with the DNL exposure estimates for the other operational scenarios are provided in the noise exposure assessment summary (Section 8).

7.3 Reasonably Forseeable Future Actions: Sonic Boom Exposure: CDNL Contours

Figure 51 shows the CDNL contours for the Reasonably Foreseeable Future Action operations in Table 18, including the CDNL 60 through 80 dBC contours in 5 dB increments. The CDNL 60 dBC contour, which represents the significance threshold for noise sensitive areas, extends beyond the KSC and CCSFS property lines into parts of Titusville to the west and extends beyond the City of Cape Canaveral, and parts of Cocoa and Cocoa Beach to the south. The primary reason these CDNL contours extend as far as they do into residential areas is the overall high number of annual nighttime landing operations (Table 18) which include a 10-decibel penalty compared to daytime operations. Additional details of the Reasonably Foreseeable Future Action CDNL exposure, and comparison with the CDNL exposure estimates for the other operational scenarios, are provided in the noise exposure assessment summary (Section 8).

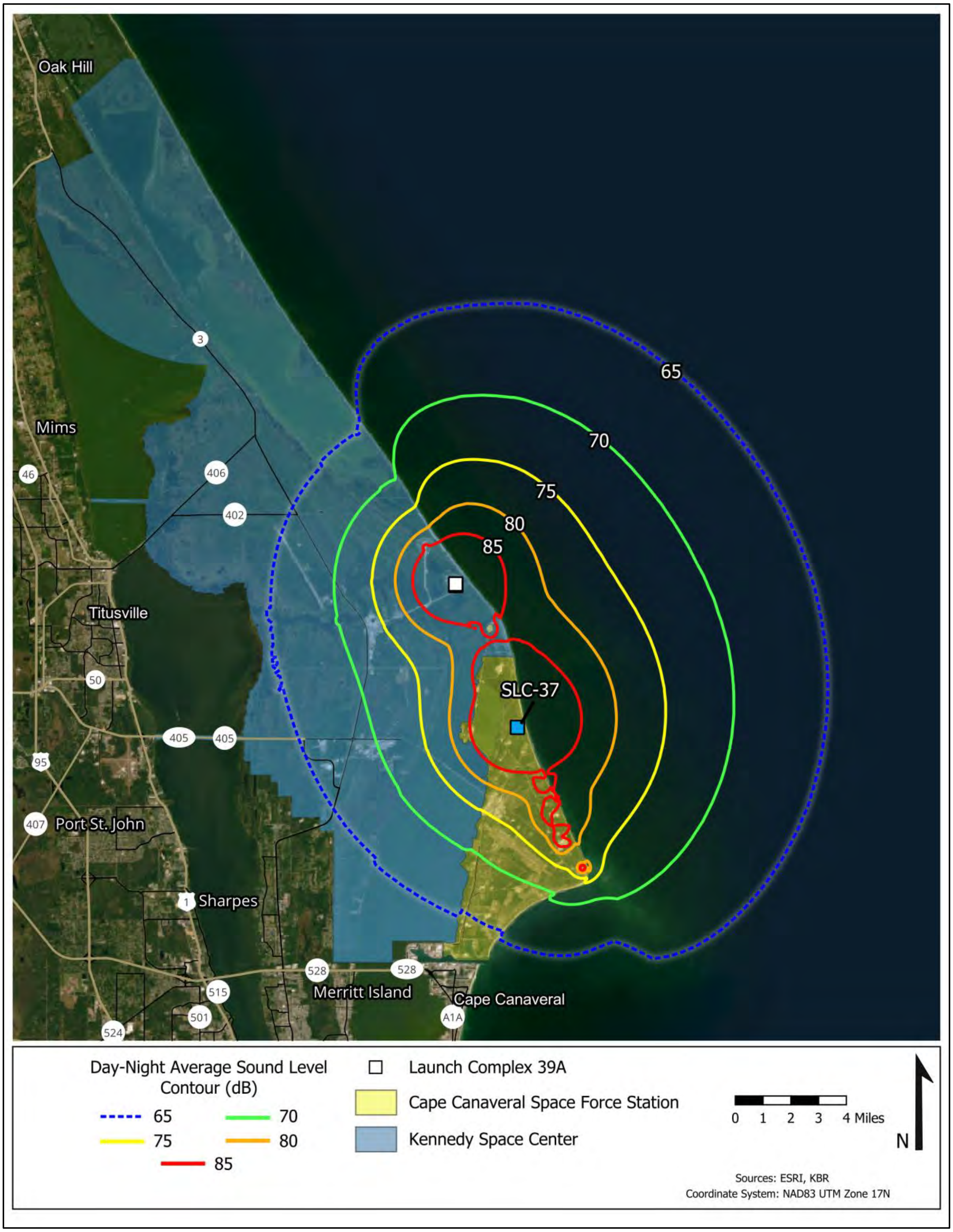

Figure 50. Reasonably Foreseeable Future Actions Rocket Noise Exposure: DNL Contours

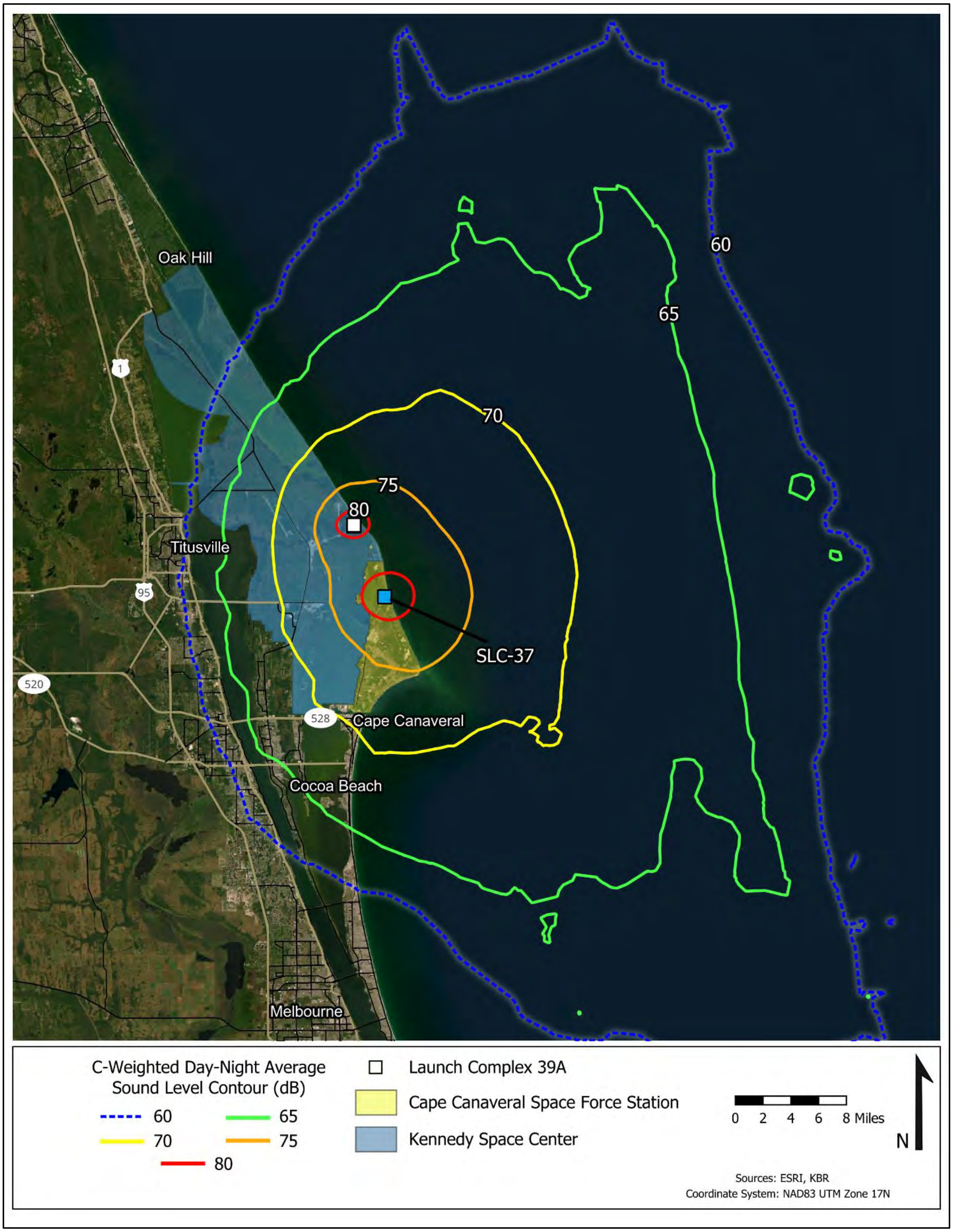

Figure 51. Reasonably Foreseeable Future Actions Sonic Boom Exposure: CDNL Contours

8 NOISE EXPOSURE ASSESSMENT SUMMARY

This section presents the primary modeling study results, for each of the operational scenarios examined in this study, shown together in figures and tables so the results can be easily compared. First, the rocket noise exposures for each operational scenario are compared using the DNL metric, followed by a comparison of the sonic boom exposures using the CDNL metric.

8.1 ROCKET NOISE EXPOSURE SUMMARY

A comparison of the DNL 65 dBA contours for all operational scenarios is shown in Figure 52 which also includes the study POIs for reference. The 65 DNL contours are color coded to represent each operating scenario which are identified in the legend. As mentioned previously, proposed Starship operations at LC-39A represent Starship operations alone, as described in Section 5, to understand what the potential impacts are from these operations only, whereas the Proposed Action represents Starship operations at LC-39A plus all the launch and landing operations associated with the No Action Scenario. Also noted previously, none of the DNL 65 dBA contours, for any of the operating scenarios, extend beyond the KSC and CCSFS properties. The DNL 65 dBA contours do not extend into any residential areas, except for Merritt Island.

The DNL contours shown on Figure 52 are associated with the DNL contour exposure data presented in Table 19 and the DNL estimates at the points of interest in Table 20. Table 19 lists, for each operational scenario, the total acreage inside each DNL contour band (from 65 to 85 dBA in 5 dB increments) along with the number of households and population in each contour band. Table 20 shows a comparison of the DNL values estimated at each POI, for each operating scenario including the Proposed Action. Noise levels less than 45 dBA DNL are similar to typical ambient sound levels and are listed as "<45".

Potential impacts from noise associated with the Proposed Action would be beneficial if the number of sensitive receptors exposed to unacceptable noise levels is reduced. Adverse impacts would occur if noise associated with the Proposed Action permanently exceeded the 65 dBA cumulative noise threshold below which most types of land use are compatible.

The FAA defines a threshold for significant noise impacts as an increase in noise by 1.5 dB DNL or more in a noise sensitive area that is exposed to noise at or above the 65 dB DNL noise exposure level, or that will be exposed at or above the 65 dB DNL level due to a 1.5 dB or greater increase, when compared to the No Action DNL exposure for the same timeframe (FAA Order 1050.1F)[7].

FAA requires that an action proponent identify where noise will change by the following specified amounts in noise sensitive areas (FAA Order 1050.1F):

- For DNL 65 dB and higher: +/- DNL 1.5 dB (significant)
- For DNL 60 dB to <65 dB: +/- DNL 3 dB (reportable)
- For DNL 45 dB to <60 dB: +/- DNL 5 dB (reportable)

According to the above definitions for noise impacts, significant impacts are identified at the POIs in Table 20 for the Proposed Action and Reasonably Foreseeable Future Actions by the shaded cells in the columns including (Δ dBA wrt No Action). DNL increases at many of the other POIs would be considered reportable.

Per FAA Order 1050.1F[7], a noise sensitive area is defined as an area where noise interferes with normal activities associated with its use. Normally, noise sensitive areas include residential, educational, health, and religious structures and sites, cultural and historical sites, and parks, recreational areas, wilderness areas, and wildlife refuges. The FAA recognizes that there are settings where the 65 dB DNL standard for land use compatibility may not apply. These areas would likely be areas of extreme quiet, very rural areas, or natural areas with little human activity, such as wilderness areas or other protected natural areas.

The primary effect of recurring aircraft noise on exposed communities is long-term annoyance. The scientific community has adopted the use of long-term annoyance as a primary indicator of community response because it attempts to account for all negative aspects of effects from noise, including sleep disturbance, speech interference, and distraction from other human activities. Attitudinal surveys conducted over the past 30 years show a consistent relationship between DNL and the percentages of people who express annoyance. DNL estimates for the operational scenarios addressed in this study can be evaluated using Table 21 to provide an estimate of the percentage of the population that would be "highly annoyed" by the noise[28].

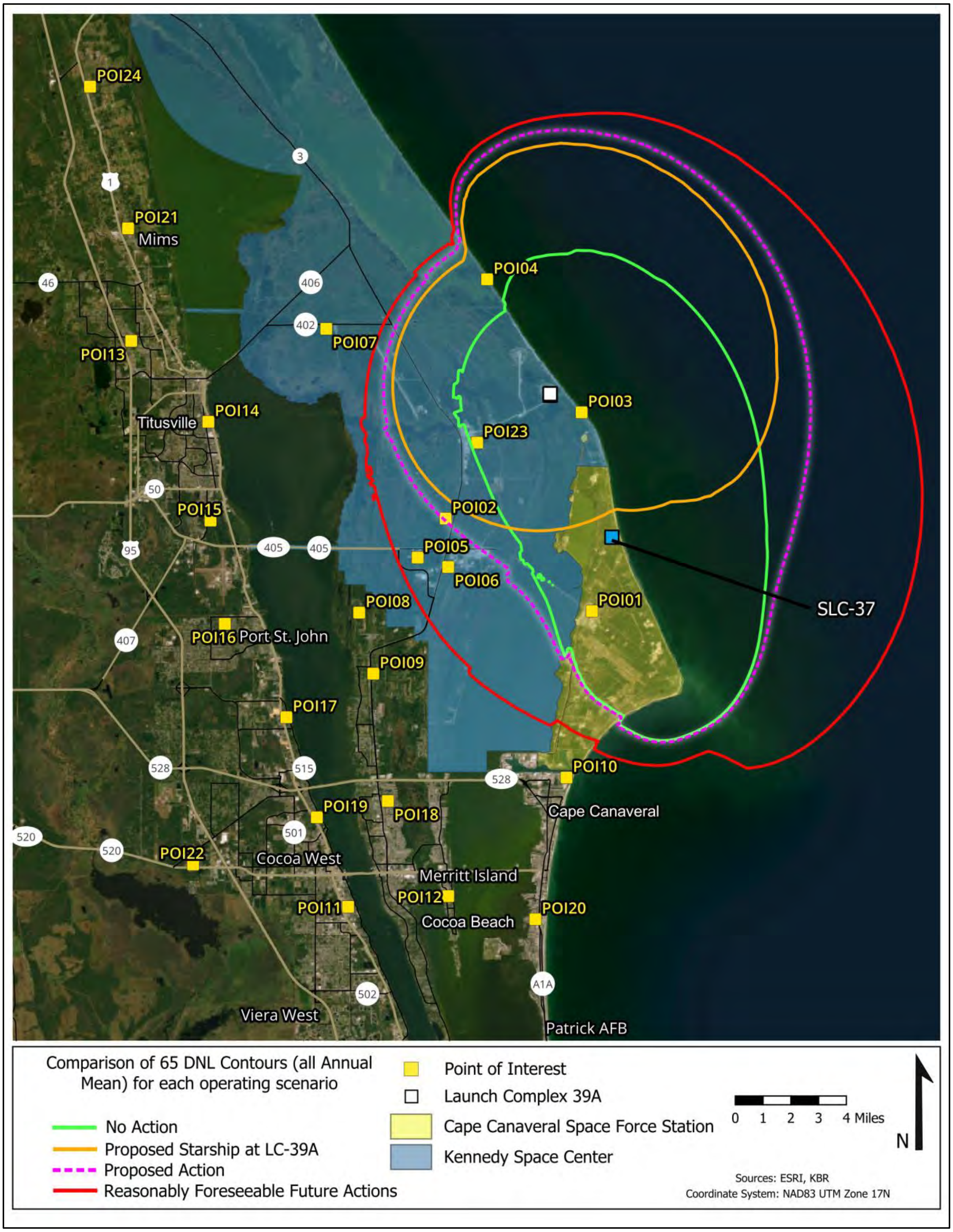

Figure 52. Comparison of 65 DNL Contours for All Operation Scenarios

Table 19. Comparison of DNL Contour Exposure Estimates for all Operation Scenarios Examined

No Action: Day-Night Average Sound Level Exposure			
DNL Band (dB)	Acreage Total	Households	Population[1]
65-70	8,683	0	0
70-75	7,075	0	0
75-80	3,609	0	0
80-85	3,000	0	0
85+	3,079	0	0
Total	**25,446**	**0**	**0**
Proposed Starship Operations (only): Day-Night Average Sound Level Exposure			
DNL Band (dB)	Acreage Total	Households	Population[1]
65-70	12,646	0	0
70-75	5,850	0	0
75-80	3,403	0	0
80-85	1,578	0	0
85+	1,906	0	0
Total	**25,383**	**0**	**0**
Proposed Action: Day-Night Average Sound Level Exposure			
DNL Band (dB)	Acreage Total	Households	Population[1]
65-70	16,943	0	0
70-75	10,756	0	0
75-80	5,852	0	0
80-85	3,731	0	0
85+	4,339	0	0
Total	**41,621**	**0**	**0**
Reasonably Foreseeable Future Action: Day-Night Average Sound Level Exposure			
DNL Band (dB)	Acreage Total	Households	Population[1]
65-70	23,783	0	0
70-75	13,211	0	0
75-80	7,175	0	0
80-85	4,313	0	0
85+	7,972	0	0
Total	**56,454**	**0**	**0**

Note: DNL = Day-Night Average Sound Level; dB = decibel (A-weighted).

1. Because there are no full-time residents living on KSC/CCSFS, and DNL exceeding 65 dB remains within the boundaries of KSC/CCSFS, the number of residents within the 65 dB DNL contour is zero. According to the 2020 Census, six people reside within the Census Tract that includes KSC/CCSFS. However, there is no on-base housing on CCSFS, and those individuals are assumed to live in parts of the Census Tract outside KSC/CCSFS.

Table 20. Comparison of DNL at the Points of Interest for all Operation Scenarios Examined

Point of Interest	Day-Night Average Sound Level (dBA)						
	Baseline	No Action	Proposed Starship Operations	Proposed Action	Proposed Action Δ dBA wrt No Action	Reasonably Foreseeable Future Actions (RFFA)	RFFA Δ dBA wrt No Action
Cape Canaveral Space Force Station (CCSFS)	61.9	70.4	58.3	70.6	0.3	77.7	7.3
SpaceX Operations Area	54.3	60.1	63.5	65.1	5.1	68.9	8.8
Titusville Beach	75.0	92.8	84.0	93.3	0.5	93.3	0.6
Playalinda Beach	53.7	61.1	68.4	69.2	8.1	69.6	8.5
Kennedy Space Center Visitor Complex	51.0	57.0	60.0	61.8	4.8	66.2	9.2
KSC Child Development Center	52.5	58.4	60.5	62.6	4.1	67.9	9.5
Merritt Island National Wildlife Refuge Visitor Center	46.2	52.8	59.7	60.5	7.8	61.9	9.1
Pine Island Conservation Area/Pine Island Estates	46.2	52.6	55.6	57.4	4.8	61.9	9.3
Kings Park Estates - Courtenay	<45	51.5	53.6	55.7	4.2	60.8	9.3
Jetty Park Campground	48.4	56.8	50.8	57.7	1.0	62.0	5.2
Rockledge High School	<45	<45	45.5	48.1	3.1	53.1	8.1
Merritt Island	<45	46.9	46.5	49.7	2.8	54.9	8.0
Oak Park Elementary School	<45	45.0	51.1	52.0	7.0	54.2	9.2
Titusville High School	<45	48.2	54.1	55.1	6.9	57.4	9.2
Summerwood Villas	<45	47.9	53.0	54.2	6.3	57.2	9.3
Atlantis Elementary School	<45	47.2	51.3	52.8	5.5	56.5	9.3
Fairglen Elementary School	<45	47.6	50.3	52.1	4.6	56.7	9.2
Lewis Carroll Elementary School	<45	48.4	49.2	51.8	3.4	57.1	8.7
Cocoa	<45	46.1	47.8	50.0	3.9	55.0	8.9
Cocoa Beach	<45	48.7	46.1	50.6	1.9	55.3	6.6
Pinegrove Estates	<45	<45	50.1	51.0	6.0	53.0	8.0
Fern Meadows	<45	<45	<45	46.6	1.6	51.1	6.1
KSC Office Outside BDA	59.7	65.9	72.4	73.3	7.4	74.2	8.2
The Rock Church	<45	<45	46.9	47.8	2.8	49.8	4.8

Note: Shaded cells indicate DNL increase greater than 1.5 dB.

Table 21. Relationship of Annoyance to DNL

DNL (dBA)	Percent Highly Annoyed
45	0.83
50	1.66
55	3.31
60	6.48
65	12.29
70	22.10

Source: Federal Interagency Committee on Aviation Noise[27].

8.2 Sonic Boom Exposure Summary

A comparison of the C-weighted Day-Night Average Sound Level (CDNL) 60 dBC contours for all operational scenarios is shown on Figure 53 which also includes the study POIs for reference. In 1981, the National Research Council (NRC) determined that CDNL was the most suitable metric to evaluate how communities would react to high-energy impulsive noise, essentially signifying that this measurement best captured the community annoyance caused by loud, sudden sounds like explosions or sonic booms[29]. CDNL 60 dBC is equivalent to DNL 65 dBA in terms of the percent of people highly annoyed. The 60 CDNL contours are color coded to represent each operating scenario which are identified in the legend. As described previously in this report, all the CDNL 60 dB contours shown on Figure 53 extend off KSC and CCSFS property into adjacent residential areas.

The CDNL contours shown on Figure 53 are associated with the CDNL contour exposure data presented in Table 22 and the CDNL estimates at the points of interest in Table 23. Table 22 lists, for each operational scenario, the total acreage inside each CDNL contour band (from 60 to 80 dBA in 5 dB increments) along with the number of households and population in each contour band. Table 22 shows a comparison of the CDNL values estimated at each POI, for each operating scenario including the Proposed Action.

Using the FAA definition for significant noise impacts (Section 8.1) except taking 60 CDNL as the threshold level, in this case, significant impacts are identified at the POIs in Table 23 using shaded cells in the columns including (Δ dBA wrt No Action). Sonic boom noise levels less than 45 dB CDNL are below relevant impact thresholds and are similarly listed as “<45” where values are below 45 dB. As can be seen for both the Proposed Action and the Reasonably Foreseeable Future Actions scenarios, most of the POIs including most of the POIs located off KSC and CCSFS properties would have a significant impact (i.e., resulting CDNL above 60 dBC and greater than a 1.5 dB increase).

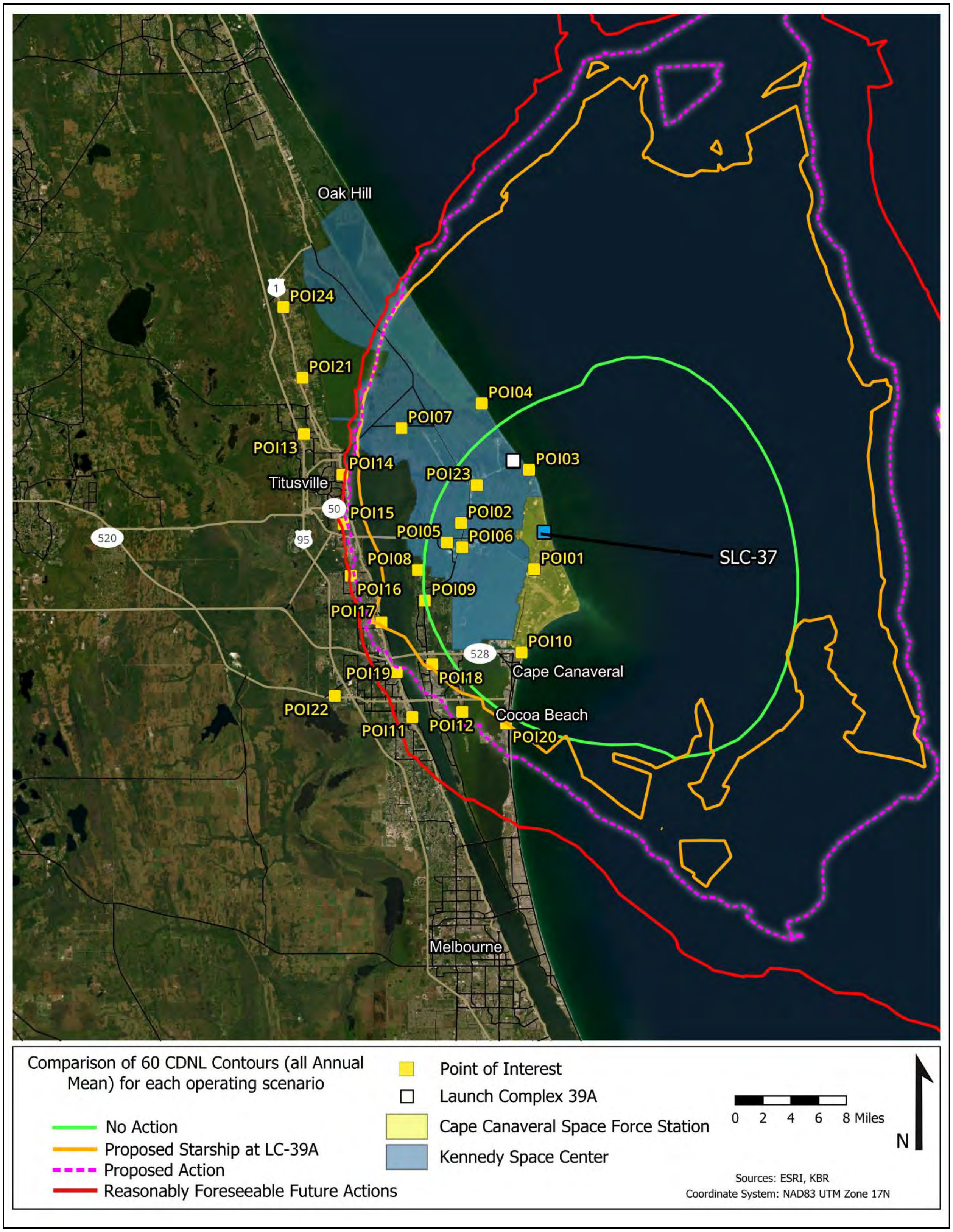

Figure 53. Comparison of 60 CDNL Contours for All Operation Scenarios

Table 22. Comparison of CDNL Exposure Estimates for all Operation Scenarios Examined

No Action: C-Weighted Day-Night Average Sound Level Exposure			
CDNL Band (dB)	Acreage	Households	Population
	Total		
60-65	43,849	15,035	18,824
65-70	10,434	0	0
70-75	5,179	0	0
75-80	0	0	0
80+	0	0	0
Total	**59,462**	**15,035**	**18,824**
Proposed Starship Operations (only): C-Weighted Day-Night Average Sound Level Exposure			
CDNL Band (dB)	**Acreage**	**Households**	**Population**
	Total		
60-65	45,345	22,726	34,957
65-70	43,035	0	
70-75	14,947	0	0
75-80	3,669	0	0
80+	1,063	0	0
Total	**108,059**	**22,726**	**34,957**
Proposed Action: C-Weighted Day-Night Average Sound Level Exposure			
CDNL Band (dB)	**Acreage**	**Households**	**Population**
	Total		
60-65	41,318	28,382	58,440
65-70	45,288	10,563	11,900
70-75	27,508	0	0
75-80	4,362	0	0
80+	1,079	0	0
Total	**119,555**	**38,945**	**70,340**
Reasonably Foreseeable Future Action: C-Weighted Day-Night Average Sound Level Exposure			
CDNL Band (dB)	**Acreage**	**Households**	**Population**
	Total		
60-65	36,427	29,575	69,774
65-70	46,931	30,803	47,499
70-75	33,537	2,958	3,665
75-80	17,089	0	0
80+	4,605	0	0
Total	**138,589**	**63,336**	**120,938**

Note: CDNL = C-Weighted Day-Night Average Sound Level; dBC = decibel (C-weighted).

Table 23. Comparison of CDNL at the Points of Interest for all Operation Scenarios Examined

Point of Interest	C-Weighted Day-Night Average Sound Level (dBC)						
	Baseline	No Action	Proposed Starship Operations	Proposed Action	Proposed Action Δ dBA wrt No Action	Reasonably Foreseeable Future Actions (RFFA)	RFFA Δ dBA wrt No Action
Cape Canaveral Space Force Station (CCSFS)	59.6	70.0	68.7	72.2	2.2	77.5	7.5
SpaceX Operations Area	50.2	61.6	67.9	68.8	7.2	72.1	10.5
Titusville Beach	52.1	62.7	78.1	78.3	15.5	79.4	16.7
Playalinda Beach	45.2	58.8	70.1	70.4	11.5	71.8	13.0
Kennedy Space Center Visitor Complex	48.9	61.2	65.7	67.0	5.8	70.5	9.3
KSC Child Development Center	51.5	62.2	67.1	68.3	6.1	72.0	9.9
Merritt Island National Wildlife Refuge Visitor Center	<45	57.0	64.1	64.9	7.8	66.4	9.3
Pine Island Conservation Area/Pine Island Estates	46.6	59.7	62.7	64.4	4.7	67.6	7.9
Kings Park Estates - Courtenay	46.8	60.0	62.4	64.4	4.4	67.5	7.5
Jetty Park Campground	53.0	63.6	64.3	67.0	3.4	70.7	7.2
Rockledge High School	<45	56.4	53.8	58.4	1.9	62.9	6.5
Merritt Island	45.0	58.8	56.2	61.0	2.2	65.5	6.7
Oak Park Elementary School	<45	<45	52.3	52.3	7.3	56.0	11.0
Titusville High School	<45	<45	57.1	57.5	12.5	59.3	14.3
Summerwood Villas	<45	55.3	56.8	59.0	3.7	60.5	5.1
Atlantis Elementary School	<45	55.5	55.8	58.7	3.2	60.1	4.7
Fairglen Elementary School	<45	57.4	60.2	62.0	4.7	63.7	6.3
Lewis Carroll Elementary School	45.3	59.1	60.5	62.8	3.8	66.8	7.7
Cocoa	<45	57.3	55.6	59.6	2.3	63.2	5.9
Cocoa Beach	46.0	59.6	60.0	62.8	3.1	67.5	7.9
Pinegrove Estates	<45	<45	51.8	51.8	6.8	55.5	10.5
Fern Meadows	<45	<45	51.4	51.4	6.4	56.2	11.2
KSC Office Outside BDA	50.4	61.4	72.6	72.9	11.6	74.7	13.4
The Rock Church	<45	<45	50.8	50.8	5.8	54.6	9.6

Notes: Shaded cells indicate CDNL increase greater than 1.5 dB. The POIs without noise values reported are located outside of the sonic boom footprint.

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