Comprehensive Pinniped Monitoring Report Missile Launches on San Nicolas Island, California, June 2014 – June 2019

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ACRONYMS AND ABBREVIATIONS

ASL	above sea level
ATAR	Autonomous Terrestrial Acoustic Recorder
B807	Building 807
B809	Building 809
CFR	Code of Federal Regulations
cm	centimeter
dB	decibel
dBA	decibel, A-weighted, to emphasize mid-frequencies and to de-emphasize low and high frequencies to which human (and pinniped) ears are less sensitive
FOV	field of view
ft	feet
hr	hour
Hz	Hertz
IHA	Incidental Harassment Authorization
in	inches
kg	kilogram
kHz	kilohertz
km	kilometer (1 km = 3281 ft, 0.62 mi, or 0.54 n.mi)
kts	knots or nautical miles per hour
LOA	Letter of Authorization
m	meter
mi	mile
min	minute
mm	millimeter
MMPA	Marine Mammal Protection Act
M_{pa}	Frequency weighting appropriate for pinnipeds in air (see Gentry et al. 2004; Southall et al. 2007)
NAWCWD	Naval Air Warfare Center Weapons Division
nm	nautical miles
NMFS	National Marine Fisheries Service
PTS	Permanent Threshold Shift
rms	root mean square (a type of average)
s	second
SEL	sound exposure level
SEL-A	A-weighted sound exposure level
SEL-M	M_{pa}-weighted sound exposure level
SNI	San Nicolas Island
SPL	sound pressure level
SPL-f	flat-weighted sound pressure level
TTS	Temporary Threshold Shift
µPa	micropascal

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EXECUTIVE SUMMARY

The U.S. Navy held a Letter of Authorization (LOA) issued by the National Marine Fisheries Service (NMFS) (Appendix A, 79 FR 32678) for the period of June 3, 2014 through June 3, 2019. The LOA allowed for the 'take by harassment' of California sea lions (*Zalophus californianus*), Pacific harbor seals (*Phoca vitulina*) and northern elephant seals (*Mirounga angustirostris*) resulting from missile launches on San Nicolas Island (SNI), California, an island owned and managed by the Navy. Past IHAs and Letters of Authorizations (LOAs) allowed take of seals and sea lions (pinnipeds) for missile launches from SNI from July 2001 through June 2014 (66 FR 41834, 67 FR 56271, 68 FR 52132, 74 FR 26580). Under the 2014-2019 LOA, the Navy submitted annual monitoring reports to NMFS in 2014, 2015, 2016 and 2017 (Ugoretz 2014, Ugoretz 2015, Ugoretz 2016, Burke 2017). This comprehensive report combines pinniped monitoring data reported in previous years with data collected in 2018. There were no launch events at SNI in the last five months of the LOA term (Jan 2019 through June 3, 2019).

The 2014-2019 LOA required submission of annual monitoring reports to NMFS in December of each calendar year. This created some confusion as events occurring late in the calendar year were reported in the following calendar year when analysis of data could be completed. Thus, annual reports often included data from two calendar years. The reporting schedule required by the LOA also did not match the permit years (June – June) for the LOA. This made it difficult to use the annual reports to evaluate whether pinniped take exceeded allowances in any given permit year. For this comprehensive report, data are organized by permit year. This allows for a direct comparison of launch numbers and pinniped harassment observations with the launch numbers and take allowed by the LOA for each permit year.

Missiles Launched

From June 3, 2014 through June 3, 2019, the Navy conducted 27 launch events at SNI using 34 missiles. Seven (7) of these events used two missiles launched within five (5) seconds of each other (dual launches). The LOA authorized up to 200 launch events for this 5-year period (40 launch events per year). Launch activity did not exceed that allowed in the LOA for any permit year.

Monitoring Equipment deployed during Missile Launches

Up to three unattended video cameras were set up to monitor pinnipeds at different sites near the missile launch trajectory. Autonomous Terrestrial Acoustic Recorders (ATARs) were deployed next to the video cameras. An additional ATAR was deployed near the launch site for each missile. Beaches monitored during launches varied based on presence of hauled out pinnipeds and proximity to the launch.

Estimated Numbers of Pinnipeds Affected

For each launch, the number of pinnipeds affected was estimated using the video recordings. Extrapolations of the number of pinnipeds affected were made when the field of view of the camera did not include the entire beach being monitored.

All pinnipeds became alert when a missile launch sound was audible on the video tape. When quantifying effects, only pinnipeds that moved more than 10 meters or entered the water were counted as being "taken" for the purposes of this permit. No evidence of pinniped injuries, fatalities or pup abandonment related to the launches was observed during this or any other monitoring period since 2001.

Approximately 3,876 California sea lions, 99 Pacific harbor seals and 11 northern elephant seals were estimated to have been affected by launches conducted during the June 2014 through June 2019 monitoring period. These estimates are approximate and include extrapolations for pinnipeds on portions of the beach that were not within the field of view of the camera and likely include instances where the

same individuals were counted more than once at different times and/or different days. These estimates correspond to an average rate of 144 sea lions, 3.6 harbor seals and 0.4 elephant seals affected per launch event. The 2014-2019 LOA authorized the take of up to 24,360 California sea lions, up to 3,430 Pacific harbor seals and up to 2,460 northern elephant seals for the 5-year period (4,872 sea lions, 686 harbor seals and 492 elephant seals per year). Estimates of affected pinnipeds did not exceed that allowed in the LOA for any permit year. Year-by-year estimates of sea lions and seals affected by launch events are included in Appendix B.

The data collected during this LOA monitoring period and pinniped monitoring data collected at SNI since 2001 suggest that any effects of the launch operations on pinnipeds were minor, short-term, and localized. It is not likely that any of the pinnipeds on SNI were adversely impacted by behavioral reactions to missile launches from the island.

The types of missiles launched during the 2014-2019 LOA monitoring period were the same or similar as those launched in previous years. The two launch sites used during this period were the same as those used during all previous reporting periods. Based on past data analyses and information collected during this period, it is unlikely that any pinnipeds incurred any temporary threshold shift (TTS) during launches at SNI. If TTS were to occur, hearing loss would have presumably been mild and recoverable and thus not have caused permanent damage.

1. MONITORING PROGRAM AND MISSILE LAUNCHES DESCRIBED

1.1 Monitoring Program

San Nicolas Island (SNI) is located approximately 65 miles (mi) (~100 kilometers (km)) from the mainland coast of southern California (Fig. 1.1). Missiles are launched from one of two land-based launch complexes on the western part of SNI. Building 807 (B807) Launch Complex is located on the west coast of SNI, approximately 35 feet (ft) (11 meters (m)) above sea level (ASL), and the Alpha Launch Complex is located approximately 625 ft (190.5 m) ASL on the west-central part of SNI (Fig. 1.2). Missiles launched from these sites pass over or near pinniped haul-out sites located around the northwestern periphery of SNI. The pinniped species that commonly occur on SNI include California sea lions (*Zalophus californianus*), Pacific harbor seals (*Phoca vitulina*) and northern elephant seals (*Mirounga angustirostris*).

The 2014-2019 LOA included provisions to monitor effects of missile launch activities on pinnipeds hauled out at SNI in a manner similar to pinniped monitoring that took place during Navy launch activities from 2001–2014 (66 FR 41834, 67 FR 56271, 68 FR 52132, 74 FR 26580). The Navy submitted annual monitoring reports for this LOA to NMFS in 2014, 2015, 2016 and 2017 (Ugoretz 2014, Ugoretz 2015, Ugoretz 2016, Burke 2017). Pinniped species monitored on SNI included the California sea lion, Pacific harbor seal and northern elephant seal. Selection of monitoring sites focused on California sea lions and Pacific harbor seals because past monitoring efforts confirmed that northern elephant seals had little to no reactions to launches from SNI (NMFS 2010, 75 FR 71672).

This comprehensive report combines the data reported in previous years (2014-2017) with data collected in 2018. There were no launch events at San Nicolas in the last five months of the LOA term (Jan 2019 through June 3, 2019.

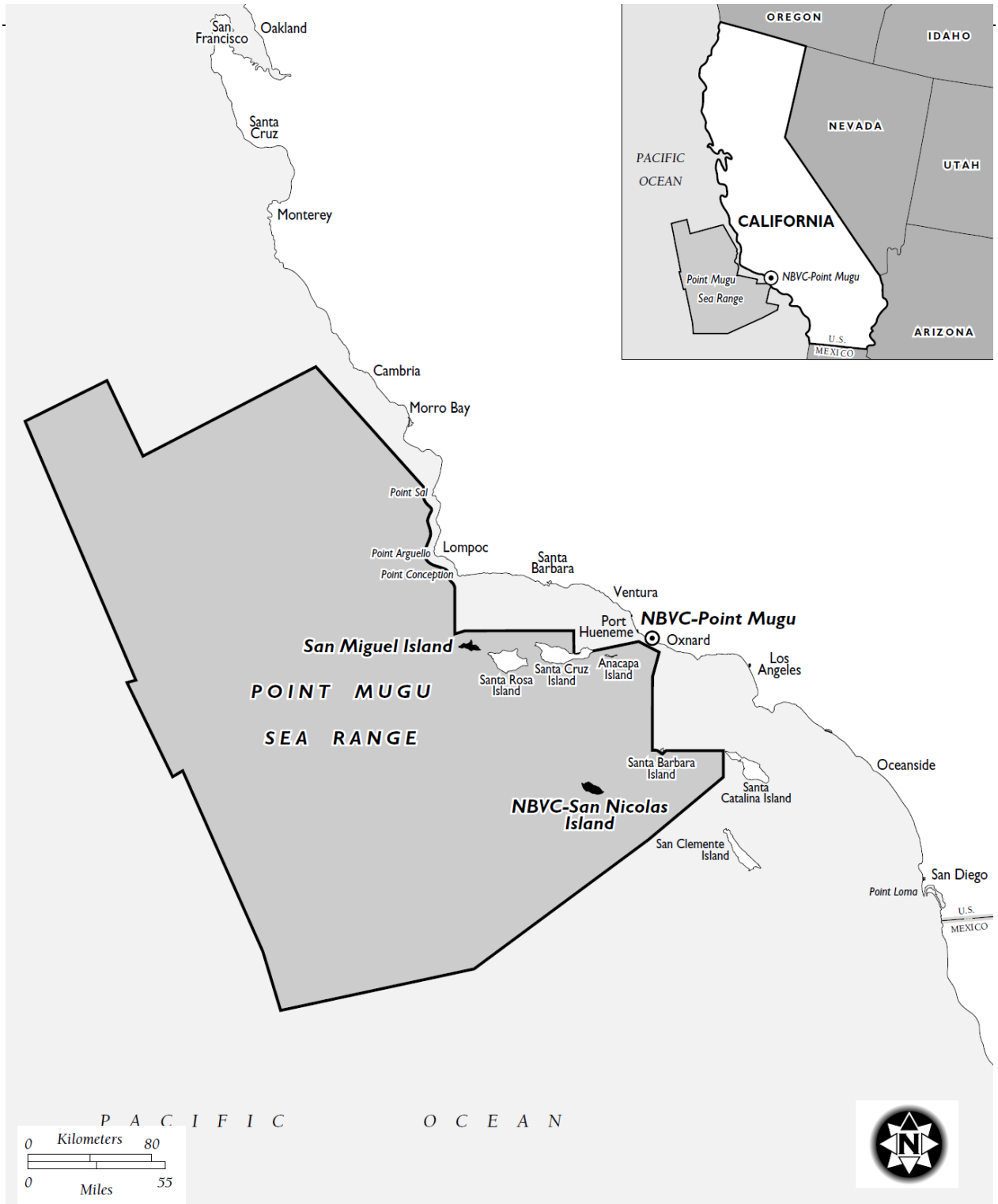

FIGURE 1.1. Regional site map of the Point Mugu Sea Range and San Nicolas Island, California

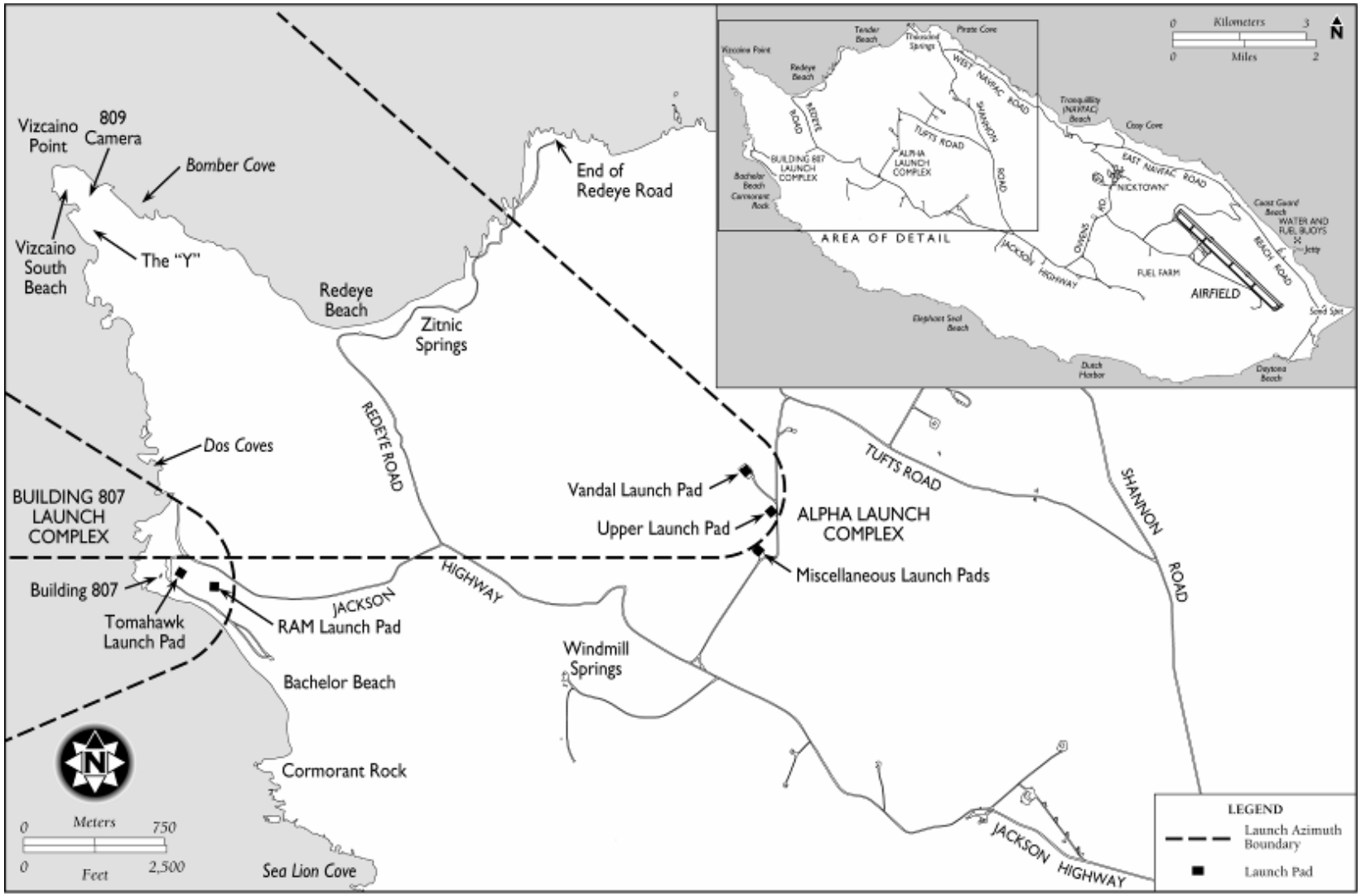

FIGURE 1.2. Map of San Nicolas Island, California, and the general launch azimuths (dashed lines) for each launch complex. These launch azimuths are typical, although occasionally launch paths could pass outside these boundaries.

The monitoring plan required that, for each launch event conducted on SNI, simultaneous autonomous audio recording of launch sounds and video recording of pinniped behavior occur. Generally, monitoring occurred at three haul outs during each launch, dependent upon the presence of pinnipeds in various locations. This monitoring provides data required to characterize the extent and nature of "taking". In particular, it provides information needed to document the nature, frequency, occurrence, and duration of any changes in pinniped behavior resulting from missile launches, including the occurrence of stampedes (if any).

1.1.1 Audio Monitoring

During all launches in this monitoring period Autonomous Terrestrial Acoustic Recorders (ATARs) were placed in the same location as video cameras documenting pinniped reactions, thus obtaining paired acoustic and pinniped-response data, in addition to recording launch sounds, these audio recordings also documented ambient noise levels prior to and following the launches. Objectives of the audio monitoring program included:

1. Document levels and characteristics of launch sounds at several distances from the missile paths;
2. Document levels and characteristics of ambient sounds at the same locations as launch sounds, as a measure of the background noise against which the pinnipeds will (or will not) detect the launch sounds; and
3. Determine if the sound levels from missile launches were high enough to have the potential to induce Temporary Threshold Shift (TTS) in pinnipeds exposed to launch sounds.

1.1.2 Visual Monitoring

Video and direct visual monitoring provides data on focal groups of pinnipeds hauled out on SNI during launches (See Chapter 3 for details). The accumulation of such data across numerous launches provides information necessary to characterize the nature and extent of disturbance effects. In particular, it provides the information needed to document the nature, frequency, occurrence, and duration of any changes in pinniped behavior resulting from the missile launches, including the occurrence of stampedes from haul-out sites if they occur.

Video records documented pinniped responses to missile launches. Objectives include the following:

1. Identify and document any change in behavior or movements that occurred at the time of the launch;
2. Quantify the interval required for pinniped numbers and behavior to return to normal if there was a change as a result of launch activities;
3. Ascertain periods or launch conditions when pinnipeds are most and least responsive to launch activities;
4. Document numbers of pinnipeds affected by missile launches and, although unlikely, any mortality or injury.

1.2 Impact Estimates

The monitoring program for the missile launches on SNI was designed, in part, to provide data necessary to estimate the numbers of pinnipeds affected by launches and the manner in which they were affected. For military readiness activities, the MMPA defines harassment as:

"1) any act that injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild; or, (2) any act that disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns, including, but not limited to,

migration, surfacing, nursing, breeding, feeding, or sheltering, to a point where such behavioral patterns are abandoned or significantly altered." [10 USC Ch. 631§7235]

Since no injuries or deaths were observed and no pups were abandoned during the monitored launches in either this monitoring period or earlier monitoring dating back to August 2001, determining disturbance level, rather than injury or mortality, became the primary monitoring objective. The number of pinnipeds on the monitored beaches that may have been affected by the launches is estimated. Estimates were always conservative, assuming the highest possible level of impact. The Navy, consistent with NMFS guidance (NMFS 2002), assumes that a pinniped blinking its eyes, lifting or turning its head, or moving a few feet along the beach as a result of a human activity is not significantly affected (i.e., not harassed).

In this report, consistent with previous related reports (Holst et al., 2008, 2011; Ugoretz and Greene 2012, Ugoretz, 2013, Ugoretz 2014, Ugoretz 2015, Ugoretz 2016, and Burke 2017), it was assumed that only those pinnipeds meeting either of the following criteria were affected by launches:

1. Pinnipeds exposed to launch sounds strong enough to cause TTS; and
2. Pinnipeds that left the haul-out site, or exhibited prolonged movement (> 10 m) or prolonged behavioral changes (such as pups separated from mothers) relative to their behavior immediately prior to the launch.

In practice, since August 2001, no pinnipeds have received sounds strong enough to elicit PTS, and few, if any, are believed to have received sounds strong enough to elicit TTS (section 4.2). Thus, the number of pinnipeds counted as potentially affected during the monitoring period was based on criterion (2) – the number that left the haul-out site, or exhibited prolonged movement.

1.3 Launch Dates and Information

From June 3, 2014 through June 3, 2019, the Navy conducted 27 launch events at SNI using 34 missiles (Table 1.1). Seven (7) of these events used two missiles launched within five (5) seconds of each other (dual launches). All missiles crossed SNI's shoreline on the western end of the island.

TABLE 1.1. Launch data for June 2014 through June 2019.

Launch Date	Launch Time (local)	Launch Complex	
06/17/2014	14:58	B807	
08/05/2014	11:42	B807	
08/06/2014	13:32	B807	
09/04/2014	14:36	Alpha	Permit Year 1
09/04/2014	17:30	Alpha	
12/18/2014	11:24	Alpha	
05/13/2015	13:49	Alpha	
06/06/2015	18:00	B807	
10/15/2015	10:30	B807	
10/21/2015	12:27	B807	
10/27/2015	14:10	B807	Permit Year 2
12/08/2015	0600	B807	
12/17/2015	1400	Alpha	
02/04/2016	10:45	Alpha	
04/07/2016	10:50	Alpha	
10/19/2016	12:32	B807	
10/27/2016	14:55	B807	Permit Year 3
12/03/2016	09:56	Alpha	
05/12/2017	09:30	Alpha	
09/14/2017	09:45	Alpha	
11/21/2017	10:33	B807	
11/29/2017	14:18	Alpha	
11/30/2017	0935	B807	Permit Year 4
04/22/2018	10:00	Alpha	
04/22/2018	11:20	Alpha	
10/02/2018	11:25	B807	
10/18/2018	11:20	B807	Permit Year 5

2. ACOUSTIC MEASUREMENTS OF MISSILE LAUNCHES

2.1 Introduction

The acoustic measurement program for the monitoring period was consistent in approach and methodology with that used during the preceding years (Ugoretz 2016, Ugoretz 2015, Holst et al. 2011). Recordings of each missile's sound, as well as background sounds, were attempted at up to three pinniped haulout sites as well as the launch pad during each missile launch. ATARs were developed for this purpose by the Navy's acoustical contractor, Greeneridge Sciences Inc. of Santa Barbara, California. The specific design of the ATARs was described in earlier reports (Ugoretz 2016, Ugoretz 2015, Holst et al. 2011).

Sound levels that might cause notable disturbance for each pinniped species are variable and context-dependent (Lawson et al. 1998). Lawson et al. (1998) estimated the minimum received level, on an A-weighted Sound Exposure Level (SEL-A, measuring the "loudness" of the sound) basis, that might elicit substantial disturbance as 100 A-weighted decibels (dBA) reference 20 micropascals squared second (re 20 $\mu Pa^2 \cdot s$) for all pinnipeds. The 100 dBA re 20 $\mu Pa^2 \cdot s$ SEL pertains to exposures to prolonged sounds, which were taken to last at least several seconds. Measured durations of sound from various types of missiles launched from SNI typically range from less than 1 s up to 21 s (Holst et al. 2008). In any event, the assumption that reactions might occur at distances up to those where received levels diminished to 100 dBA SEL (see Fig. 2.39 *in* Greene and Malme 2002) was one influencing factor in selecting acoustic (and video) monitoring sites during the first year of monitoring (2001). Sites at distances up to ~4 km from the launcher and/or launch trajectory are currently monitored, though closer sites are selected when animals are present.

After reviewing video recordings of pinnipeds during launches at SNI during 2001–2002 (Holst and Lawson 2002), the 100-dBA SEL is reasonable as a minimum received level that might elicit disturbance of California sea lions. However, 90 dBA SEL is more appropriate for Pacific harbor seals, as they showed a strong response to most launches, including a number of launches where received levels were <100 dBA SEL. In contrast, the majority of northern elephant seals usually exhibited little or no reaction to launch sounds. The received levels of sounds from the larger missiles, as measured in the first year of monitoring, indicated that levels at or above 90 dBA SEL could be expected out to distances of ~4 km from the launch trajectory (see Fig. 2.39 *in* Greene and Malme 2002). Thus, monitoring at sites located ~4 km from the launcher and/or launch trajectory continued during subsequent years. Continuing data collection and monitoring shows some behavioral responses may extend to received sound levels lower than 90 dBA SEL.

Southall et al. (2007) note that M_{pa}-weighted (i.e., frequency-weighted appropriately for pinnipeds in air) SELs of 100 dB re 20 $\mu Pa^2 \cdot s$ could result in takes by harassment for pinniped species (M-weighted values are greater than A-weighted SELs for launch sounds). Previous monitoring at SNI shows that California sea lions and Pacific harbor seals typically move along the beach and/or enter the water at M_{pa}-weighted SELs ≥100 dB re 20 $\mu Pa^2 \cdot s$. In fact, both species can be disturbed at lower levels. For example, Holst et al. (2008) noted that some Pacific harbor seals leave the haul out site and/or enter the water at SELs as low as 60 dB M_{pa}.

2.2 Field Methods

2.2.1 Deployment of ATARs

Prior to each launch, ATARs were positioned at the launch pad and near pinniped haul out sites at varying distances from the launch locations. The recordings provided data for later quantitative analysis of the levels and characteristics of the received flight sounds. ATARs were set up between one and four hours prior to the launch and retrieved in the hour following the launch. The ATAR units were deployed at sites

as close as practical to the pinniped haul-out sites being monitored with video cameras. The total number of sites monitored depended upon the presence of pinnipeds on beaches in the potentially impacted area.

Analyses of acoustic data collected between August 2001 and October 2008 were reported by Holst et al. (2011). In those analyses, factors considered included missile type, launch azimuth, launch characteristics (e.g., low- vs. high-angle launch), as well as weather, which has important effects on the received sounds. Holst et al. reported that the majority of observed California sea lions startled and showed increased vigilance up to 2 min after each launch; responses often included movement on the beach or into the water and were significantly related to received sound level and distance from the vehicle's closest point of approach. Most observed northern elephant seals showed little reaction to launches and merely raised their heads briefly. Nonetheless, their responses were also related to received sound level and distance from vehicle trajectory. Pacific harbor seals were the most responsive with an average of 68% (range 7 to 100%) of observed harbor seals within ~4 km of the launch trajectory departing haul-out sites by entering the water. Within the range of conditions studied, there was no clear correlation between the degree of harbor seal response and received sound level or distance from the closest point of approach of the vehicle.

2.3 Audio Data Analysis Methods

Both time-series and frequency-domain analyses are performed on the acoustic data. Time-series results included signal waveform and duration, peak pressure level (peak), root mean square (rms) sound pressure level (SPL), and SEL. SPL and SEL were determined with three alternative frequency weightings: flat-weighted (SPL-f and SEL-f), A-weighted (SPL-A and SEL-A), and M_{pa}-weighted (SPL-M and SEL-M) basis. The M_{pa}-weighting procedure, appropriate for pinnipeds in air, is described in Southall et al. (2007) and in past monitoring reports (Ugoretz 2016, Ugoretz 2015, Holst et al. 2011). Frequency-domain results included estimation of SPLs in one-third octave bands for center frequencies from 4 to 16,000 kHz. The following subsection describes how these values are defined

2.3.1 Frequency Weighting

Frequency weighting is a form of filtering that serves to measure sounds over a broad frequency band with various schemes for de-emphasizing sounds at frequencies not heard well and retaining sounds at frequencies that animals hear well. The concept is that sound at frequencies not heard by animals is less likely to injure or disturb them, and therefore such sounds should not be included in measurements relevant to those animals. Time-series results for the full 3 to 20,000 Hz bandwidth are calculated for flat-, A-, and M_{pa}-weightings.

Flat-weighting leaves the signal spectrum unchanged. For instantaneous peak pressure, where the highest instantaneous pressure is of interest, it is not useful to diminish the level with filtering, so only the flat-weighted instantaneous peak pressure is relevant. Also, non-uniform weighting is not useful when reporting results for specific frequencies or narrow frequency bands. Therefore, only flat-weighting is used for frequency-domain analyses.

A-weighting shapes the signal's spectrum based on the standard A-weighting curve (Kinsler et al. 1982, p. 280; Richardson et al. 1995, p. 99). This slightly amplifies signal energy at frequencies between 1 and 5 kHz and attenuates signal energy at frequencies outside this band. This process is designed to mimic the frequency response of the human ear to sounds at moderate levels. It is a standard method of presenting data on airborne sounds. The relative sensitivity of pinnipeds listening in air to different frequencies is more-or-less similar to that of humans (Richardson et al. 1995), so A-weighting may be relevant to pinnipeds listening to moderate-level sounds, as a first approximation.

M_{pa}-weighting arose from the ongoing effort to develop science-based guidelines for regulating sound exposures (Gentry et al. 2004; Southall et al. 2007). During this process, separate weighting functions were developed for five categories of marine mammals, with these functions being appropriate in relation to the hearing abilities of those groups of mammals (Gentry et al. 2004; Southall et al. 2007). Two of these categories are pinnipeds hearing in water and in air, for which the weighting functions were designated M_{pw} and M_{pa}, respectively. The five "M-weighting" functions are almost flat between the known or inferred limits of functional hearing for the species in each group, but down-weight ("attenuate") sounds at higher and lower frequencies. As such, they are analogous to the C-weighting function that is often applied in human noise exposure analyses where the concern is about potential effects of high-level sounds. With M_{pa}-weighting, the lower and upper "inflection points" are 75 Hz and 30 kHz[1]. For each launch whose sounds are reported, we include the M_{pa}-weighted results as well as flat- and A-weighted results. Acoustic data based on M_{pa}-weighting are included because these values are likely to be needed in the future for purposes of assessing impacts on pinnipeds of sounds with high received levels, such as those during some missile overflights.

2.4 Acoustic Monitoring Results

2.4.1 Missile Flight Sounds

A detailed analysis of sound data collected from the ATARs during this period can be found in the reports submitted to NMFS for this period (Ugoretz 2014, Ugoretz 2015, Ugoretz 2016, Burke 2017) and in Appendix C for launches from mid-November 2017 and the expiration of the LOA on June 3, 2019. The types of missiles launched during this monitoring period were the same or similar to those launched in previous years. The two launch sites used from 2014-2019 were the same as those used for all previous reporting periods. Based on data collected during the 2014-2019 LOA period, it is unlikely that any pinnipeds incurred any temporary threshold shift (TTS) during launches at SNI. If TTS were to occur, hearing loss would have presumably been mild and recoverable and thus not have caused permanent damage.

[1] The data obtained during the current monitoring period were only recorded at frequencies up to 20 kHz, so the (probably negligible) energy at 20–30 kHz is not included in calculating the M_{pa} (or other) measures.

3. PINNIPED BEHAVIOR DURING MISSILE LAUNCHES

3.1 Introduction

Three species of pinnipeds are common on SNI beaches – California sea lion, Pacific harbor seal, and northern elephant seal. No other pinniped species were observed during this or previous monitoring periods since August 2001 (Burke 2017, Ugoretz 2016, Ugoretz 2015, Ugoretz 2014, Holst et al. 2011).

California sea lions often show startle responses to launches and movement along the beach. In most cases, sea lion behavior returns to pre-launch levels within seconds or minutes following the launches (Holst et al. 2011). Behavior as well as numbers of sea lions hauled-out several hours after a launch appears similar to the behavior and numbers observed before a launch.

In contrast, Pacific harbor seals often react strongly to launch sound. They commonly leave their haul-out sites to enter the water. Early monitoring reports suggested that harbor seals did not return to a haul out site for several hours or the next tide cycle (Holst et al. 2011). Holst and Lawson (2002) noted that the behavior and numbers of Pacific harbor seals hauled out on the day following a launch were similar to those on the day of the launch. Focused monitoring of harbor seals during this monitoring period indicate that harbor seals will return to their haul out within minutes of a launch. Distribution and abundance of harbor seals at the sites monitored were strongly influenced by the height of the tide.

Northern elephant seals are often startled by missile launch sounds but have otherwise shown little or no reaction to previous missile launches and directed monitoring of elephant seals was not required by the 2014-2019 LOA. During this monitoring period, elephant seals were present on many of the monitored haul-outs along with other species and were included in the camera's field of view. On most occasions, elephant seal reactions were similar to those in the past (generally no movement or very minor movement down the beach) reconfirming their lack of reaction to missile launches.

3.2 Field Methods

The launch monitoring program is based primarily on remote video recordings and later analysis. Remote cameras are essential because, during missile launches, safety requirements prevent personnel from being present in many of the areas of interest. Video data are obtained via video cameras mounted on tripods at the monitoring locations. In addition, trained staff make notes on the status of pinnipeds on monitored beaches as well as other locations around the island prior to and following launches.

3.2.1 Visual Observations

Video recordings were obtained before, during, and after each missile launch. Navy biologists also make direct visual observations of the pinniped groups prior to deployment of the cameras and ATARs as well as after the launch when collecting equipment. Records from these visual observations include the local weather conditions, the type of launch activity planned, types and locations of any pinnipeds hauled out and notable impacts if any, as well as notes on tidal changes or other confounding factors.

Video recordings continue for approximately 15-60 min or more after the launch. If reactions to the launch occur, recordings during the post-launch period determine how quickly animals returned to pre-launch behaviors. These recordings also help determine whether the relative number of pinnipeds at the haul-out site have changed, and if there was obvious evidence of recent injury or mortality.

During the launches described in this report, use of video methods allowed for observations of up to three pinniped species during the same launch. The actual number of species observed depended on the number of video systems deployed during a launch and on the number of species hauled out at the monitoring sites.

Cameras were placed at locations overlooking haul-out sites prior to each launch in a manner that minimized disturbance to pinnipeds. When the entire haul-out aggregation at a given site could not be captured in the camera's field of view, a representative focal subgroup within the haul-out aggregation was selected. The number of animals affected at a given location was estimated based on the percentage of beach observed and percentage of the focal group affected with the assumption that animals were equally distributed along the beach.

3.2.2 Digital Video Cameras

To monitor daytime launches, Navy biologists place up to three portable Sony high definition digital video cameras (HDR-CX160) on tripods overlooking haul-out sites. Missile and other sounds detected by the microphones built into these cameras were also recorded. The audio data collected by the video cameras were used during behavioral analyses (e.g., to confirm the exact time when the missile was launched), but were not calibrated and not of sufficient quality to provide detailed launch sound information.

Video Monitoring Analysis

Digital video recordings were reviewed by an experienced biologist on a high-resolution color monitor. The recordings before, during, and up to 60 min after each launch were reviewed to document the types and numbers of pinnipeds present, the nature of any overt responses to the launch, and the number of pinnipeds that overtly responded. The number, proportion and age class (adult or pup - where determinable) of the individuals that responded in various ways is determined from the video, along with comparable data for those that did not respond. Following NMFS guidance [NMFS 2002], subtle behavioral reactions persisting for only a few minutes are considered unlikely to have biologically significant consequences for the pinnipeds. Pinnipeds that moved into the water or greater than 10 m (33 ft) along the beach were considered to have been affected.

3.3 Implementation of Mitigation Measures

Table 3.1 shows a summary of the mitigation measures that were specified by NMFS in the LOA, and how they were implemented during the June 2014 through June 2019 monitoring period.

TABLE 3.1. Implementation of mitigation measures.

Mitigation Measure	Implementation
Prohibiting personnel from entering pinniped haul-out sites below the missile's predicted flight path for two (2) hours prior to planned missile launches.	Personnel on San Nicolas Island were prohibited from entering pinniped haul-out areas. Monitoring personnel set up video and audio equipment near haul-outs without disturbing pinnipeds.
Avoiding launch activities during harbor seal pupping season (February through April), unless constrained by factors including, but not limited to, human safety, national security, or for launch trajectory necessary to meet mission objectives.	Four (4) launch events occurred from February through April during this period (02/04/2015, 04/07/2015, and two events on 04/27/2018). These launches were required to meet mission objectives. No harbor seal injury, mortality or pup separations were observed during monitoring efforts.
Limiting launch activities during other pinniped pupping seasons, unless constrained by factors including, but not limited to, human safety, national security, or for launch trajectory	Some mission critical launch events were conducted during the sea lion and elephant seal pupping seasons. Elephant seals do not tend to move from their resting spots during launch events and there is no evidence that pups were harmed or separated from their mothers. The sea lion pup rearing season runs through much of the year. No

necessary to meet mission objectives.	launch events occurred in July, at the peak of the breeding season, and there is no evidence of pup injury, mortality or separation resulting from launches.
Not launching missiles from the Alpha Complex at low elevation (less than 1,000 ft [305m]) on launch azimuths that pass close to pinniped haul-out site(s) when occupied.	No missiles launched from Alpha Complex pass less than 1,000 ft. over pinniped haul-out sites
Avoiding the launch of multiple missiles in quick succession over haul-out sites, especially when young pups are present, except when required by mission objectives.	There were seven dual launch events, two missiles fired within 5-seconds of each other, during this reporting period. These events were all required to meet mission objectives. Given the exceedingly short period between launches, dual launches are treated as one event.
Limiting launch activities during nighttime hours, except when required by mission objectives.	No launch events were conducted at night during this period.
Ensuring that aircraft and helicopter flight paths maintain a minimum altitude of 1,000 ft (305m) from pinniped haul-outs and rookeries, except in emergencies or for real-time security incidents	All aircraft maintained a minimum altitude of 1000 ft. from pinniped haul-out areas and rookeries.
Reviewing the launch procedure and monitoring methods, in cooperation with NMFS, if any incidents of injury or mortality of a pinniped discovered during post-launch surveys or indications of effects to the distribution, size, or productivity of the affected pinniped populations as a result of the authorized activities are thought to have occurred.	No injured or dead pinnipeds related to launch activities were observed during the monitoring period. No evidence of effects to the distribution, size or productivity of affected pinniped populations.

4. TOTAL ESTIMATED NUMBERS OF PINNIPEDS AFFECTED

4.1 Pinniped Behavioral Reactions to Noise and Disturbance

Some of the pinnipeds on the beaches at SNI exhibit disturbance reactions to missile launches, but others do not. The levels, frequencies, and types of noise that elicit a response vary between and within species, individuals, locations, and seasons. Reactions to the same missile types also varied from one launch to the next, possibly due to weather conditions, tide height, ambient noise or other factors. It is possible that pinnipeds hauled out on land may react to the sight (light at night), or the combined sight plus sound, of a missile launch but reaction to the sudden change in sound during a launch is likely the primary triggering factor. Furthermore, pinnipeds, at times, react to the sight and sound of seabirds and other pinnipeds reacting to a launch. Thus, responses are not expected to be a direct function of received sound level. However, some correlation between pinniped responses and received sound level has been shown, at least for California sea lions and elephant seals, based on data from previous monitoring periods (Holst et al. 2011).

For pinnipeds hauled out on land, behavioral changes ranged from a momentary startle reaction or an upright posture to movement – either abrupt or deliberate – into the water. Previous studies indicate that the reaction threshold and degree of response are related to the activity of the pinniped at the time of the disturbance. In general, there is much variability and pinnipeds often show considerable tolerance of noise and other forms of human-induced disturbance, though at other times certain pinnipeds can be quite responsive (Richardson et al. 1995; Reeves et al. 1996; Lawson et al. 1998).

It is possible that pinnipeds exposed to launch noise might "stampede" from the haul-out sites in a manner that causes injury or mortality but this was not observed during monitoring of launches from SNI. During some launches in the 2002-2003 monitoring period, several Pacific harbor seal pups were knocked over by adult seals as both pups and adults moved toward the water in response to the launch though no injuries were observed (Holst 2008). Similarly, during the 2004-2005 monitoring period, several California sea lion pups were knocked over by adult sea lions as the adults moved along the beach in response to a launch (Holst and Greene 2008). The pups were momentarily startled, but did not appear to be injured.

Since no injuries or deaths were observed and no pups were abandoned during the monitored launches in either this monitoring period or earlier monitoring dating back to August 2001, determining disturbance level, rather than injury or mortality, became the primary monitoring objective. The number of pinnipeds on the monitored beaches that may have been affected by the launches is estimated. Estimates were always conservative, assuming the highest possible level of impact. The Navy, consistent with NMFS guidance (NMFS 2002), assumes that a pinniped blinking its eyes, lifting or turning its head, or moving a few feet along the beach as a result of a human activity is not significantly affected (i.e., not harassed).

In this report, consistent with previous related reports (Holst et al., 2008, 2011; Ugoretz and Greene 2012, Ugoretz, 2013, Ugoretz 2014, Ugoretz 2015, Ugoretz 2016, and Burke 2017), it was assumed that only those pinnipeds meeting either of the following criteria were affected by launches:

1. Pinnipeds exposed to launch sounds strong enough to cause TTS; and
2. Pinnipeds that left the haul-out site, or exhibited prolonged movement (> 10 m) or prolonged behavioral changes (such as pups separated from mothers) relative to their behavior immediately prior to the launch.

In practice, since August 2001, no pinnipeds have received sounds strong enough to elicit PTS, and few, if any, are believed to have received sounds strong enough to elicit TTS (see §4.2, below). Thus, the number of pinnipeds counted as potentially affected during the monitoring period was based on criterion (2) – the number that left the haul-out site, or exhibited prolonged movement.

The numbers of affected pinnipeds were calculated for both observed pinnipeds and pinnipeds on unobserved portions of beaches being monitored. Disturbance reactions were short-lived for California sea lions and did not appear to extend into subsequent days. Pacific harbor seals often enter the water during a launch but recent observations suggest that they return to haul out areas within minutes if tide conditions permit. Based on this and past monitoring, it is assumed that no long-term affects to pinnipeds have occurred.

4.2 Possible Effects on Pinniped Hearing Sensitivity

Temporary or permanent hearing impairment is a possibility when pinnipeds are exposed to very strong sounds in air. Based on data from terrestrial mammals, the minimum sound level necessary to cause PTS is presumed to be higher, by a variable and generally unknown amount, than the level that induces barely-detectable TTS. Given what is known about the thresholds for TTS and PTS in terrestrial mammals and humans, the PTS threshold is expected to be well above the TTS threshold for non-impulsive sounds. For impulsive sounds, such as sonic booms and artillery shots, the difference may be smaller (Kryter 1985; Southall et al. 2007). As described below, missile launch sounds are sometimes impulsive.

4.2.1 Temporary Threshold Shift

There are few published data on TTS thresholds for pinnipeds in air exposed to impulsive or brief non-impulsive sounds. J. Francine, quoted in NMFS (2001, p. 41837), has mentioned evidence of mild TTS in captive California sea lions exposed to a 0.3 s transient sound with an SEL of 135 dBA re 20 $\mu Pa^2 \cdot s$ (see also Bowles et al. 1999). Katsak, et al. (2007) estimated TTS onset for California sea lions in air at 159 dB re 20 $\mu Pa^2 \cdot s$. However, mild TTS may occur in harbor seals exposed to received levels lower than 135 dB SEL (A. Bowles, pers. comm., 2003). Initial evidence from more prolonged (non-pulse) exposures suggests that the TTS threshold on an SEL basis may actually be around 129–131 dB re 20 $\mu Pa^2 \cdot s$ (M_{pa}-weighted) for harbor seals, within their frequency range of good hearing (Kastak et al. 2004; Southall et al. 2007). The same research teams have found that the TTS thresholds of California sea lions and northern elephant seals exposed to strong sounds are higher as compared to harbor seals (Kastak et al. 2005). Based on these studies and other available data, Southall et al. (2007) proposed that sounds may induce mild TTS if the received peak pressure is ~143 dB re 20 µPa, or if received SEL-M is ~129 dB re 20 $\mu Pa^2 \cdot s$ (for pulses) or 131 dB re 20 $\mu Pa^2 \cdot s$ (for non-pulses received in air). Those levels apply specifically to harbor seals and are not expected to elicit TTS in elephant seals or California sea lions (Southall et al. 2007). Thus, as a conservative estimate, it is assumed that all three species might have TTS onset at a received SEL-M of >129 dB re 20 $\mu Pa^2 \cdot s$.

The sounds received from missile launches on SNI are sometimes impulse sounds (e.g., when near the launcher). At other times and locations they are non-impulsive. During monitoring of missile launches from SNI during 2001-2017, few if any pinnipeds were exposed to sound levels above 122 dB SEL-M (Burke 2017, Ugoretz 2016, Ugoretz 2015, Ugoretz 2014, Holst et al. 2008, 2011). In addition, peak pressure levels at pinniped haul-out beaches were generally <143 dB re 20 µPa, although for some launches that produced a sonic boom (impulse), peak pressure levels were as high as 159 dB (Holst et al. 2008). Thus, a few pinnipeds, particularly Pacific harbor seals, may incur TTS during some missile launches, especially larger missiles, from SNI. Because of their higher TTS thresholds, it is likely that fewer California sea lions and northern elephant seals may incur TTS as compared to Pacific harbor seals.

Acoustic data collected during the June 2014 through June 2019 monitoring period are comparable to all previous reporting periods.

4.2.2 Permanent Threshold Shift

Southall et al. (2007) estimate that received SELs would need to exceed the TTS threshold by at least 15 dB for pulses and 13.5 dB for non-pulses in air for there to be risk of PTS. In the harbor seal, the SEL-M that is estimated to result in onset of PTS is 144 dB re 20 $\mu Pa^2 \cdot s$ (Southall et al. 2007). As already noted above, the SEL-M measurements nearshore did not exceed the SEL-based PTS threshold. Even SEL-M measurements taken close to the launcher were far less than 144 dB re 20 $\mu Pa^2 \cdot s$, with a maximum of 137.3 dB re 20 $\mu Pa^2 \cdot s$ (Table 2.2).

However, there is some possibility that a few pinnipeds at SNI might receive peak pressures exceeding those that elicit onset of TTS or perhaps even PTS. In animals (or humans) exposed to strong impulsive sound (e.g., close to an artillery shot), there is a possibility of PTS as a result of the high peak pressure even if the received energy did not exceed the SEL criterion for PTS onset. When considering peak pressures rather than energy levels, PTS onset may occur when the received level is as little as 6 dB higher than the TTS threshold, or 149 dB re 20 μPa in the case of the harbor seal (Southall et al. 2007).

Given the higher TTS thresholds in northern elephant seals and California sea lions than in harbor seals, PTS thresholds in those other species are also expected to be higher than in the harbor seal. Thus, it is unlikely that PTS occurred in California sea lions or northern elephant seals during those launches. Pacific harbor seal haul-out sites are located farther from the launch complexes at SNI, so peak levels at haul-out locations will be lower than nearer the launch pads. Thus, Pacific harbor seals are also unlikely to incur PTS during launches at SNI. During the monitoring period, it is unlikely that the sounds were strong enough at pinniped haul-out sites to have induced PTS in any pinniped species.

4.2.3 Conclusions Regarding Effects on Pinniped Hearing Sensitivity

Overall, the results to date indicate that there is little potential for appreciable TTS or PTS in pinnipeds hauled out on SNI near the missile launch paths during launch operations. This conclusion is necessarily speculative given the limited TTS data (and lack of PTS data) for pinnipeds in air exposed to strong sounds for brief periods. In the event that levels are occasionally sufficiently high to cause TTS, these levels probably would be only slightly above the presumed thresholds for mild TTS. Thus, in the event that TTS did occur, it would typically be mild and reversible and thus PTS would necessarily not occur. Given the relatively infrequent launches from SNI, the low probability of TTS during any one launch, and the fact that a given pinniped is not always present on land, there appears to be no likelihood of PTS from the cumulative effects of multiple launches.

4.3 Estimated Numbers of Pinnipeds Affected by Launches

The approach to estimating the numbers of pinnipeds affected by launches from June 2014 through June 2019 was based on video and direct observations of pinnipeds, combined with estimates of the numbers of hauled out pinnipeds in the same general vicinity not videotaped but exposed to the same launches. Pinnipeds on unobserved portions of beach were presumed to have reacted in the same manner and number as those whose responses were videotaped. For pinnipeds on the unobserved portion of beach, the percentage of the affected species on the observed portion of beach was applied to the unobserved beach.

When an entire beach was not within the field of view, the proportion of pinnipeds in the focal subgroups affected during each launch (based on the disturbance criteria listed in section 4.1) were extrapolated to the estimate the total number of individuals affected in the unobserved area. It was not possible to extrapolate the proportions of pinnipeds affected on the monitored beaches to the entire island as not all beaches could

be observed on the day of a launch. However, whenever possible, surveys of surrounding beaches were conducted during monitoring set up to determine if additional pinnipeds were in the area. Additionally, individual pinnipeds were likely affected on more than one occasion, but were counted here as separate individuals. The estimate of pinnipeds affected for the entire island may be underestimated but are representative of affects to pinnipeds overall.

Northern fur seals (*Callorhinus ursinus*), Guadalupe fur seals (*Arctocephalus townsendi*), Steller sea lions (*Eumetopias jubatus*) were not observed on SNI during launches during the June 2014 – June 2019 monitoring period, and none were evident in the video segments that were analyzed.

Observations from 2001-2019 indicate that all of the pinniped haul-out sites continue to be occupied on subsequent days following the launches. There is no evidence of injury or mortality during any launch event.

4.4 Summary

There is no evidence that pinniped injuries or fatalities occurred during launch events, nor was any expected based on past measurements and observations. It is also unlikely that any pinnipeds were exposed to received levels of sound energy above levels at which PTS or TTS would occur.

Approximately 3,876 California sea lions, 99 Pacific harbor seals and 11 northern elephant seals were estimated to have been affected during the June 2014 through June 2019 monitoring period. These figures are approximate and include extrapolations for pinnipeds on portions of the beach that were not within the field of view of the camera and likely include instances where the same individuals were counted more than once at different times and/or different days. These estimates correspond to an average rate of 144 sea lions, 3.6 harbor seals and 0.4 elephant seals affected per launch event. The LOA authorized take of up to 24,360 California sea lions, up to 3,430 Pacific harbor seals and up to 2,460 northern elephant seals launch for this 5-year period (4,872 sea lions, 686 harbor seals and 492 elephant seals per year). Estimates of affected pinnipeds did not exceed that allowed in the LOA for any permit year.

The results from the June 2014 through June 2019 monitoring period (and those from previous monitoring periods) suggest that any effects of the launch operations were minor, short-term, and localized. Some Pacific harbor seals left their haul-out site on offshore reefs, but numbers occupying haul-out sites shortly after a launch or the next day were comparable to pre-launch levels. It is not likely that any of the pinnipeds on SNI were adversely impacted by such behavioral reactions.

These results are supported by continuing population increases of pinnipeds on San Nicolas Island. Counts of all three species of pinnipeds have significantly increased on SNI over the past three decades (Barlow, et al., 1997, Fluharty, 1999, Le Boeuf, et al., 1978, Lowry 2002, Lowry and Maravilla, 2005, Lowry, et al., 1996 and 2008 and Lowry, Pers. Comm.). This includes increases in pinniped counts in the portions of the island closest to the missile launch trajectories.

5. ACKNOWLEDGEMENTS

United States Navy biologists John Ugoretz, John Burke, and Greg Sanders identified monitoring sites, collected data, analyzed video and prepared reports for this LOA. Navy staff Grace Smith, Gina Smith, Lisa Thomas, and Claudia Makeyev provided critical support collecting the audio and video recordings from SNI along with ancillary visual observations, weather data, and other information.

Bob Norman and Clay Rushing, consultants to Greeneridge, were largely responsible for the design of the ATARs, and continue to improve their operation. Bob Norman and Katherine Kim of Greeneridge Sciences Inc. analyzed the recordings and prepared the figures of launch-by-launch acoustic results.

We are grateful to all concerned.

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APPENDIX A:
NMFS LETTER OF AUTHORIZATION
03 JUNE 2014 – 03 JUNE 2019

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

JUN 03 2014

Mr. Tony Parisi
Naval Air Warfare Center Weapons Division
Code 5090 Ser 52F00ME/
575 "I" Avenue, Suite 1
Point Mugu, California 93042-5049

Dear Mr. Parisi:

Enclosed is a Letter of Authorization (LOA), issued to the Naval Air Warfare Center Weapons Division, U.S. Navy, under the authority of Section 101(a)(5)(A) of the Marine Mammal Protection Act (16 U.S.C. 1361 *et seq.*), to harass Pacific harbor seals, California sea lions, and northern elephant seals incidental to missile launch activities at San Nicolas Island. This LOA is valid from June 3, 2014, through June 3, 2019.

The Naval Air Warfare Center Weapons Division, U.S. Navy, is required to comply with the conditions contained in the LOA and implementing regulations. In addition, the Naval Air Warfare Center Weapons Division, U.S. Navy, must submit an annual report to the National Marine Fisheries Service (NMFS) Office of Protected Resources (PR) and NMFS' West Coast Regional (WCR) Office, no later than December 31 of each year for the duration of the regulations. Along with other mitigation measures to be incorporated, the LOA requires monitoring the presence of Pacific harbor seals and California sea lions; reporting any behavioral modifications resulting from this activity as observed by a qualified individual; and the collection of acoustic measurements from missile launch activities. Modifications and future issuance of an LOA for this activity will be determined according to the outcomes documented under the current authorization and based on (a) regular monitoring of pinniped reactions from missile launches, (b) degree of implementation of mitigation requirements, and (c) marine mammal impacts associated with this action.

If you have any questions concerning the LOA or its requirements, please contact John Fiorentino, NMFS/PR at 301-427-8477 or Monica DeAngelis, NMFS/WCR at 562-980-3232.

Sincerely,

Perry Gayaldo

for Donna S. Wieting, Director
Office of Protected Resources

Enclosure

Letter of Authorization

The Department of the Navy, Naval Air Warfare Center Weapons Division, Point Mugu, 1 Administration Circle, China Lake, California 93555 is hereby authorized to take marine mammals incidental to missile launch activities at San Nicolas Island, California, in accordance with 50 CFR 217, Subpart F – Taking of Marine Mammals Incidental to Missile Launch Activities from San Nicolas Island, CA, subject to the provisions of the Marine Mammal Protection Act (16 U.S.C. 1361 *et seq.*) and the following conditions:

1. This Authorization is valid from June 3, 2014, through June 3, 2019.

2. This Authorization is valid only for activities associated with the launching of a maximum of 40 Coyote (or similar sized and smaller) missiles per year from San Nicolas Island, California.

3. General Conditions:

(a). The taking, by Level B harassment only, is limited to the species listed under condition 5 below. The taking by Level A harassment, serious injury (injury that is likely to lead to mortality) or death of these species and the taking by harassment, injury or death of any other species of marine mammal is prohibited and may result in the modification, suspension, or revocation of this Authorization.

(b). The taking of any marine mammal in a manner prohibited under this Authorization must be reported immediately to the Permits and Conservation Division, Office of Protected Resources, National Marine Fisheries Service (NMFS) at 301-427-8401 and to the West Coast Regional Office, NMFS at 562-980-3232.

(c). If a freshly dead or seriously injured pinniped is found during post-launch monitoring, it must be reported immediately to the parties listed above in 3(b).

4. Cooperation:

The holder must notify the Administrator, West Coast Regional Office, NMFS, by letter, e-mail, or telephone (562-980-3232) at least one (1) week prior to launches (unless constrained by the date of issuance of this Authorization).

5. The marine mammal species authorized for taking by incidental harassment on an annual basis are: 686 Pacific harbor seals (*Phoca vitulina*); 492 northern elephant seals (*Mirounga angustirostris*); and 4872 California sea lions (*Zalophus californianus*).

6. Mitigation Requirements: The Holder of this Authorization must ensure the least practicable adverse impacts on Pacific harbor seals, northern elephant seals, and California sea lions, by:

(a). Prohibiting personnel from entering pinniped haul-out sites below the missile's predicted flight path for two (2) hours prior to planned missile launches.

(b). Avoiding launch activities during harbor seal pupping season (February through April), unless constrained by factors including, but not limited to, human safety, national security, or for launch trajectory necessary to meet mission objectives.

(c). Limiting launch activities during other pinniped pupping seasons, unless constrained by factors including, but not limited to, human safety, national security, or for launch trajectory necessary to meet mission objectives.

(d). Not launching missiles from the Alpha Complex at low elevation (less than 1,000 ft [305 m]) on launch azimuths that pass close to pinniped haul-out site(s) when occupied.

(e). Avoiding the launch of multiple missiles in quick succession over haul-out sites, especially when young pups are present, except when required by mission objectives.

(f). Limiting launch activities during nighttime hours, except when required by mission objectives.

(g). Ensuring that aircraft and helicopter flight paths maintain a minimum altitude of 1,000 ft (305 m) from pinniped haul-outs and rookeries, except in emergencies or for real-time security incidents (e.g., search-and-rescue, fire-fighting, adverse weather conditions), which may require approaching pinniped haul-outs and rookeries closer than 1,000 ft (305 m).

(h). Reviewing the launch procedure and monitoring methods, in cooperation with NMFS, if any incidents of injury or mortality of a pinniped discovered during post-launch surveys or indications of affects to the distribution, size, or productivity of the affected pinniped populations as a result of the authorized activities are thought to have occurred. If necessary, appropriate changes must be made through modification to this Authorization prior to conducting the next launch of the same vehicle.

7. Monitoring Requirements:

(a). General:

(1). The holder of this Authorization must designate biologically-trained, on-site individual(s), approved in advance by NMFS, to record the effects of the launch activities and the resulting noise on pinnipeds.

(2). NMFS must be informed immediately of any changes or deletions to any portions of the monitoring plan.

(b). Visual Land-Based Monitoring:

(1). Prior to each missile launch, an observer(s) will place three (3) autonomous digital video cameras overlooking chosen haul-out sites located varying distances from the missile launch site. Each video camera will be set to record a focal subgroup within the larger haul-out aggregation for a maximum of four (4) hours or as permitted by the videotape capacity.

(2). Systematic visual observations, by those individuals described in condition 7(a)(1) above, on pinniped presence and activity will be conducted and recorded in a field logbook or recorded on digital video for subsequent analysis for no less than one (1) hour prior to the estimated launch time and for up to one (1) hour immediately following each missile launch.

(3). Documentation, both via autonomous video camera and human observer, will consist of:

(i). numbers and sexes of each age class in focal subgroups;
(ii). description and timing of launch activities or other disruptive event(s);
(iii). movements of pinnipeds, including number and proportion moving, direction and distance moved, and pace of movement;
(iv). description of reactions;
(v). minimum distances between interacting and reacting pinnipeds;
(vi). study location;
(vii). local time;
(viii). substratum type;
(ix). substratum slope;
(x). weather condition;
(xi). horizontal visibility; and
(xii). tide state.

(c). Acoustic Monitoring:

(1). During all missile launches, calibrated recordings of the levels and characteristics of the received launch sounds will be obtained from three (3) different locations of varying distances from the missile's flight path. To the extent practicable, these acoustic recording locations will correspond with the haul-out sites where video monitoring is done.

(2). Acoustic recordings will be supplemented by the use of radar and telemetry systems to obtain the trajectory of target missiles in three (3) dimensions, whenever data coverage allows.

(3). Acoustic equipment used to record launch sounds will be suitable for collecting a wide range of parameters, including the magnitude, characteristics, and duration of each missile.

8. Reporting:

(a). For each missile launch, the lead contractor or lead observer for the holder of this Authorization must provide a status report by telephone to the West Coast Regional Office, NMFS (562-980-3232), providing reporting items found under condition 8(b), unless other arrangements for monitoring are agreed in writing.

(b). An annual report must be submitted to the Office of Protected Resources, NMFS, and the West Coast Regional Office, NMFS, no later than December 31 of each year for the duration of the regulations. This report must contain the following information:

(1). Timing and nature of launch operations;

(2). Summary of pinniped behavioral observations;

(3). Estimate of the amount and nature of all takes by harassment or by other means; and

(4). Evidence of compliance with mitigation measures.

(c). A draft comprehensive technical report will be submitted to the Office of Protected Resources, NMFS, and the West Coast Regional Office, NMFS, 180 days prior to the expiration of the regulations providing full documentation of the methods, results, and interpretation of all monitoring tasks for launches to date plus preliminary information for missiles launches planned during the first six (6) months of the Letter of Authorization.

(d). A revised final comprehensive technical report, including all monitoring results during the entire period of the Letters of Authorization will be due 90 days after the end of the period of effectiveness of the regulations contained in 50 CFR 216.150 through 216.159.

(e). The draft and final reports will be subject to review and comment by NMFS. Any recommendations made by NMFS must be addressed in the final comprehensive report prior to acceptance by NMFS.

(f). The draft final technical report must contain documentation on the effectiveness of the implementation of the mitigation measures described in condition 6 of this Authorization, including a description of launch activity during the harbor seal pupping season (February through April).

9. Activities related to the monitoring described in this Authorization and as described in the holders application, do not require a separate scientific research permit issued under section 104 of the Marine Mammal Protection Act.

10. Failure to comply with the terms and conditions contained in Subpart F – Taking of Marine Mammals Incidental to Missile Launch Operations from San Nicolas Island, CA (50 CFR 217.50-217.59) may result in the modification, suspension or revocation of this Authorization

11. A copy of this Authorization must be in the possession of each observer or group operating under the authority of this Letter of Authorization.

12. Penalties and Permit Sanctions: Any person who violates any provision of this Letter of Authorization is subject to civil and criminal penalties, permit sanctions, and forfeiture as authorized under the MMPA.

Perry Gayaldo

JUN 0 3 2014

Donna S. Wieting
Director
Office of Protected Resources
National Marine Fisheries Service

Date

APPENDIX B:
ESTIMATES OF PINNIPEDS AFFECTED BY LAUNCHES AT SNI
03 JUNE 2014 – 03 JUNE 2019

The following tables summarize pinniped monitoring data by LOA permit year, June 2014 through June 2019. In the monitoring report for 2015 (Ugoretz 2015), there was an attempt to estimate affected sea lion numbers on unmonitored beaches by averaging aerial sea lion survey counts made during peak sea lion abundance between 2001 and 2011. This method certainly overestimated the number of sea lions for any given launch event and yielded inconsistent and subjective results. For the summary below, only observations and direct extrapolations to the monitored areas for all years is considered.

CALIFORNIA SEA LION ESTIMATES BY PERMIT YEAR (Page 1 of 3)

Estimated numbers of California sea lions harassed by launches from the Navy's SNI missile launch program LOA Year 1: June 3, 2014 – June 3, 2015

Launch Date	Launch Site	Monitoring Site	# of Focal Animals Potentially Affected	Total # Potentially Affected in Monitored Area	Subtotals
17 June 2014	B807	Dos Coves	20	40	
		Redeye Beach	5	100	
		B809	37	154	294
5 August 2014	B807	Dos Coves	8	15	
		B809	-	0	
		Rock Crusher	0	0	15
6 August 2014	B807	Dos Coves	10	12	
		B809	0	0	
		Bachelor Beach	0	0	12
4 September 2014	Alpha	Dos Coves	35	35	
		B809	18	245	
		Redeye Beach	15	15	295
4 September 2014*	Alpha	Dos Coves	1	1	
		B809	50	308	
		Redeye Beach	1	1	310
18 December 2014	Alpha	Dos Coves	0	0	
		Dos Coves Cliff	75	75	
		Coast Guard Beach	0	0	75
13 May 2015	Alpha	Dos Coves	25	54	
		B809	0	0	
		Vizcaino Point	8	31	85
		Total number of California sea lions potentially affected LOA Year 1: 1,096		***Average per Launch Event: 155***	

Estimated numbers of California sea lions harassed by launches from the Navy's SNI missile launch program LOA Year 2: June 4, 2015 – June 3, 2016

Launch Date	Launch Site	Monitoring Site	# of Focal Animals Potentially Affected	Total # Estimated Affected in Monitored Area	Subtotals
6 June 2015	B807	Dos Coves	0	0	
		B809	0	0	
		Vizcaino Point	0	0	0
15 October 2015	B807	Dos Coves	14	39	
		B809	30	350	389
21 October 2015	B807	Dos Coves	20	20	
		B809	10	11	33
27 October 2015	B807	Dos Coves	0	0	
		B809	5	20	20
8 December 2015	B807	Dos Coves	13	30	
		Building 809	50	95	
		Vizcaino Point	70	233	358
17 December 2015	Alpha	Dos Coves	2	3	
		Building 809	34	41	
		Vizcaino Point	34	136	180
4 February 2016	Alpha	Dos Coves	0	0	
		Building 809	29	29	
		Vizcaino Point	100	100	129
7 April 2016	Alpha	Dos Coves	0	0	
		Vizcaino Point	12	40	40
		Total number of sea lions potentially affected LOA Year 2: 1,149		***Average per Launch Event: 144***	

CALIFORNIA SEA LION ESTIMATES BY PERMIT YEAR (Page 2 of 3)

Estimated numbers of California sea lions harassed by launches from the Navy's SNI missile launch program LOA Year 3: June 4, 2016 – June 3, 2017

Launch Date	Launch Site	Monitoring Site	# of Focal Animals Potentially Affected	Total # Estimated Affected in Monitored Area	Subtotals
19 October 2016	B807	Dos Coves	41	82	
		Vizcaino Point	40	100	182
27 October 2016	B807	Dos Coves	130	252	
		Building 809	26	260	
		Redeye Beach	0	0	512
03 December 2016	Alpha	Dos Coves	10	140	
		Building 809	0	0	
		Redeye Beach	30	10	150
12 May 2017	Alpha	Dos Coves	200	70	
		Redeye Beach	10	28	98

Total number of sea lions potentially affected LOA Year 3: 942 Average per Launch Event: 236

Estimated numbers of California sea lions harassed by launches from the Navy's SNI missile launch program LOA Year 4: June 4, 2017 – June 3, 2018

Launch Date	Launch Site	Monitoring Site	# of Focal Animals Potentially Affected	Total # Estimated Affected in Monitored Area	Subtotals
14 September 2017	Alpha	Dos Coves	80	219	
		Redeye Beach	35	35	254
21 November 2017		Dos Coves	70	105	
	B807	Redeye	0	0	
		Phoca Reef	0	0	105
29 November 2017		Dos Coves	40	120	
	Alpha	Redeye	-	-	
		Phoca Reef	0	0	120
30 November 2017		Dos Coves	10	100	
	B807	Redeye	0	0	
		Bachelor Beach	0	0	100
27 April 2018		Dos Coves	-	-	
	Alpha	Redeye	-	-	
		Phoca Reef	-	-	--
27 April 2018		Dos Coves	-	-	
	Alpha	Redeye	-	-	
		Phoca Reef	-	-	--

Total number of sea lions potentially affected LOA Year 4: 579 Average per Launch Event (does not include the two launch events with no data): 145

(-) No Data, equipment failure

CALIFORNIA SEA LION ESTIMATES BY PERMIT YEAR (Page 3 of 3)

Estimated numbers of California sea lions harassed by launches from the Navy's SNI missile launch program LOA Year 5: June 4, 2018 – June 3, 2019

Launch Date	Launch Site	Monitoring Site	# of Focal Animals Potentially Affected	Total # Estimated Affected in Monitored Area	Subtotals
02 October 2018	B807	Dos Coves	70	70	
		Redeye	0	0	
		Bachelor	0	0	70
18 October 2018	B807	Dos Coves	40	40	
		Redeye Beach	0	0	
		Bachelor	0	0	40
		Total number of sea lions potentially affected LOA Year 5: 110 Average per Launch Event: 55			

PACIFIC HARBOR SEAL ESTIMATES BY PERMIT YEAR (Page 1 of 2)

Estimated numbers of Pacific Harbor Seals harassed by launches from the Navy's SNI missile launch program LOA Year 1: June 3, 2014 – June 3, 2015

Launch Date	Launch Site	Monitoring Site	# of Focal Animals Potentially Affected	Total # Potentially Affected in Monitored Area
17 June 2014	B807	Redeye Beach	4	10
5 August 2014	B807	All Areas	0	0
6 August 2014	B807	All Areas	0	0
4 September 2014	Alpha	Vizcaino Pt.	0	40
4 September 2014	Alpha	Vizcaino Pt.	0	0
13 May 2015	Alpha	All Areas	0	0
			Total number of harbor seals potentially affected: 50	***Average per Launch Event: 8.3***

Estimated numbers of Pacific Harbor Seals harassed by launches from the Navy's SNI missile launch program LOA Year 2: June 4, 2015 – June 3, 2016

Launch Date	Launch Site	Monitoring Site	# of Focal Animals Potentially Affected	Total # Potentially Affected in Monitored Area
6 June 2015	B807	B809	1	11
15 October 2015	B807	All Areas	0	0
21 October 2015	B807	B809	20	20
27 October 2015	B807	All Areas	0	0
8 December 2015	B807	All Areas	0	0
17 December 2015	Alpha	All Areas	0	0
4 February 2015	Alpha	All Areas	0	0
7 April 2016	Alpha	Pirates Cove	4	4
		Total number of harbor seals potentially affected: 35	***Average per Launch Event: 4.4***	

Estimated numbers of Pacific Harbor Seals harassed by launches from the Navy's SNI missile launch program LOA Year 3: June 4, 2016 – June 3, 2017

Launch Date	Launch Site	Monitoring Site	# of Focal Animals Potentially Affected	Total # Potentially Affected in Monitored Area
19 October 2016	B806	Phoca Reef	0	0
27 October 2016	B806	All Areas	0	0
3 December 2016	Alpha	Redeye	0	0
12 May 2017	Alpha	Pirates Cove	4	4
		Total number of harbor seals potentially affected: 4	***Average per Launch Event: 1***	

PACIFIC HARBOR SEAL ESTIMATES BY PERMIT YEAR (Page 2 of 2)

Estimated numbers of Pacific Harbor Seals harassed by launches from the Navy's SNI missile launch program LOA Year 4: June 4, 2017 – June 3, 2018

Launch Date	Launch Site	Monitoring Site	# of Focal Animals Potentially Affected	Total # Potentially Affected in Monitored Area
14 September 2017	Alpha	Phoca Reef	4	4
21 November 2017	B807	Phoca Reef	0	0
29 November 2017	Alpha	Phoca Reef	6	6
30 November 2017	B807	All Areas	0	0
27 April 2018	Alpha	Phoca Reef	-	-
27 April 2018	Alpha	Phoca Reef	-	-
Total number of harbor seals potentially affected: 10 Average per Launch Event (does not include launch events without data): 2.5				

(-) No data, equipment failure

Estimated numbers of Pacific Harbor Seals harassed by launches from the Navy's SNI missile launch program LOA Year 4: June 4, 2018 – June 3, 2019

Launch Date	Launch Site	Monitoring Site	# of Focal Animals Potentially Affected	Total # Potentially Affected in Monitored Area
02 October 2018	B807	All areas	0	0
18 October 2018	B807	All areas	0	0
Total number of harbor seals potentially affected: 0 Average per Launch Event: 0				

NORTHERN ELEPHANT SEAL ESTIMATES FOR ALL PERMIT YEARS (Page 1 of 1)

Note: In June 2010, a revised monitoring plan was submitted to NMFS that proposed the discontinuation of directed monitoring for northern elephant seals, as this species had shown little reaction to missile launches at SNI. NMFS accepted this proposed change to the monitoring plan (NMFS 2010); thus, beaches dominated by elephant seals were not usually targeted for monitoring after December 2010, but any reactions of elephant seals observed in the field of view of cameras monitoring other species were still recorded.

Elephant seals were frequently present on beaches monitored during the 2014-2019 LOA Period. This summary includes only those instances where elephant seals were potentially affected by launches over the 5-year period.

Estimated numbers of Northern Elephant Seals harassed by launches from the Navy's SNI missile launch program for <u>all</u> LOA Years: June 3, 2014 – June 3, 2019

Launch Date	Launch Site	Monitoring Site	# of Focal Animals Potentially Affected	Total # Potentially Affected in Monitored Area
13 May 2015	Alpha	Dos Coves	1	1
18 October 2018	B807	Dos Coves	5	10
			Total number of harbor seals potentially affected: 11 Average per Launch Event: 0.4 (11/27 events)	

APPENDIX C:
ACOUSTIC MEASUREMENT AND ANALYSIS
MID-NOVEMBER 2017 – 03 JUNE 2019

Acoustic measurements and analysis for acoustic monitoring conducted from June 3, 2014 through early November 2017 were provided to NMFS in earlier reports (Ugoretz 2014, Ugoretz 2015, Ugoretz 2016, Burke 2017).

Acoustic Analysis San Nicolas Island Launches

Mid-November 2017 through June 2019

GREENRIDGE SCIENCES, INC.
90 ARNOLD PLACE, SUITE D • SANTA BARBARA, CALIFORNIA 93117 • TEL/FAX 805-967-7720

The following report was prepared by Katherine H. Kim and Robert G. Norman from Greenridge Sciences Inc.

Introduction

The material in this document has been provided for inclusion in the technical report stipulated by NAVAIR's current Letter of Authorization under the Marine Mammal Protection Act. The material presents the results of sound measurements of seven missile launches from San Nicolas Island on 21 November 2017, 29 November 2017, 30 November 2017, 27 April 2018 (two launches), 2 October 2018, and 10 October 2018.

Methods

Various federal, state, and other organizations recommend specific acoustic thresholds for the onset of temporary threshold shift (TTS) and permanent threshold shift (PTS) in marine mammals. The thresholds cited in the *Results* section below are from the U.S. Navy technical report by J.J. Finneran and A.K. Jenkins, *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis*, published by the Space and Naval Warfare Systems Center Pacific, San Diego, CA in April 2012 (Accession Number: ADA561707). For pinnipeds in air, these thresholds are given in terms of weighted (M-weighted or Type 1) sound exposure level, i.e., SEL-M, and unweighted peak sound pressure ("Pk in Table 1"). Specifically, for pinnipeds in air, TTS thresholds are 129 dB re 20 µPa^2-s SEL-M and 143 dB re 20 µPa unweighted peak pressure (Pk), while PTS thresholds are 144 dB re 20 µPa^2-s SEL-M or 149 dB re 20 µPa unweighted peak pressure (Pk).

Results

Measured missile sounds exceeding the level considered sufficient to cause temporary threshold shift (TTS) in pinnipeds, specifically, SEL-M level of 129 dB re 20 µPa^2-s or (unweighted) peak pressure of 143 dB re 20 µPa:

SEL-M was 134.1 dB re 20 µPa^2-s and unweighted (flat weighting) peak pressure level was 151.2 dB re 20 µPa for a 88SSM missile measured next the launch site at B807 on 30 November 2017. Likewise, SEL-M was 133.9 dB re 20 µPa^2-s and unweighted (flat weighting) peak pressure level was 150.3 dB re 20 µPa for a 88SSM missile measured next to the launch site at B807 on 10 October 2018. These sound

measurements were taken next to the source of the sound with no pinnipeds in the vicinity. Launches from the B807 site are near shore and missiles launched from this site do not cross over beaches occupied by pinnipeds.

Measured missile sounds exceeding the level considered sufficient to cause permanent threshold shift (PTS) in pinnipeds, specifically, SEL-M level of 144 dB re 20 µPa^2-s or (unweighted) peak pressure of 149 dB re 20 µPa:

No measured sound levels exceeded the SEL-M threshold for permanent threshold shift (PTS).

The highest levels measured for the six missile flights:

The highest measured sound levels—peak pressure, SPL, and SEL—corresponded to the 88SSM missile launches noted above, which took place on 30 November 2017 and 10 October 2018.

The highest measured peak pressure (unweighted, i.e., flat weighting) was 151.2 dB re 20 µPa at launch site B807 on 30 November 2017.

The highest measured sound pressure level (SPL; flat weighting) was 137.0 dB re 20 µPa^2 and was measure at both the B807 launch site on 30 November 2017 and the B807 launch site on 10 October 2018.

The highest measured sound exposure level (SEL; flat weighting) was 134.8 dB re 20 µPa^2-s at launch site B807 on 10 October 2018. A close second in unweighted SEL level was 134.7 dB re 20 µPa^2-s at launch site B807 on 30 November 20187.

Atypical processing of missile flights:

At the launch site B807 of the 88SSM missile launch on 21 November 2017, the sound file contained 24-bit samples collected at a sample rate of 48 kHz instead of the typical 16-bit samples collected at a 44.1 kHz sample rate. This recording was deemed unreliable to use. The recording and analysis of this launch's other pinniped monitoring site (Dos Coves) was nominal.

For the GQM missile launches on 27 April 2018, recordings from two of the four monitoring sites exhibited unusually low recording levels. At monitoring site Phoca Reef, the sound of missiles from the launch, at both times 10:00:00 and 11:20:00, was barely audible on the right channel (corresponding to the more sensitive of the two microphones) and below the noise floor of the left channel (corresponding to the less sensitive of the two microphones). Thus, these recordings could not be processed. At monitoring site Red Eye, the launch event was heard on the sensitive right channel, but the left channel was near flat line. The accompanying data sheet did not indicate the channels' gain settings, so these recordings were unusable. However, data collected at the Dos Coves and Alpha Pad monitoring sites were nominal and analyzed.

For the 88SSM missile launch on 2 October 2018, recordings from all four monitoring sites suffered from various problems. At the Bachelor Beach monitoring site, pre-event spectral levels were dissimilar. The gain settings documented on the accompanying data sheet were inconsistent with the acoustic data, yet swapping them increased the spectral level discontinuity. These acoustic data were not analyzed. At the Dos Coves monitoring site, pre-event levels were again dissimilar. In addition, the level of the noise floor of the insensitive channel was inexplicably lower than that of the sensitive channel. Gain settings recorded on the data sheet were again inconsistent with the acoustic data. These acoustic data were not

analyzed. At the B807 launch site, pre-event spectral levels and documented gain settings suggested that the left and right channels appeared to have been swapped, and the values logged in the data sheet were also swapped. Regardless, the signal recorded on the insensitive channel was clipped (i.e., distorted due to its levels exceeding a given threshold), so the analysis could not proceed.

At monitoring site Dos Coves of the 88SSM launch on 10 October 2018, the recording exhibited problems similar to the recording at Dos Coves of the 88SSM launch eight days earlier: dissimilar pre-event spectral levels, contradictory noise floor levels, and inconsistent gain settings. As a result, these acoustic data were not analyzed. The recordings and analyses of the remaining three monitoring sites for this launch were nominal.

In summary, 16 out of 25 total recordings of missiles/monitoring sites were analyzed and presented in this report.

TABLE 1. Pulse parameters for flat-, A-, and M_{pa}-weighted sound from SNI missile launches, November 2017 – October 2018.

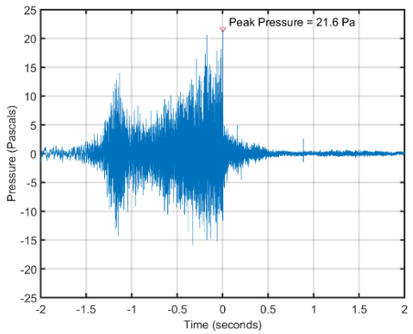
Launch Date & Monitoring Site	CPA (km)	Flat-weighted sound				A-weighted sound			M_{pa}-weighted sound		
		Pk	SPL	SEL	Dur	SPL	SEL	Dur	SPL	SEL	Dur
21 November 2017: 88SSM											
Dos Coves		120.7	106.1	107.0	1.2	103.5	104.2	1.2	105.7	106.4	1.2
B807		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
29 November 2017: FSSTT											
Phoca Reef		99.8	85.3	88.2	2.0	78.8	83.3	2.8	84.0	88.6	2.9
Red Eye		96.9	81.3	87.4	4.1	78.0	81.9	2.4	80.6	86.4	3.7
Alpha Pad		118.9	104.2	109.5	3.4	97.1	101.0	2.5	101.4	106.4	3.1
30 November 2017: 88SSM											
Red Eye		100.2	83.1	87.7	2.9	69.3	71.3	1.6	82.3	83.0	1.2
Dos Coves		122.8	107.5	110.6	2.0	103.5	105.2	1.5	107.0	108.9	1.6
Bachelor Beach		117.8	102.6	106.9	2.7	95.5	97.6	1.6	102.4	104.6	1.7
B807		151.2	137.0	134.7	0.6	135.1	132.0	0.5	136.8	134.1	0.5
27 April 2018: GQM x 2											
Phoca Reef (1/2)		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phoca Reef (2/2)		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dos Coves (1/2)		144.0	134.3	120.9	0.0	109.0	106.0	0.5	123.7	114.4	0.1
Dos Coves (2/2)		144.4	135.6	120.7	0.0	106.9	105.2	0.7	122.1	113.1	0.1
Red Eye (1/2)		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Red Eye (2/2)		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alpha Pad (1/2)		136.1	119.6	122.8	2.1	107.9	111.0	2.1	114.0	117.3	2.1
Alpha Pad (2/2)		138.7	121.0	123.8	1.9	110.1	113.0	1.9	115.7	118.7	2.0
2 October 2018: 88SSM											
Bachelor Beach		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dos Coves		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Red Eye Beach		103.4	84.9	91.6	4.6	70.5	72.8	1.7	77.7	81.0	2.1
B807		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10 October 2018: 88SSM											
Bachelor Beach		117.4	104.0	108.2	2.6	98.7	100.9	1.7	103.1	105.5	1.7
Dos Coves		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Red Eye Beach		102.5	81.3	85.7	2.8	64.4	66.8	1.7	73.4	76.8	2.2
B807		150.3	137.0	134.8	0.6	134.7	131.1	0.4	136.9	133.9	0.5

Note: Peak levels (Pk) and SPLs are in dB relative to 20 µPa. SELs or energy levels are in dB re 20 $\mu Pa^2 \cdot s$. Durations (Dur) are in seconds. N/A = data not available.

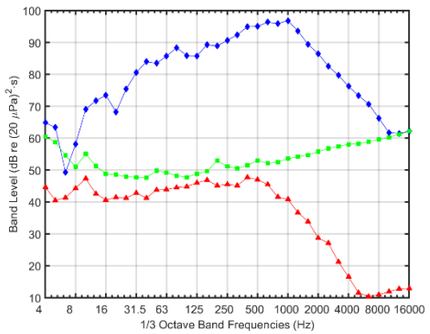
TABLE 2. Ambient broadband (10–20,000 Hz) sound levels (in dB re 20 µPa) as recorded before launches.

Date	Missile	Site	Flat-weighted	A-weighted	M_{pa}-weighted
21 November 2017	88SSM	Dos Coves	57.7	49.9	54.4
		B807	N/A	N/A	N/A
29 November 2017	FSSTT	Phoca Reef	56.4	46.2	50.2
		Red Eye	61.5	48.1	55.9
		Alpha Pad	52.0	21.6	34.2
30 November 2017	88SSM	Red Eye	67.2	51.3	59.8
		Dos Coves	75.1	57.1	65.5
		Bachelor Beach	66.1	54.0	61.0
		B807	69.6	55.3	61.3
27 April 2018	GQM x 2	Phoca Reef (1/2)	N/A	N/A	N/A
		Phoca Reef (2/2)	N/A	N/A	N/A
		Dos Coves (1/2)	82.5	53.0	61.3
		Dos Coves (2/2)	74.9	52.2	57.9
		Red Eye (1/2)	N/A	N/A	N/A
		Red Eye (2/2)	N/A	N/A	N/A
		Alpha Pad (1/2)	72.2	32.0	41.9
		Alpha Pad (2/2)	74.6	34.8	42.6
2 October 2018	88SSM	Bachelor Beach	N/A	N/A	N/A
		Dos Coves	N/A	N/A	N/A
		Red Eye Beach	76.4	39.4	45.7
		Rock Crusher, West End	N/A	N/A	N/A
10 October 2018	88SSM	Bachelor Beach	60.5	52.4	57.8
		Dos Coves	N/A	N/A	N/A
		Red Eye Beach	57.6	48.8	54.0
		B807	64.6	57.3	61.8

N/A = data not available.

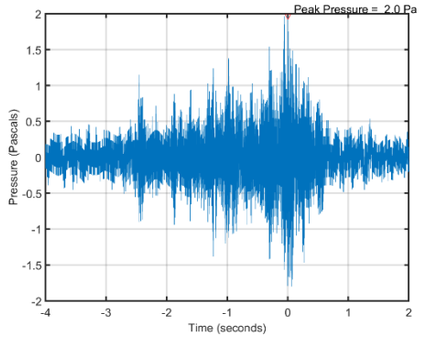


Dos Coves - A

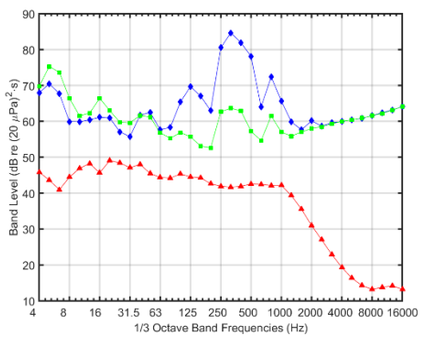


Dos Coves - B

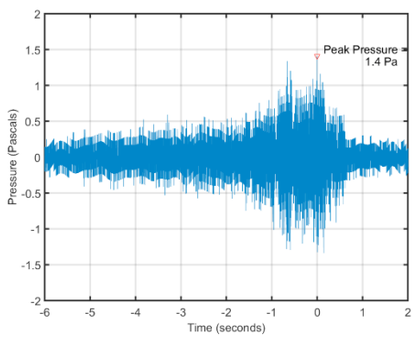
FIGURE 1. (A) Pressure waveform and (B) one-third octave band levels for a 88SSM flight at unknown launch time on 21 November 2017.
In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).



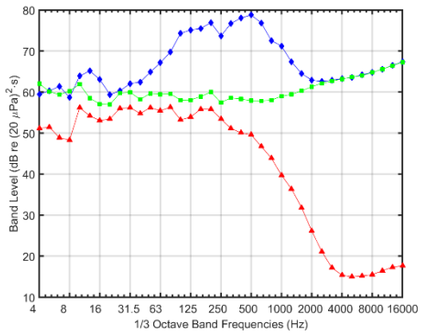
Phoca Reef - A



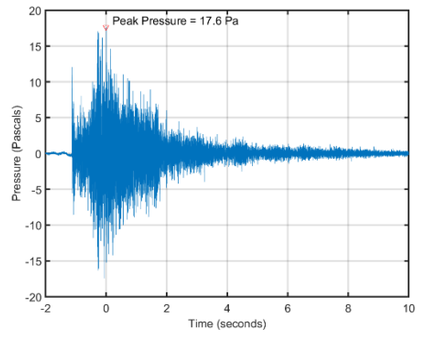
Phoca Reef - B



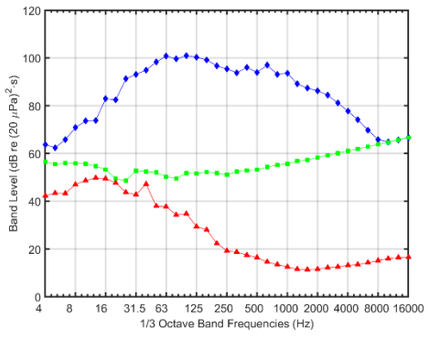
Red Eye - A



Red Eye - B



Alpha Pad - A



Alpha Pad - B

FIGURE 2. (A) Pressure waveform and (B) one-third octave band levels for a FSSTT flight at 14:18:00 on 29 November 2017.
In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

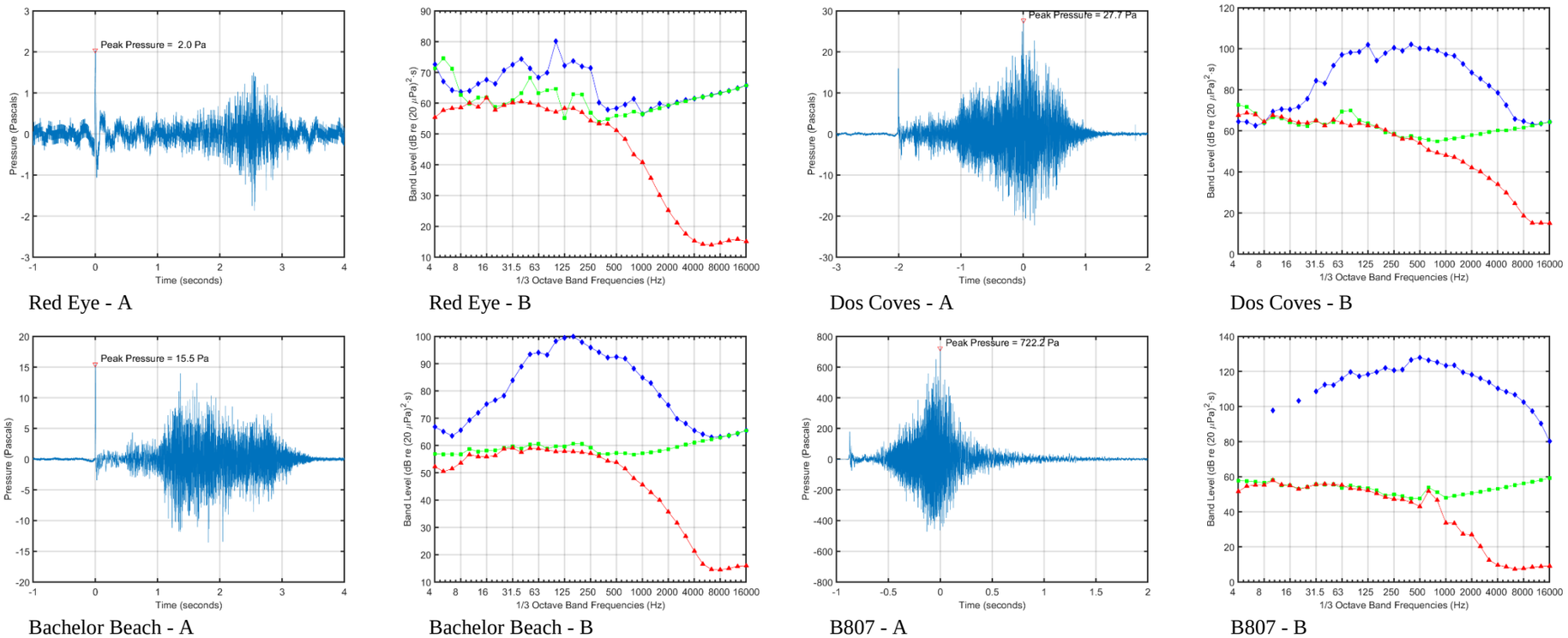
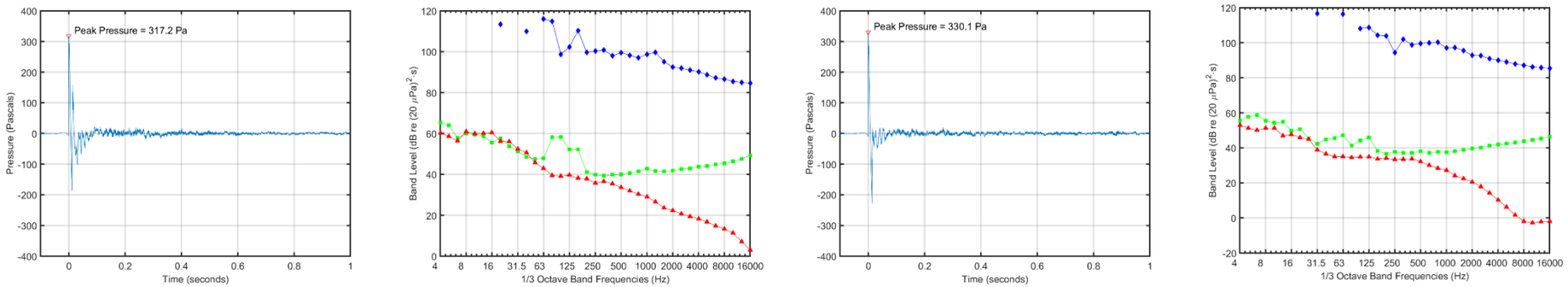
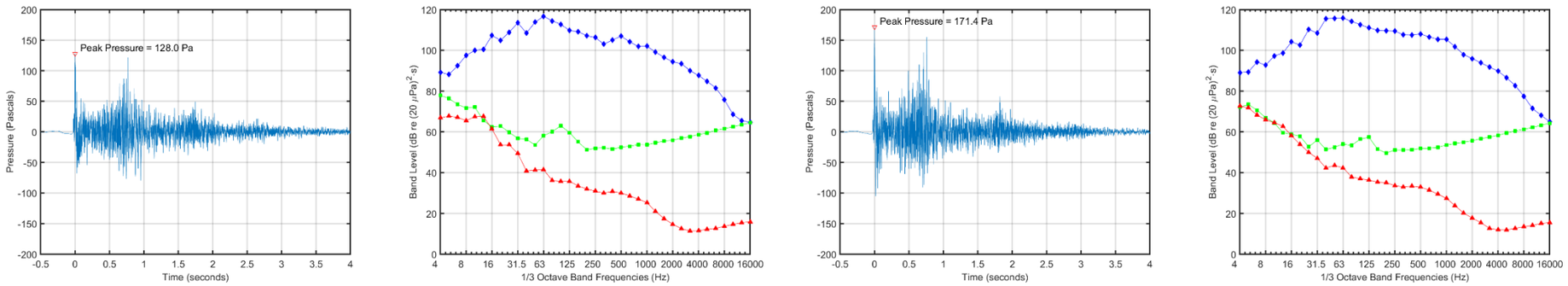


FIGURE 3. (A) Pressure waveform and (B) one-third octave band levels for a 88SSM flight at unknown launch time on 30 November 2017.
In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

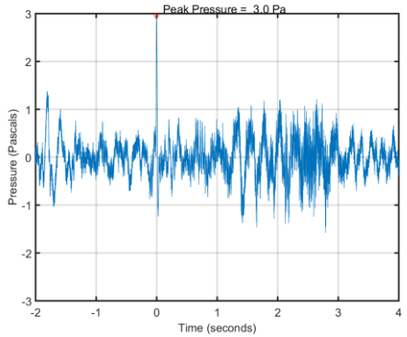


Dos Coves (1/2) - A | Dos Coves (1/2) - B | Dos Coves (2/2) - A | Dos Coves (2/2) - B

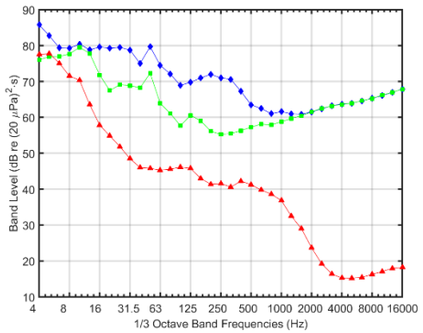


Vandal Pad (1/2) - A | Vandal Pad (1/2) - B | Vandal Pad (2/2) - A | Vandal Pad (2/2) - B

FIGURE 4. (A) Pressure waveform and (B) one-third octave band levels for a GQM x 2 flight at 10:00:00 and 11:20:00 on 27 April 2018.
In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

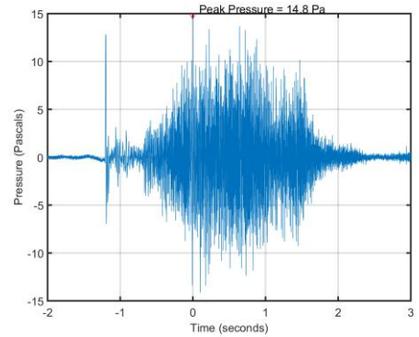


Red Eye Beach - A

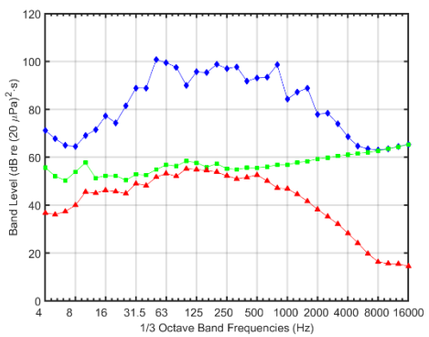


Red Eye Beach - B

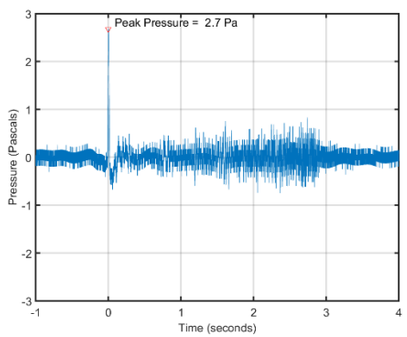
FIGURE 5. (A) Pressure waveform and (B) one-third octave band levels for a 88SSM flight at 11:25:00 on 2 October 2017.
In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).



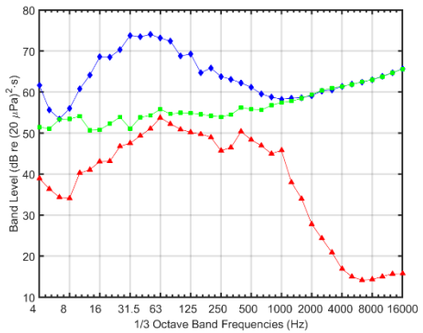
Bachelor Beach - A



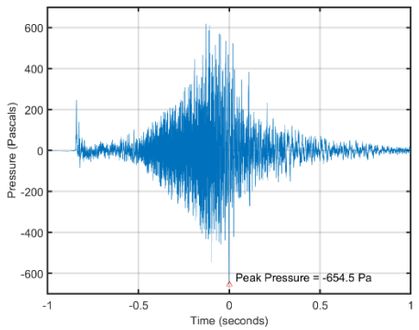
Bachelor Beach - B



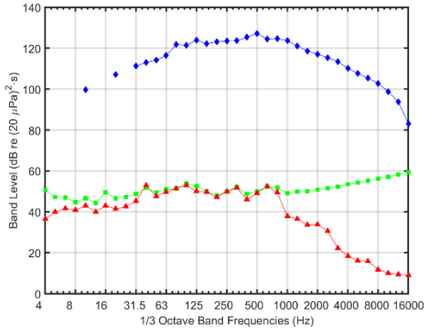
Red Eye Beach - A



Red Eye Beach - B



B807 - A



B807 - B

FIGURE 6. (A) Pressure waveform and (B) one-third octave band levels for a 88SSM flight at 11:20:00 on 10 October 2018.
In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).