Marine Mammal and Acoustical Monitoring during Vehicle Launches on San Nicolas Island, California, June – December 2009

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Naval Air Warfare Center Weapons Division
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to

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Silver Spring, Maryland, and Long Beach, California

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Marine Mammal and Acoustical Monitoring during Vehicle Launches on San Nicolas Island, California, June – December 2009

by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

3-D	3-dimensional
ABL	Airborne Laser
ASL	above sea level
ATAR	Autonomous Terrestrial Acoustic Recorder
CFR	Code of Federal Regulations
cm	centimeter
CPA	Closest Point of Approach
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 (of video camera)
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)
kt	knots or nautical miles per hour
lb	pounds
LOA	Letter of Authorization
m	meter
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
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
SEL-M	M_{pa}-weighted sound pressure level
TTS	Temporary Threshold Shift
μPa	micropascal

EXECUTIVE SUMMARY

Naval Air Warfare Center Weapons Division (NAWCWD) currently holds a Letter of Authorization (LOA) issued by the National Marine Fisheries Service (NMFS) allowing non-lethal takes of pinnipeds incidental to the Navy's vehicle launch operations on San Nicolas Island (SNI), California. The current LOA is valid from 4 June 2009 through 3 June 2010. The LOA was issued pursuant to 50 Code of Federal Regulations (CFR) 216.151–158 and §101(a)(5)(A) of the Marine Mammal Protection Act (MMPA), 16 United States Code (USC) §1371(a)(5)(A). Those regulations were initially issued for the period from 2 October 2003 through 2 October 2008 and were reissued in 2009 for the period 2 June 2009 through 2 June 2014. The regulations and associated LOAs allow for the 'take by harassment' of small numbers of northern elephant seals (*Mirounga angustirostris*), harbor seals (*Phoca vitulina*), and California sea lions (*Zalophus californianus*) during routine launch operations on Navy-owned SNI.

Previously, separate LOAs were issued for this purpose for the periods October 2003 to October 2004, October 2004 to October 2005, February 2006 to February 2007, February 2007 to February 2008, and February to October 2008. No launches took place during the February to October 2008 LOA period or during two intervals between expiry of one LOA and issuance of another (8 October 2005 to 2 February 2006 and 3 October 2008 through 3 June 2009). Before any LOAs were issued, two separate Incidental Harassment Authorizations (IHAs) were issued by NMFS; those provided similar incidental take authorization for the periods August 2001 to July 2002 and August 2002 to August 2003.

In the Navy's Petition for Regulations that led to promulgation of 50 CFR 216.151–158, a Marine Mammal Monitoring Plan was proposed. This plan included provisions to monitor any effects of vehicle launch activities on pinnipeds hauled out at SNI in a manner similar to the monitoring that took place during 2001–2008.

This report describes the results of the marine mammal and associated acoustic monitoring program for vehicle launches from SNI during the June–December 2009 period. It includes results from three single launches at SNI on 6 June, 13 June, and 10 August 2009. Holst et al. (2008) provided corresponding results concerning 77 launches during the period 2001–2008.

The following subsections briefly summarize the monitoring program during the June–December 2009 period. Details are provided in subsequent chapters of this report.

Description of Vehicle Launches and Monitoring Program

During the June–December 2009 period, three single launches occurred from SNI on three different days. These launches occurred at night during the Airborne Laser (ABL) testing program. For this program, vehicles must be launched at night when the laser is visible. A single Terrier-Lynx was launched on each of two days, 6 and 13 June 2009, and a single Terrier-Black Brant was launched on 10 August 2009. Vehicles were launched from the 807 Launch Complex located close to shore on the western end of SNI, 11 meters (m) above sea level (ASL). The vehicles were launched at an elevation angle of 70–71.1º above horizontal and crossed the west end of SNI at an altitude of 366–381 meters (m).

The launch azimuths caused the vehicles to pass over or near various pinniped monitoring and acoustic measurement sites where Autonomous Terrestrial Acoustic Recorders (ATARs) and video systems had been deployed. Audio recordings were obtained to document launch sounds at several distances from the launch trajectories of the vehicles. The video and visual monitoring provided data on the behavioral reactions of pinnipeds hauled out during launches.

Acoustic Measurements during Vehicle Launches

Vehicle flight sounds were measured as received at various locations on the periphery of SNI or near the launcher during the launches conducted during the monitoring period. Recordings of received sound levels were generally attempted at three (but on one occasion four) different locations during each of the launches. For the Terrier-Lynx launches, flat-weighted sound pressure levels (SPL-f), measured over the 3–20,000 hertz (Hz) bandwidth, were 97.6–114.4 decibels (dB) reference 20 micropascals (re 20 µPa) at sites located 0.6–1.7 kilometers (km) from the closest point of approach (CPA) of the launched vehicle. The M-weighted (for pinnipeds in air, M_{pa}) sound exposure level (SEL-M) values ranged from 101.5 to 118.0 dB reference 20 micropascal squared second (re 20 $\mu Pa^2 \cdot s$) at those same sites. For the Terrier-Black Brant vehicle, SPL-f ranged from 102.7–115.0 dB, and SEL-M ranged from 106.5 to 118.4 dB at pinniped haul-out sites located 0.6–1.3 km from the CPA. Sounds near the launcher reached 134 dB SPL-f and 130.4 dB re 20 $\mu Pa^2 \cdot s$ SEL-M.

Behavior of Pinnipeds during Vehicle Launches

Behavior of pinnipeds around the periphery of western SNI during vehicle launches was monitored by unattended video cameras which were set up before each launch. The video data were supplemented by direct visual scans of the haul-out groups several hours prior to the launches and following one of the launches. Monitoring was typically attempted at three sites during each launch, with launch-to-launch variation in the locations monitored. Acoustic measurements were obtained at many of the same locations and times. For each launch, the number, proportion, and (where determinable) ages of the individual pinnipeds that responded in various ways were extracted from the video, along with comparable data for those that did not respond overtly. No evidence of injury or mortality was observed during or immediately succeeding the launches for the monitored pinniped species.

California sea lions

California sea lions were observed during all three launches (total of four site-date-launch combinations). During all four video recordings of sea lions, all animals observed exhibited startle responses and moved along the beach at sites 0.6–1.3 km from the CPA. Details of behavior could not be observed subsequent to these night launches, but based on daytime observations from previous monitoring periods, sea lions showed increased vigilance for a short period after a launch, but settled back to pre-launch behavior patterns within 1 or 2 minutes (min) after the launch (Holst et al. 2008).

Northern elephant seals

Elephant seals were observed during all three launches (five site-date-launch combinations). At 0.2–1.7 km from the CPA, most elephant seals exhibited little reaction to launches; they merely raised their heads. During at least three of the five recordings, a small percentage (3–7%) of hauled out elephant seals moved short distances (0.5–3 m) away from their resting site in response to the launch. Details of behavior could not be observed subsequent to these night launches, but daytime observations during previous monitoring periods showed that most elephant seals exhibited little reaction to launches and returned to their previous activity pattern (e.g., sleeping, resting) within seconds (Holst et al. 2008).

Harbor seals

Harbor seals were not monitored during the launches in 2009. Emphasis during the current monitoring period was placed on observing breeding/pupping California sea lions. All vehicles were launched from the 807 Launch Complex, situated at least 1 km away from the nearest harbor seal haul-out site. Previous launch monitoring has shown that, for daytime launches in which the CPA is as much as 3.5 km away, harbor seals commonly leave their haul-out sites on rocky ledges and do not return during the duration of the video-recording period (Holst et al. 2008). Nonetheless, Holst and Lawson (2002) noted that during post-launch monitoring on the days following launches, harbor seals were usually hauled out again at these sites.

Estimated Numbers of Pinnipeds Affected by Vehicle Launches

No evidence of pinniped injuries or fatalities related to vehicle launches was evident, nor was it expected, during the monitoring period. Few, if any, pinnipeds were exposed to SELs above 118.4 dB re 20 µPa^2·s on an M_{pa}-weighted basis (SEL-M). The maximum exposure levels (on an M_{pa} basis) at pinniped beaches were below the levels at which any of the three species would be expected to incur temporary or permanent hearing impairment (*cf.* Southall et al. 2007). However, levels near the launcher (located close to a northern elephant seal haul-out site) did reach a peak pressure of 145.5 dB re 20 µPa and a SEL-M of 130.4 dB. Although these levels would not be expected to elicit permanent threshold shift (PTS) in any pinniped species, temporary threshold shift (TTS) is possible at these levels, particularly in harbor seals. However, harbor seals are not known to haul out on the beaches closest to the launcher where sounds were strongest; thus, harbor seals were unlikely to have incurred TTS. In the unlikely event that an animal did incur TTS, it would have been mild and reversible.

Pinniped groups generally extended farther along the beach than encompassed by the field of view of the video camera. In these cases, an estimate was made of the total number of individuals that were hauled out on the monitored beaches prior to the launch based on video pans of the area. The proportions of animals in the focal subgroups that were counted as affected during analysis of launch video records were extrapolated to the estimated total number of individuals hauled out in the area to derive a minimum estimate of the total number of pinnipeds affected. An attempt was also made to extrapolate the proportions of animals affected on the monitored beaches to unmonitored haul-out sites. However, this was not always possible, because it was generally unknown which beaches were used as haul-out sites on specific launch dates and how many animals were hauled out. In addition, data from previous launches were used to estimate the number of pinnipeds affected during launch days when no recordings of that species were possible. We considered pinnipeds that left the haul-out site, exhibited prolonged movement, or entered the water, as affected.

Approximately 750 California sea lions, 60 harbor seals, and no elephant seals are estimated to have been affected by launches during the June–December 2009 monitoring period. These estimates include animals that left the haul-out site in response to the launch or exhibited prolonged movement. These numbers may be underestimates, because not all pinniped beaches around western SNI could be monitored during any given launch, even though extrapolation of data for other potential haul-out sites was attempted. However, it is also possible that some proportion of individuals were affected by more than one launch and thus included more than once in the estimates.

Behavior of some pinnipeds occurring near the launch azimuths during the launch operations was affected. However, the lack of evidence of any serious effects on pinnipeds at the sites that were monitored during this study and during previous monitoring periods suggests that any effects of these launch operations were minor, short-term, and localized, with no consequences for local pinniped populations. Thus, it is unlikely that many (if any) pinnipeds on SNI were adversely impacted by the launches.

1. VEHICLE LAUNCHES AND MONITORING PROGRAM DESCRIBED

San Nicolas Island (SNI) is located ~100 kilometers (km) from the mainland coast of southern California (Fig. 1.1). Vehicles are launched from one of two land-based launch complexes on the western part of SNI: the 807 Launch Complex is located on the west coast of SNI, 11 meters (m) above sea level (ASL), and the Alpha Launch Complex is located 190.5 m ASL on the west-central part of SNI (Fig. 1.2). The vehicles pass over or near pinniped haul-out sites located around the periphery of SNI. The pinniped species that commonly occur on SNI include northern elephant seals (*Mirounga angus-tirostris*), harbor seals (*Phoca vitulina*), and California sea lions (*Zalophus californianus*).

Naval Air Warfare Center Weapons Division (NAWCWD) holds a Letter of Authorization (LOA) issued by the National Marine Fisheries Service (NMFS) allowing non-lethal takes of pinnipeds incidental to the Navy's vehicle launch operations on SNI (Appendix A). The current LOA is valid from 4 June 2009 through 3 June 2010. Previously, separate LOAs were issued for this purpose for the periods October 2003 to October 2004, October 2004 to October 2005, February 2006 to February 2007, February 2007 to February 2008, and February 2008 to October 2008. No launches took place during the February to October 2008 LOA period or during two intervals between expiry of one LOA and issuance of another (8 October 2005 to 2 February 2006 and 3 October 2008 to 3 June 2009). In addition, before any LOAs were issued, two separate Incidental Harassment Authorizations (IHAs) were issued by NMFS; those provided similar incidental take authorization for the periods August 2001 to July 2002 and August 2002 to August 2003. These authorizations, issued by NMFS under the Marine Mammal Protection Act (MMPA), allow the 'take by harassment' of small numbers of northern elephant seals, harbor seals, and California sea lions during routine launches from Navy-owned SNI.

A Marine Mammal Monitoring Plan was proposed in the Petition for Regulations under which the current LOA has been issued. The purpose of the monitoring was to characterize any effects of vehicle launch activities on pinnipeds hauled out at SNI. This report describes the results of the marine mammal and associated acoustic monitoring program during the period from June to December 2009. During that period, a total of three launches of single vehicles took place from SNI. Results concerning 77 previous launches during 2001–2008 were reported by Holst et al. (2008).

This report describes the vehicles and their launch processes, the associated monitoring program, and the monitoring results for the launches conducted by the Navy at SNI during June–December 2009. This report includes four chapters: (1) background, introduction, and description of the Navy's vehicle launches [this chapter]; (2) acoustical monitoring during the vehicle launches [Chapter 2]; (3) visual monitoring of pinnipeds during those launches [Chapter 3]; and (4) estimated numbers of pinnipeds affected by the vehicle sounds during these launches [Chapter 4].

1.1 Terrier-Lynx

The Terrier-Lynx is a two-stage, unguided, fin-stabilized, solid propellant rocket system designed to provide a realistic simulation of a medium-range ballistic missile (Fig. 1.3). The first stage consists of the Terrier Mark 70 booster (body diameter of 45.7 centimeters [cm]), and the second stage consists of the Lynx rocket. The Lynx is 36 cm in diameter and 2.8 m long. The Terrier-Lynx vehicle has an overall length of ~9 m and a total weight at lift off of ~1270 kilograms [kg].

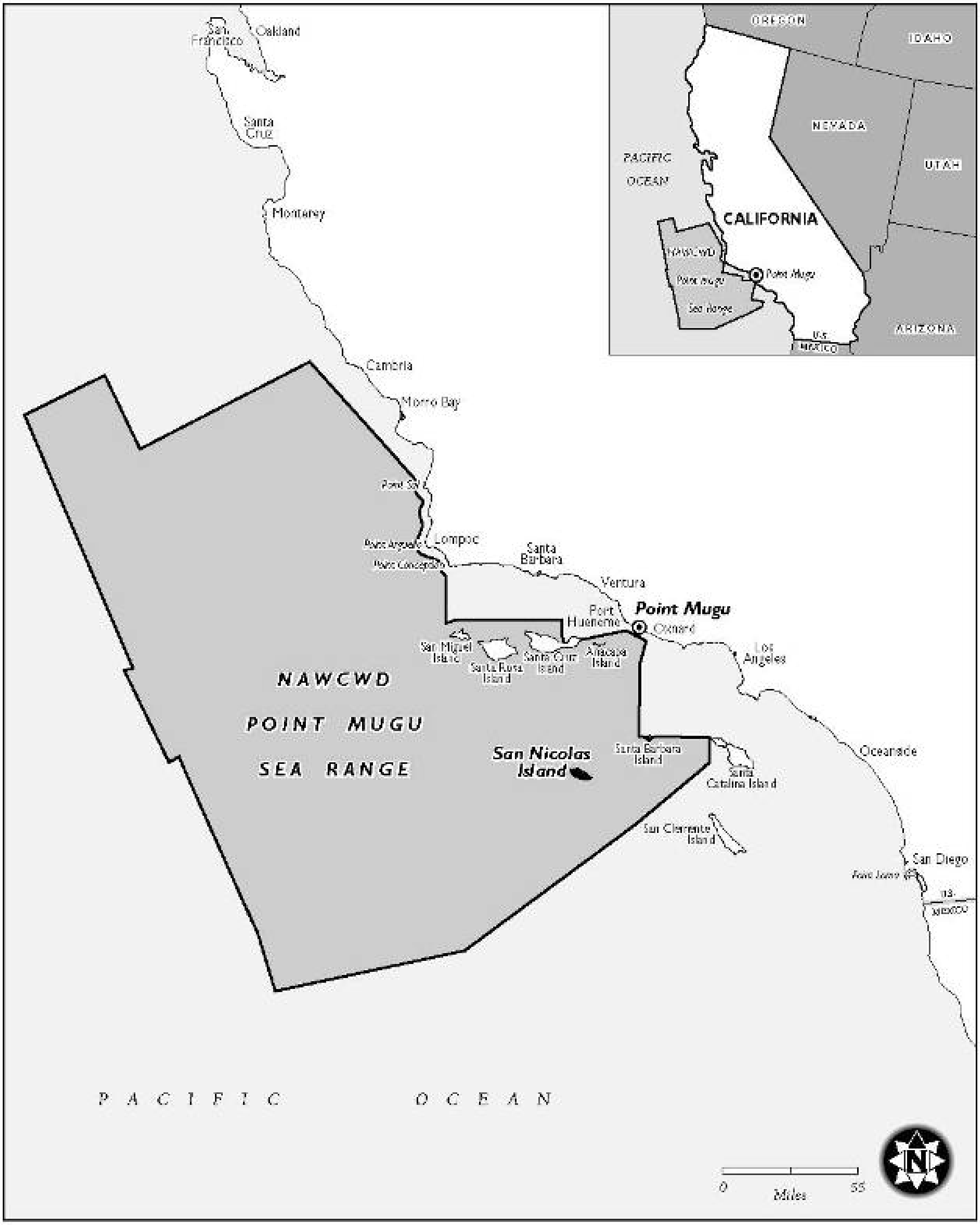

FIGURE 1.1. Regional site map of the Point Mugu Sea Range and San Nicolas Island (map by TEC).

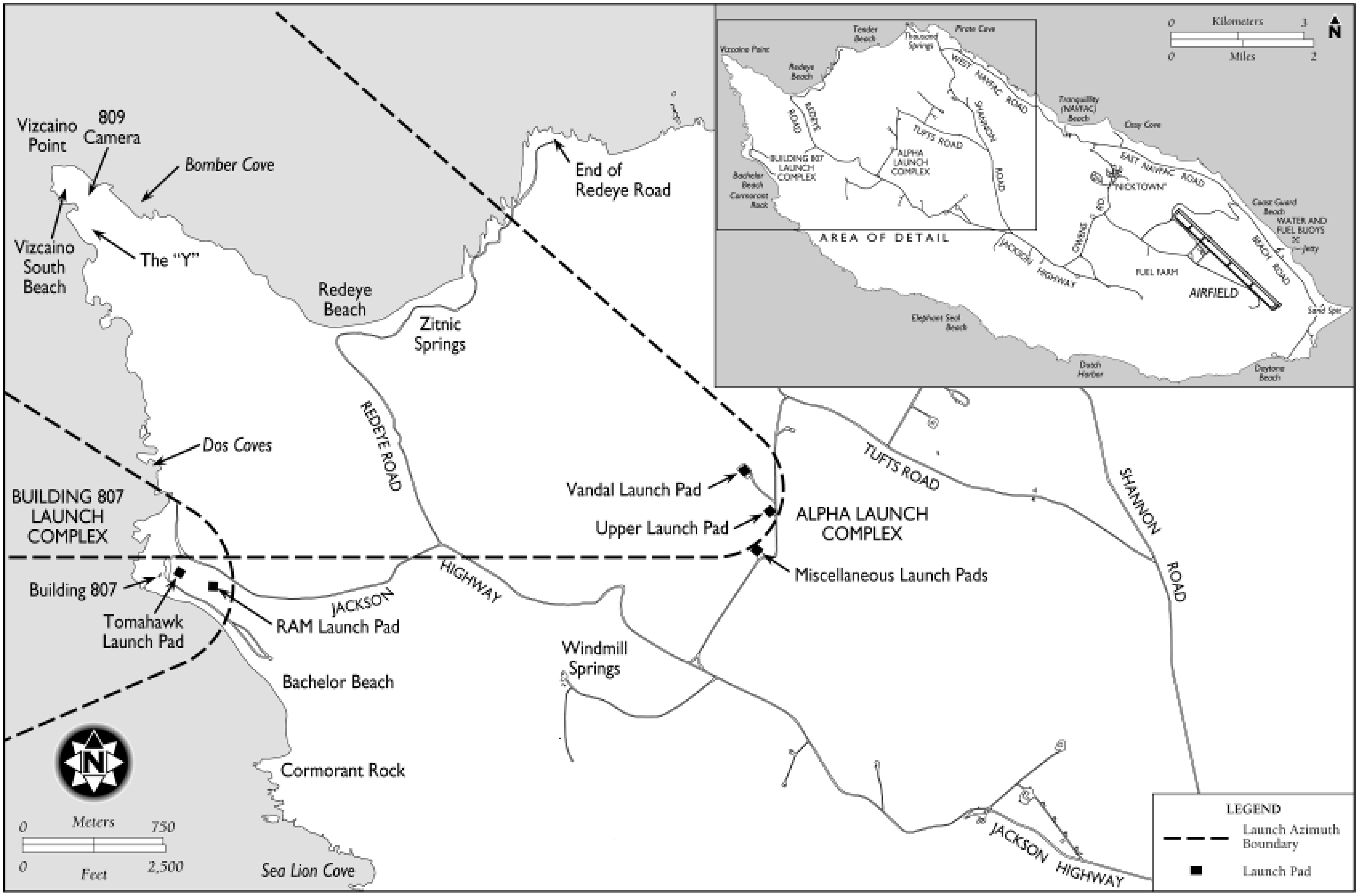

FIGURE 1.2. Map of San Nicolas Island, California, showing the Alpha Launch Complex, the 807 Launch Complex, and the names of adjacent beaches on which pinnipeds are known to haul out. Also shown are the anticipated launch azimuths (dashed lines) for each launch complex. These launch azimuths are typical, although occasionally launch paths could pass outside these boundaries.

FIGURE 1.3. A Terrier-Lynx vehicle and launcher.

This Terrier-Lynx vehicle reaches an altitude of 84 km and has a range of 99 km. Terrier burnout occurs after 6.2 seconds (s) at an altitude of 2.3 km; Lynx burnout occurs after 58.5 s at 43.5 km. The Terrier-Lynx's launch trajectory was near-vertical at 70º (Fig. 1.4), crossing the west end of SNI at an altitude of 366 m.

1.2 Terrier-Black Brant

The Terrier-Black Brant is a two-stage, unguided, fin-stabilized, solid propellant rocket system designed to provide a realistic simulation of a medium-range ballistic missile (Fig. 1.5). The first stage consists of the Terrier Mark 70 booster, which has a body diameter of 46 cm. The second stage consists of the Black Brant rocket, which has diameter of 44 cm, is 5.3 m long, and weighs 1265 kg. The Terrier-Black Brant vehicle has an overall length of ~11 m and a total weight at lift off of ~1936 kg.

Terrier burnout occurs after 6.2 s at an altitude of 3 km, and Black Brant burnout occurs after 44.5 s at an altitude of 37.7 km. The Terrier-Black Brant's launch trajectory at SNI was near-vertical (71.1º), crossing the west end of SNI at an altitude of ~381 m.

FIGURE 1.4. View of the Terrier-Lynx launch at SNI on 6 June 2009 (photograph by U.S. Navy)

1.3 Vehicle Launches during the Monitoring Period

During the period June–December 2009 there were a total of three launches from SNI on three separate days (Table 1.1). These launches occurred at night during the Airborne Laser (ABL) testing program. For this program, vehicles must be launched at night when the laser is visible. The ABL is part of the Missile Defense Agency's plan to stop ballistic missiles in the ascent phase. A single Terrier-Lynx was launched on each of 6 and 13 June 2009, and a single Terrier-Black Brant was launched on 10 August 2009. The temperature during launches ranged from 14 to 18°C, with winds up to 8 knots (kt) (Table 1.1).

All vehicles were launched from the 807 Launch Complex. The Terrier-Lynx vehicles had a launch azimuth of 260º and an elevation angle of 70º, and the Terrier-Black Brant was launched at an azimuth of 258.1º and an elevation angle of 71.1º (Fig. 1.2; Table 1.1). These launch azimuths caused the vehicles to pass over or near various acoustic measurement and pinniped monitoring sites where Autonomous Terrestrial Acoustic Recorders (ATARs) and video systems had been deployed. The latter consisted of tripod-mounted digital cameras.

FIGURE 1.5. A Terrier-Black Brant vehicle.

1.4 Acoustical Monitoring of Vehicle Launches

Audio recordings were attempted to document launch sounds at several distances from the launch trajectories of the vehicles; details are given in Chapter 2. During most launches, audio recorders were placed near video cameras and recorders that were documenting pinniped reactions, thus obtaining paired acoustic and pinniped-response data. In addition to recording launch sounds, these audio recordings also documented the ambient noise levels to which the pinnipeds were exposed prior to and following launches. Objectives of the audio monitoring program included

1. documenting the levels and characteristics of launch sounds at several distances from the azimuths of the vehicles;
2. documenting the levels and characteristics of ambient sounds at the same locations as for the launch sounds, as a measure of the background noise against which the pinnipeds will (or will not) detect the launch sounds; and
3. determining whether the sound levels from vehicle overflights were high enough to have the potential to induce Temporary Threshold Shift (TTS) in pinnipeds exposed to launch sounds.

TABLE 1.1. Details of the three launches at SNI during June–December 2009. The weather data were collected at the SNI airport, which is located at an elevation of 152 m ASL toward the east end of the island; therefore weather conditions at pinniped haul-out sites may have differed somewhat.

Launch Date in 2009	Launch Time (local)	Vehicle Type	Launch Complex	Launch Azimuth (true)	Elevation Angle / Altitude Over Beach	Weather at SNI Airport	Video Quality	Audio Quality
6 June	22:16	Terrier-Lynx	807	260°	70° / 366 m	18°C; winds 315° at <5 kt	1 camera ok; 2 poor	2 ATARs ok; 1 ATAR no event
13 June	22:31	Terrier-Lynx	807	260°	70° / 366 m	14°C; winds 315° at 5-8 kt	2 cameras ok; 1 poor	3 ATARs ok
10 August	20:50	Terrier-Black Brant	807	258.1°	71.1° / 381 m	14°C; winds variable at 5-6 kt	3 cameras ok	4 ATARs ok

Based on a review of the literature (Lawson et al. 1998) completed prior to the start of monitoring, it was evident that the sound levels that might cause notable disturbance for each pinniped species are variable and context-dependent. Lawson et al. (1998) estimated the minimum received level, on an A-weighted Sound Exposure Level (SEL-A) 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. It is arguable how many of the launch sounds should be considered to be "prolonged" from the perspective of a pinniped at a fixed location on a beach. Measured durations of sound from various types of vehicles launched from SNI typically range from much 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 factor in selecting acoustic (and video) monitoring sites during the first year of monitoring in 2001. Sites at distances up to ~4 km from the launcher and/or launch trajectory were monitored in the first year.

After reviewing video recordings of pinnipeds during launches at SNI during 2001–2002 (Holst and Lawson 2002), the 100-dBA SEL still seemed reasonable as a minimum received level that might elicit disturbance of California sea lions. However, 90 dBA SEL seemed more appropriate for 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 elephant seals usually exhibited little or no reaction to launch sounds. The received levels of sounds from the larger vehicles, 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 monitoring work (Chapter 3) has shown that 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; see Chapter 2). Previous monitoring at SNI has shown that sea lions and harbor seals 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 harbor seals leave the haul out site and/or enter the water at SELs as low as 60 dB M_{pa}.

1.5 Visual Monitoring of Pinnipeds during Vehicle Launches

The Navy conducted video and visual monitoring of pinnipeds during the three vehicle launches from SNI during the June–December 2009 period, supplemented by simultaneous autonomous audio recording of launch sounds (see Chapter 2). The video and visual monitoring provided data on samples of the pinnipeds hauled out on western SNI during launches. The accumulation of such data across numerous launches is providing the data required to characterize the extent and nature 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 vehicle launches, including the occurrence of stampedes from haul-out sites if they occur. A detailed description of the methods for the visual monitoring can be found in Section 3.2 of Chapter 3.

The video records were to be used to document pinniped responses to the launches. The objectives included 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. compare received levels of launch sound with pinniped responses, based on acoustic and behavioral data from monitoring sites at different distances from the launch site and flightline during each launch; from the data accumulated across a series of launches, establish the "dose-response" relationship[1] for vehicle sounds under different launch conditions;
4. ascertain periods or launch conditions when pinnipeds are most and least responsive to launch activities, and
5. document numbers of pinnipeds affected by vehicle launches and, although unlikely, any mortality or injury.

During the June–December 2009 period, there were three launches involving two different types of vehicles (Table 1.1). Determination of the dose-response relationship (objective 3, above) and conditions when pinnipeds were most or least responsive to launch sounds (objective 4) requires consideration of additional data, including data from the previous years of monitoring (Holst et al. 2008) and data from planned future monitoring. Therefore, objectives (3) and (4) are not addressed in the present report. However, an analysis using data from all previous monitoring years can be found in Holst et al. (2008).

1.6 Estimated Numbers of Pinnipeds Affected

The monitoring programs for the Navy's vehicle launches were designed, in part, to provide the data needed to estimate the numbers of pinnipeds affected by the launches and the manner in which they were affected. Pinnipeds are assumed to be 'taken by harassment' if there is a reason to believe that auditory impairment (TTS) might have occurred as a result of a launch, or if biologically significant behavioral patterns of pinnipeds are disrupted. NMFS (2000) defined a biologically significant behavioral response as one "…that affects biologically important behavior[s], such as survival, breeding, feeding and migration, which have the potential to affect the reproductive success of the animal". As a corollary of that, NMFS (2002) stated that "…one or more pinnipeds blinking its eyes, lifting or turning its head, or moving a few feet along the beach as a result of a human activity are not considered a 'take' under the MMPA definition of harassment".

In this report, consistent with previous related reports, we have assumed that only those animals that met the following criteria would be counted as affected by launches:

1. pinnipeds that were injured or killed during launches, if any (e.g., by stampedes);
2. pinnipeds exposed to launch sounds strong enough to cause permanent or temporary auditory impairment (permanent threshold shift [PTS] or TTS);
3. pinnipeds that left the haul-out site, or exhibited prolonged movement or behavioral changes (such as pups separated from mothers) relative to their behavior immediately prior to the launch.

In practice, no pinnipeds are known to have been injured or killed during launches monitored since August 2001, and few are believed to have received sounds strong enough to elicit TTS (Holst et al. 2008). Thus, the number of pinnipeds counted as potentially affected during the current monitoring

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[1] This is equivalent to estimating behavioral zones of influence by comparing pinnipeds' reactions to varying received levels of launch sounds.

period was primarily based on criterion (3) — the number that left the haul-out site, or exhibited prolonged movement or other behavioral changes.

1.7 Summary

From June to December 2009, NAWCWD conducted three launches from SNI on three different nights. Launches occurred from the 807 Launch Complex located near the beach on the west coast of SNI. An acoustic and visual monitoring program took place during these launches to assess the effects of the operations on pinniped species on the island. Monitoring procedures were consistent with those during previous launches during 2001–2008 (Holst et al. 2008). Monitoring procedures and results of the acoustic and visual monitoring for June–December 2009 are described in Chapters 2 and 3.

2. ACOUSTICAL MEASUREMENTS OF VEHICLE LAUNCHES

2.1 Introduction

Three vehicle launches took place from SNI during 2009, as described in Chapter 1. Table 2.1 lists the launch dates, times, and vehicles. Table 2.2 lists the acoustic monitoring locations. Maps of the launch azimuths and monitoring locations for each launch can be found in Chapter 3 (Fig. 3.1).

The acoustic measurement program during 2009 was consistent in approach and methodology with that used during the preceding years (Holst et al. 2008). Recordings of the sounds of each vehicle, as well as background sounds, were attempted at up to four sites on the island during each vehicle flight. ATARs, described below, were developed for this purpose by the Navy's acoustical contractor, Greeneridge Sciences Inc. (Greeneridge) of Santa Barbara, California. The ATARs were used to record the launch sounds at places and times where launch safety considerations required that no operator could be present during launches. Of the 10 possible recordings during the present monitoring period, 9 recordings were obtained and analyzed; for the other attempted recording, the event was not captured by the ATAR (Table 2.1).

2.2 Field Methods

2.2.1 Deployment of ATARs

During each launch within the present monitoring period, the ATARs were positioned near pinniped haul out sites at varying distances from the planned launch azimuth, specifically at locations where pinniped responses were to be monitored by video methods as well as other locations closer to the launch on occasion (see Chapter 3). The audio recordings were planned to be suitable for quantitative analysis of the levels and characteristics of the received flight sounds. In addition to providing information on the magnitude, characteristics, and duration of sounds to which pinnipeds were exposed during each flight, these acoustic data will be combined with the pinniped behavioral data to determine if there is a "dose-response" relationship between received sound levels and pinniped behavioral reactions. However, additional data acquired during previous and ongoing monitoring will be needed in order to fully meet that objective.

Measured sound levels at various microphone locations can be used to characterize sound exposure vs. distance downrange and laterally from the launch azimuth. Analyses of this type for acoustic data collected for the period August 2001 through March 2008 were reported by Holst et al. (2008). In those analyses, factors that were considered included vehicle type, launch azimuth, launch characteristics (e.g., low- vs. high-angle launch), as well as weather, which is expected to have important effects on the received sounds. Given the limited number of launches during the current monitoring period, no corresponding analysis of acoustic data has been done for the 2009 launches.

On each launch day, ATARs were set up at the recording locations during the daytime and were retrieved the next day. The ATAR units were deployed by Navy biologists at sites as close as practical to three pinniped haul-out sites (and in one case, a fourth site near the launcher) at various distances from the launch site and launch trajectory. Over the period since monitoring started (August 2001), the Navy has distributed the ATARs such that, for types of vehicles that are launched commonly at SNI, recordings have been made at a variety of different distances and locations relative to the flight trajectories and relative to the launcher itself.

TABLE 2.1. Vehicle launches recorded at SNI during 2009.

Launch Date in 2009	Local Time	Vehicle	Elevation Angle (º)	# of Acoustic Recording Sites	Acoustic Data
6 June	22:16	Terrier-Lynx	70	3	2 OK*
13 June	22:31	Terrier-Lynx	70	3	3 OK
10 August	20:15	Terrier-Black Brant	71.1	4	4 OK

* Launch event not captured on ATAR.

TABLE 2.2. Locations of ATAR recording devices during launches in 2009 (also see Fig. 3.1).

Launch Date in 2009	Vehicle	ATAR Locations
6 June	Terrier-Lynx	Bachelor Beach North, Dos Coves South*, Redeye Beach
13 June	Terrier-Lynx	Bachelor Beach North, Dos Coves South, Redeye Beach
10 August	Terrier-Black Brant	Bachelor Beach South, Dos Coves South, The “Y”, Near Launcher†

* Launch event not captured on ATAR. † ATAR was located 180 ft (55 m) from launcher.

2.2.2 ATAR Design

The ATARs were designed to record continuously and unattended for up to 13 hours (hr). It was necessary to use autonomous extended-duration recorders because safety considerations required that the ATAR units were placed at the monitoring sites during the daytime several hours before the nighttime launch. The extended recording capabilities of the ATAR units, as compared with digital audio tape (DAT) recording units used previously (e.g., Greene 1999), allow for recordings of flight sounds even if prolonged launch delays occur.

The ATARs are designed to record both high-level sounds (e.g., from vehicle launches) and normal background sounds. The ATARs record two sensor channels, each with a bandwidth of 3 to 20,000 Hertz (Hz). The principal components of an ATAR are two calibrated dissimilar microphones, two adjustable gain amplifiers (signal conditioners), and a Sound Devices 702 recorder which digitizes and records sound samples. For launches in 2009, the Sound Devices 702 recorder replaced the notebook computer that was used to store the digital audio data previously. Figure 2.1 is a block diagram of an ATAR illustrating the types and arrangement of components.

Each ATAR includes two microphones that differ in sensitivity. One microphone is a PCB 106B50 quartz microphone (PCB Piezotronics Inc., Depew, NY). These relatively insensitive microphones, with sensitivity –202 dB re 1 volt per micropascal (V/µPa), were designed for transduction of strong signals with received sound levels up to 185 dB re 20 µPa. To record ambient sounds concurrently, each ATAR includes a more sensitive microphone, the TMS 130P10 (–157 dB re 1 V/µPa). This, in conjunction with the PCB 106B50, provides additional dynamic range. Each microphone signal is sampled at 44.1 kilohertz (kHz) and digitized to a 16-bit two-byte integer.

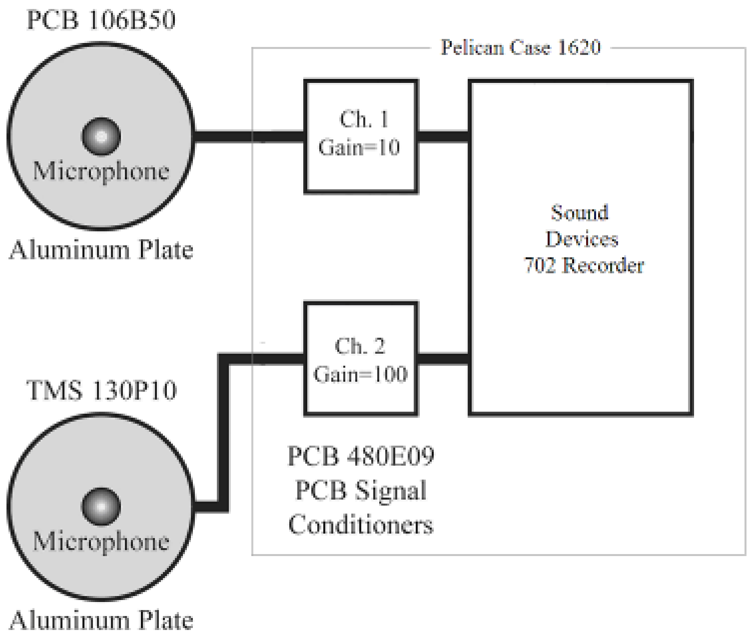

FIGURE 2.1. Block diagram of an Autonomous Terrestrial Acoustic Recorder (ATAR).

Each microphone requires a PCB model 480E09 signal conditioner. These low-noise amplifiers apply the microphone polarizing voltage. The signal conditioners have gain selections of 1, 10, and 100 (corresponding, respectively, to 0, 20, and 40 dB). These signal conditioners are mounted in waterproof Pelican cases with the other equipment, excluding the microphones (Fig. 2.1 and 2.2).

At each of the monitoring sites, the microphones were placed in hemispherical windscreens and positioned so they were 2–3 millimeters (mm) from the flat side of the hemisphere. The windscreens were then each affixed to the center of an aluminum base plate 6 mm thick and 56 cm in diameter. The two base plates were set on the ground or sand in an area generally free of vegetation (Fig. 2.3). The purpose of the aluminum base plates was to provide a hard reflecting surface for high-frequency sounds. The ground itself is acoustically reflective at low frequencies. The combination of the base plates and the ground assures that the microphones sense the combined direct and reflected sound, as would an animal whose ears are near the ground (Greene 1999).

Setting optimum recording levels presented a challenge, given that these had to be set in advance of the launch, with no opportunity to make adjustments based on initial results at that location. Setting recording levels too high would result in clipping the desired signal; setting them too low would lose the signal beneath recorder self-noise; and setting them dynamically by automatic gain control would result in uncalibrated, and hence useless, data.

During previous monitoring periods, it was observed that ATARs would sometimes not operate at certain sites despite repeated attempts, but after being moved a fraction of a kilometer away, they operated successfully on the first try. The ATARs did not fail when tested either in the laboratory at SNI or in Santa Barbara. We suggested that microwave or other electromagnetic radiation on the island, from the numerous radar and telemetry systems present there, may produce sporadic but potentially intense electromagnetic interference and cause the ATARs to fail at some times and places on SNI. Therefore, since 2004, shielding and grounding have been applied, and this has been successful in reducing the frequency of ATAR failures.

FIGURE 2.2. Photo of ATAR components in waterproof Pelican case (photograph by R. Norman, Greeneridge).

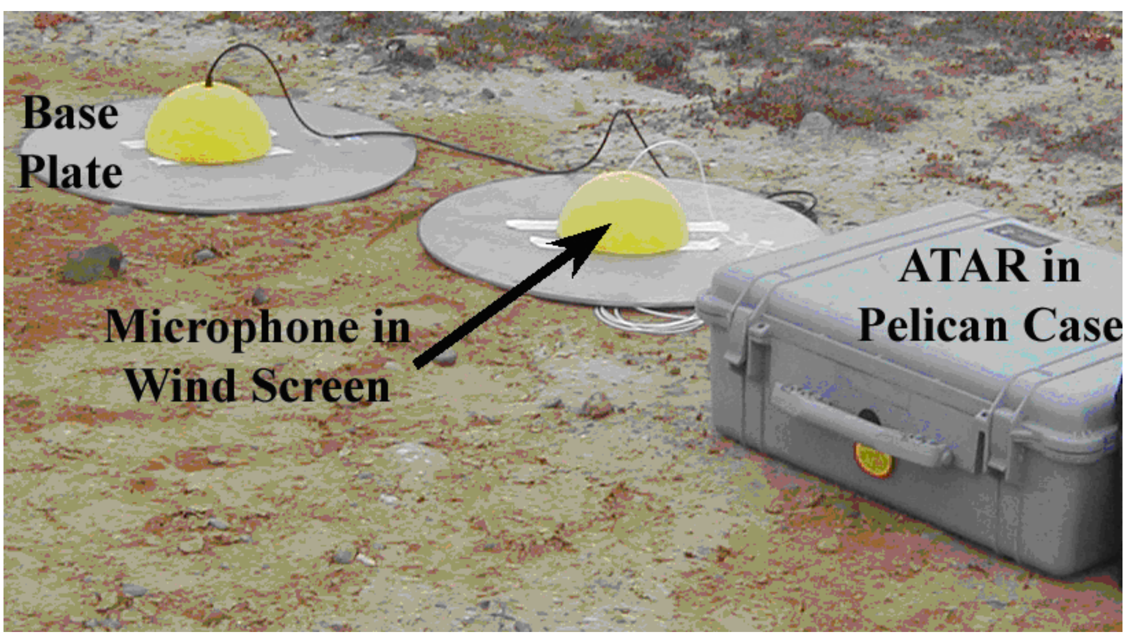

FIGURE 2.3. Typical field installation of an ATAR at the west end of SNI, California (photograph by J. Lawson, LGL).

2.3 Audio and Data Analysis Methods

The ATARs recorded digital data directly onto a Sound Devices 702 recorder. The digital data were copied to a recordable CD-ROM after the recording period and returned to the acoustical contractor, Greeneridge, for sound analysis.

Both time-series and frequency-domain analyses were 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 recently-defined M_{pa}-weighting procedure, appropriate for pinnipeds in air, is described in Southall et al. (2007) and in § 2.3.3 below. Frequency-domain results included estimation of SPLs in one-third octave bands for center frequencies from 4 to 16,000 kHz. The following subsections describe how these values are defined and calculated.

2.3.1 Time-Series Analysis

All analyses required identification of a signal's beginning and end. This identification can be complicated by background noise (whether instrumental or ambient), poorly-defined signal onsets, and gradually diminishing signal "tails". To obtain a consistent measure of signal duration for each flight, we first defined a "net energy" E. This measure of energy in excess of background was calculated as the cumulative signal energy above mean background energy:

$$E = \frac{1}{fs}\sum_{i=1}^{N} (x_i^2 - \langle n^2 \rangle) \text{ Pa}^2 \text{ s}$$

where *x* represents all data points in an event file, *n* represents only background noise data points before the flight sound, N is the total number of samples in the event file, and f_s is the sampling rate.

Based on this consistent definition of net energy E, the beginning and end of a flight sound was defined as the times associated with the accumulation of 5% and 95% of E.

Duration was defined as the difference between these start and end times.

Sound exposure was defined as 90% of E, representing total sound exposure in units of $Pa^2 \cdot s$. **SEL** was determined from $10 \cdot \log$ (sound exposure).

Sound pressure was defined as the square root of the sound exposure divided by the duration. Sound pressure is equivalent to the rms value of the signal, less background noise, over the duration. **SPL** was determined from $20 \cdot \log$ (sound pressure).

The **peak instantaneous pressure** was defined as the largest sound pressure magnitude (positive or negative) exhibited by the signal, even if the signal reached that level only momentarily. **Peak instantaneous pressure level** was determined from $20 \cdot \log$ (peak instantaneous pressure).

2.3.2 Frequency-Domain Analysis

Frequency-domain analysis was used to estimate how signal power was distributed in frequency. Flat-weighting was used for all frequency-domain analysis. Welch's (1967) "Weighted Overlapped Segment Averaging" (WOSA) method was used to generate representative power spectral densities in each case. Power spectral densities were calculated for the signal and pre-signal background noise on the low-sensitivity channel and for background noise on the high-sensitivity channel. These spectral density values were then summed into one-third octave bands.

For these analyses we defined the "signal" as consisting of the recorded data (vehicle signal plus background noise). This time series was segmented according to duration (determined from the broad-band time series analysis) as follows:

- for duration > 1 s, use 32,768-sample blocks of total length 0.74 s with Blackman-Harris (Harris 1978) minimum three-term window, overlapped by 50%. This results in frequency cells spaced by 1.35 Hz and an effective cell width (resolution) of 2.3 Hz.
- for 0.0929 s < duration < 1 s, use 4096-sample blocks of total length 0.0929 s with Blackman-Harris minimum three-term window, overlapped by 50%. This results in frequency cells spaced by 10.77 Hz and an effective cell width (resolution) of 18.3 Hz.
- for duration < 0.0929 s, use the samples spanning the signal duration and apply a uniform window. This results in cell spacing in hertz given by the reciprocal of the record length in seconds. The cell width (resolution) is the same as the cell spacing.

Background noise data recorded on the high sensitivity channel, consisting of 4 s of data selected from before the vehicle signal, were segmented into 44,100-sample blocks overlapped by 50% and weighted by the Blackman-Harris minimum three-term window. This resulted in 1-Hz cell spacing and 1.7-Hz cell width, or resolution.

The spectral density values were integrated across standard one-third octave band frequencies to obtain summed SPLs for each band. This analysis was performed for the signal, the noise on the signal channel (low sensitivity channel), and the background noise (high sensitivity channel). Note that when the cell spacing was broad, the lowest frequency one-third octave bands could not be computed. However, the cases of broad cell spacing correspond to cases of very short duration signals. Low frequencies are not important for short duration sounds.

2.3.3 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 were 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 was 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, as a first approximation, be relevant to pinnipeds listening to moderate-level sounds.

M_{pa}-weighting is a recent development that 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 have been 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 have been 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.[2] For each launch whose sounds are reported here, 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 vehicle overflights.

Measurement data from each launch are presented by one-third octave band in Appendix B. Thus, other weighting methods (e.g., C-weighting or species-specific weighting functions) could be applied to these data in the future if needed.

2.3.4 Closest Point of Approach (CPA) by the Vehicle

To relate vehicle sounds to the proximity of the vehicle's trajectory, the 3-dimensional (3-D) distance from the recording site to the CPA of the vehicle was calculated for each launch date and sound monitoring site.

2.4 Results

2.4.1 Vehicle Flight Sounds

Acoustic monitoring results for all three launches are presented in Table 2.3. Four parameters are reported for the vehicle flight sounds: peak pressure level, SPL, SEL, and duration. The last three parameters are based on flat-, A-, and M_{pa}-weighting. These values are similar to sound levels recorded during previous launches from SNI (Holst et al. 2008). It was to be expected that A- and M_{pa}-weighted levels would be less than flat-weighted levels, consistent with the greater de-emphasis of low frequency components by A-weighting. Generally, sonic boom noise is strong at frequencies below 1000 Hz, which are de-emphasized with A- and (to a lesser degree) M_{pa}-weighting; however, no sonic booms were evident at the recording sites monitored during vehicle launches in 2009.

Two graphs are presented in Appendix B for each location at which the vehicle launch sounds were recorded. For each monitored location, both graphs are based on flat-weighted data; no graphs are presented for A- or M_{pa}-weighted waveforms. One graph presents the pressure signature (pressure vs. time waveform). The second presents the SELs by one-third octave band for each of three signals: (1)

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[2] 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.

TABLE 2.3. Pulse parameters for flat-, A-, and M_{pa}-weighted sound from the vehicle launches at SNI in 2009.

Launch &	CPA	Flat-weighted sound				A-weighted sound			M_{pa}-weighted sound		
Monitoring Site	(m)	Pk	SPL	SEL	Dur	SPL	SEL	Dur	SPL	SEL	Dur
6 June 2009: Terrier-Lynx											
Dos Coves S.	645	N/A				N/A			N/A		
Bachelor Beach N.	836	122.2	109.4	115.6	4.2	99.5	105.9	4.3	106.4	112.5	4.2
Redeye Beach	1669	112.6	97.6	105.8	6.5	85.5	93.1	5.8	93.6	101.7	6.5
13 June 2009: Terrier-Lynx											
Dos Coves S.	575	130.6	114.4	120.2	3.9	107.3	112.5	3.3	112.5	118.0	3.6
Bachelor Beach N.	752	123.4	109.7	116.2	4.4	100.9	107.1	4.2	106.8	113.1	4.2
Redeye Beach	1673	112.9	97.6	105.7	6.5	86.5	94.2	5.9	93.4	101.5	6.5
10 August 2009: Terrier-Black Brant											
Dos Coves S.	604	129.2	115.0	121.1	4.1	106.5	111.6	3.2	112.8	118.4	3.6
Bachelor Beach S.	1032	123.2	107.2	114.6	5.4	98.2	104.6	4.4	104.4	111.3	4.9
The "Y"	1348	116.9	102.7	109.2	4.5	93.5	99.7	4.1	100.2	106.5	4.3
Near Launcher†	83	145.5	128.0	134.1	4.1	123.7	124.6	1.2	129.7	130.4	1.2

† ATAR was located 180 ft (55 m) from launcher. N/A = data not available. N = North; S = South. 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.

the vehicle sounds; (2) the background instrumentation noise from the low-sensitivity channel (the same sensor used to measure the vehicle sounds but using data recorded before the vehicle sounds); and (3) the background noise levels from the high-sensitivity channel (i.e., the ambient SPLs). Because the ambient sounds are continuous, expressing them as SELs is unconventional. However, for purposes of comparison with the transient vehicle sounds, one can consider the SPLs for ambient noise to be the SELs in a 1-s period.

2.4.2 Ambient Noise Levels

Background sounds were recorded on the second channel of each ATAR using a higher sensitivity microphone. As expected, this channel overloaded during the brief time while the vehicle flight sounds were received, but at other times recorded the background sounds reliably (i.e., at levels above the self-noise [instrumentation noise] of the sensing and recording electronics). The sound levels for the 10–20,000 Hz band were determined using an averaging time of 4.0 s. Flat-, M_{pa}-, and A-weighted ambient noise levels for the vehicle launches are presented in Table 2.4. The measured A-weighted values were quite low and comparable to sound levels expected in quiet residential areas. Much of the background sound was infrasonic energy in the 10–20 Hz band, probably mainly attributable to wind noise. When the 10–20 Hz components are excluded, broadband levels are typically 10 dB lower than those quoted for the 10–20,000 Hz band.

TABLE 2.4. Broadband (10–20,000 Hz) sound levels (in dB re 20 µPa) as recorded before the launch by the high-sensitivity sensor designed to measure ambient sounds.

Date 2009	Vehicle	Site	Flat-weighted	A-weighted	M_{pa}-weighted
6 June	Terrier-Lynx	Dos Coves South		N/A	
		Bachelor Beach North	62.2	49.8	57.9
		Redeye Beach	56.2	43.3	50.1
13 June	Terrier-Lynx	Dos Coves South	83.3	61.1	70.1
		Bachelor Beach North	67.2	51.8	58.5
		Redeye Beach	58.4	42.0	49.0
10 August	Terrier-Black Brant	Dos Coves South	55.2	46.1	50.5
		Bachelor Beach South	56.5	46.4	51.0
		The "Y"	51.7	34.3	41.6
		Near Launcher†	59.0	41.4	53.4

† ATAR was located 180 ft (55 m) from launcher.

2.5 Discussion and Summary

During the June–December 2009 period, three vehicles were launched from SNI. The sound levels received from the vehicles were comparable to those recorded from previous launches at SNI (see Holst et al. 2008). During the present monitoring period, the highest measured sound levels on pinniped haul-out beaches were 121.1 dB re 20 $\mu Pa^2 \cdot s$ SEL on a flat-weighted basis, 118.4 dB re 20 $\mu Pa^2 \cdot s$ on an M_{pa}-weighted basis, and 112.5 dBA SEL (Table 2.3). None of the sounds recorded at haul-out sites exceeded 129 dB re 20 $\mu Pa^2 \cdot s$ SEL-M, the energy level at which TTS onset may occur in the harbor seal (Southall et al. 2007). Sounds of 130.4 dB re 20 $\mu Pa^2 \cdot s$ SEL-M were recorded near the launcher at the 807 Launch Complex, which is located close to a beach where northern elephant seals haul out. However, the closest haul-out site for harbor seals (the most sensitive of the three pinniped species present regularly at SNI) is located at least 1 km from the 807 Launch Complex, where sound levels are lower. None of the recorded sounds exceeded the SEL-M (144 dB) or peak pressure (149 dB) at which a slight PTS may occur (Southall et al. 2007). The possibility of TTS and PTS occurring in pinnipeds hauled out on SNI during vehicle launches is further discussed in Chapter 4.

3. BEHAVIOR OF PINNIPEDS DURING VEHICLE LAUNCHES

3.1 Introduction

Three launches occurred from the west end of SNI, California, on three separate dates from 6 June to 10 August 2009. Specific information about each of the launches is given in Chapter 1. Chapter 2 documents the sounds measured on western SNI during these launches. Corresponding information concerning previous launches during 2001–2008 has been reported previously (Holst et al. 2008). This chapter documents the behavioral reactions of pinnipeds to the launches during the June–December 2009 monitoring period.

Three species of pinnipeds are common on the beaches of SNI: California sea lion, harbor seal, and northern elephant seal. However, harbor seals were not monitored during the present monitoring period. No other species were recorded during the monitoring work, either during the present monitoring period or during previous monitoring efforts since August 2001 (Holst et al. 2008).

Vehicles were launched during June and August 2009. Thus, no launches took place during the pupping/breeding season of harbor seals, and no harbor seals were monitored during the launches. However, the launches did take place when California sea lions were pupping/breeding. No evidence of injury or mortality was observed on the day of any launch during the monitoring period, nor was any launch-related injury or mortality expected based on prior monitoring results.

As in previous monitoring years, most northern elephant seals demonstrated little or no reaction to the vehicle launches. Although most sea lions showed strong reactions to the launches in 2009, monitoring from previous years showed that sea lion behavior typically returned to pre-launch states within seconds or minutes following the launches (Holst et al. 2008). Behavior as well as numbers of sea lions and elephant seals hauled-out several hours after launches is generally similar to the behavior and numbers observed before launches. In contrast, harbor seals commonly leave their haul-out sites to enter the water and do not return during the duration of the video recording (Holst et al. 2008). Nonetheless, Holst and Lawson (2002) noted that the behavior and numbers of harbor seals hauled out on the day following a launch were similar to those on the day of the launch.

3.2 Field Methods

The launch monitoring program was based primarily on remote video recordings. Remote cameras were essential because, during vehicle launches, safety rules prevent personnel from being present in many of the areas of interest. In addition, launches took place at night, when personnel are not able to visit SNI. Video data were obtained via three portable digital cameras that can be set up temporarily at any site.

During the launches described in this report, use of video methods theoretically allowed observations of up to three pinniped species during the same launch. The actual number of species studied per launch depended on the number of video systems deployed during each launch and on the number of species hauled out at those sampling sites (Table 3.1). During the current monitoring period, only California sea lions and elephant seals were observed during each of the launches. Harbor seals were not observed during the current monitoring period, because monitoring efforts were focused on breeding/pupping sea lions.

TABLE 3.1. Video data collected for California sea lions and northern elephant seals during vehicle launches at SNI during 2009.

Video Recording Location	Launch Date in 2009 / Vehicle Type: 6 June Terrier-Lynx	13 June Terrier-Lynx	10 August Terrier-Black Brant
California Sea Lion			
Dos Coves South	x†	x	x
The "Y"	-	-	x
Northern Elephant Seal			
Dos Coves South	x‡	x‡	x‡
Redeye Beach	x*	x*	-
Bachelor Beach North	x	x	-
Bachelor Beach South	-	-	x

'x' recording obtained; † Only partial views of sea lions on beach. ‡ Video recording attempted, but no elephant seals in camera field of view (FOV) at time of launch. * too dark during launch for detailed behavioral observations.

On the day of each launch, Navy biologists placed the cameras at locations overlooking haul-out sites during the daytime, several hours before the nighttime launch. Placement was such that disturbance to pinnipeds was minimal. The entire haul-out aggregation at a given site could not be recorded, as the wide-angle view necessary to encompass an entire beach would not allow detailed behavioral observations. Thus, the cameras were set to record a focal subgroup within the haul-out aggregation. It was more effective to obtain a higher-magnification view of a sample of the animals at each site.

For the combined pinniped and acoustic monitoring, the Navy usually attempts to obtain video and audio records from three locations at different distances from the vehicle flight path during each launch from SNI. Figure 3.1 shows the monitoring locations relative to the launch azimuths for 2009. Combined pinniped and acoustic monitoring is important to ascertain the lateral extent of the disturbance effects and the "dose–response" relationship between sound levels and pinniped behavioral reactions. Given the variability in types of vehicles launched at SNI, in sound propagation, and in pinniped behavioral reactions, this analysis requires data from a relatively large number of launches. The limited number of launches (of different types) during the current monitoring period did not, by itself, provide sufficient data for such an analysis. To investigate the dose–response relationships, acoustic and pinniped response data from the present monitoring period will need to be combined with corresponding data from previous monitoring; a preliminary analysis of dose–response relationships using data collected from 2001 to 2008 was presented by Holst et al. (2008).

3.2.1 Mobile Cameras

On the day of each launch, Navy biologists placed three portable Sony Handicams DCR-SR100 video cameras on tripods that overlooked haul-out sites during the daytime (Fig. 3.2). The cameras were used in the nightshot mode, with infrared illuminators. For the Terrier-Lynx launches, two illuminators per camera were used. However, two illuminators did not provide a sufficient amount of light during the nighttime launches, so four illuminators per camera were used during the Terrier-Black Brant launch. Vehicle and other sounds detected by the microphones built into these cameras were also recorded. These audio data were used during behavioral analyses (e.g., to confirm the exact time when the vehicle passed), but were uncalibrated and not of sufficient quality to provide launch sound information.

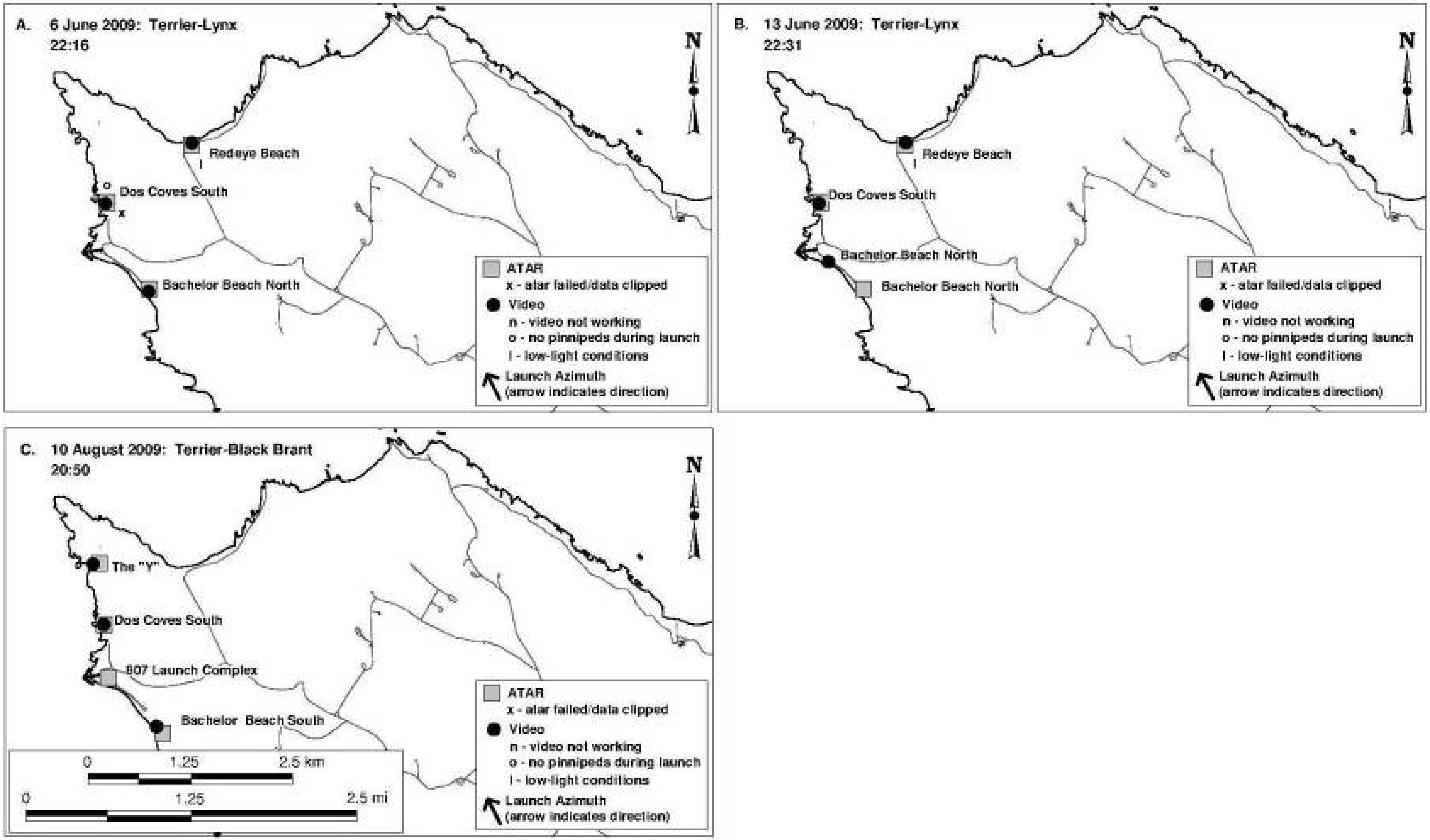

FIGURE 3.1. Launch azimuths, acoustic recording sites (ATARs), and video recording sites for launches at SNI during 2009. Pinnipeds were only in partial view at Dos Coves South during the launch on 6 June 2009.

FIGURE 3.2. Photo of video camera set-up at SNI with two infrared illuminators (photograph by G. Smith, U.S. Navy).

3.2.2 Visual Observations

Observations were obtained before, during, and after each vehicle launch. Navy biologists from NAWCWD, Point Mugu, Range Department, made direct visual observations of the pinniped groups prior to deployment of the cameras and ATARs during the daytime. Records from these visual observations included the local weather conditions, types and locations of any pinnipeds hauled out, and the type of launch activity planned. The time (to the second) was shown superimposed on the video from the mobile cameras. The video continued recording for ~30 min after the launch. Observations during that period were used to determine (when light conditions allowed) whether the relative numbers of pinnipeds at the haul-out site had changed, and if there was obvious evidence of recent injury or mortality. Because the video quality was relatively poor during these nighttime launches due to low-light conditions, it was not always possible to accurately determine behaviors or numbers of animals on the beach.

3.3 Video and Data Analysis

Digital video data were copied to DVD-ROMs to facilitate transport and playback and for backup. Video records were then transferred from the Navy to LGL Ltd., environmental research associates (LGL), for analysis. Subsequent to the launch, an experienced biologist (MH) reviewed and coded the video data on the DVD-ROMs as they were played back to a high-resolution color monitor. The videotaped data several hours before, during, and up to 30 min after each launch were reviewed in order to document the types and numbers of pinnipeds present, the nature of any overt responses to the launch, and the number of pinnipeds that responded overtly. The number, proportion and (where determinable) ages of the individuals that responded in various ways were extracted from the video, along with comparable data for those that did not respond overtly. (Following NMFS [2002], subtle behavioral reactions that persisted for only a few minutes were considered unlikely to have biologically significant consequences for the pinnipeds.) Unlike for daytime launches, detailed behavioral data before and after the launches could not be determined, due to low-light conditions during nighttime launches.

The following variables concerning the circumstances of the observations were extracted from the videotape or from direct observations at the site:

1. study location;
2. local time;
3. substratum type—a categorical description of the substratum upon which the focal group of pinnipeds was resting (sand, cobble, rock ledges, or water less than 1 m deep);
4. substratum slope (0-15º, >15º, or irregular), estimated from the video records;
5. weather, including an estimate of wind strength and direction, and presence of precipitation; these data were made available by the Navy meteorological unit;
6. horizontal visibility—the average horizontal visibility (in m) around the focal subgroup of pinnipeds, as determined by meteorological conditions and/or physical obstructions; this was estimated by identifying the farthest visible object relative to the interacting pinnipeds, as evident from the known positions of local objects and accounting for obstructing terrain; and
7. tide state—exact time for local high tide was determined from relevant tide tables.

To relate pinniped behavior to the proximity of the vehicle launch, the 3-D distance from the recording site to the CPA of the vehicle was calculated.

3.4 Descriptions of Pinniped Behavior during Specific Launches

The following subsections provide overall descriptions of pinniped responses and notable reactions during each launch in the current monitoring period. Corresponding descriptions concerning pinniped responses to launches in 2001–2008 were reported by Holst et al. (2008). Video recordings of pinniped behavior during launches in 2009 were collected on three dates for California sea lions and elephant seals (Table 3.1); harbor seals were not monitored. California sea lions were monitored at two different sites (four site-date-launch combinations), and elephant seals were observed at three different sites (five site-date-launch combinations; Table 3.1). Recordings of elephant seals were attempted at a fourth site (Dos Coves South), but no seals were observed during any of the launches at that site. The video recordings generally provided data on the responses of a sample of the total pinnipeds present on a given beach.

3.4.1 Terrier-Lynx Launch, 6 June 2009

A Terrier-Lynx was launched from the 807 Launch Complex, with an azimuth of 260º and a 70º elevation angle (Fig. 3.1A). Video recordings of California sea lions and elephants seals were attempted at Dos Coves South (CPA = 0.6 km), but at the time of the launch, animals that were hauled out on the beach were only in partial view of the camera (Table 3.1). Elephant seals were observed at Bachelor Beach North (CPA = 0.8 km) and Redeye Beach (CPA = 1.7 km) (Table 3.1). Because only two illuminators were used with all cameras, detailed observations were not possible due to low-light conditions. The light from the vehicle flight helped illuminate the beach during the launch.

ATARs were deployed at three sites (Dos Coves South, Bachelor Beach North, Redeye Beach) where video recordings of pinnipeds were attempted (Fig. 3.1A; Tables 2.2 and 2.3). The sounds from the launch were loudly audible on the audio channel of all video recordings. However, no launch event was captured on the ATAR at Dos Coves South.

California Sea Lions.—During the daytime, ~50 sea lions (including adult males and females, and pups) were hauled out at Dos Coves South. During the nighttime launch, only partial views of animals were obtained, as most sea lions were outside of the field of view (FOV) of the camera. However, some startle responses and movement of sea lions (at least five individuals) were evident during the launch, although detailed observations were not possible (Table 3.2).

Elephant Seals.—During the daytime, 100–200 elephant seals were hauled out at Dos Coves South. During the nighttime launch, no elephant seals were visible in the FOV of the camera (Table 3.3). At Bachelor Beach North, hundreds of elephant seals were hauled out during the day. Just before the nighttime launch, ~100 seals were in the FOV of the camera. All elephant seals looked up during the launch, and at least three animals moved a short distance (~0.5–3 m; Table 3.3); However, prolonged observations were not possible, as the light from the launch diminished quickly. At Redeye Beach, ~200 elephant seals were hauled out during the day. During the launch, 13 elephant seals were visible on the beach; all looked up during the launch, but it was not possible to see whether any animals moved along the beach (Table 3.3).

3.4.2 Terrier-Lynx Launch, 13 June 2009

A Terrier-Lynx was launched from the 807 Launch Complex, with an azimuth of 260º and a 70º elevation angle (Fig. 3.1B). Video recordings of California sea lions and elephants seals were attempted at Dos Coves South (CPA = 0.6 km), and elephant seals were observed at Bachelor Beach North (CPA = 0.2 km) and Redeye Beach (CPA = 1.7 km) (Table 3.1). Because only two illuminators were used per camera, detailed observations were not possible due to low-light conditions. The light from the vehicle flight helped illuminate the beach during the launch.

ATARs were deployed at three sites (Dos Coves South, Bachelor Beach North, Redeye Beach) where pinnipeds were observed (Fig. 3.1B; Tables 2.2 and 2.3). The sounds from the launch were audible on the audio channel of all video recordings.

California Sea Lions.—During the daytime, ~200 sea lions (including adult males, females, and pups) were hauled out at Dos Coves South. During the launch, six sea lions were observed on the beach. All sea lions startled and moved along the beach in response to the launch; four sea lions moved out of the FOV (at least 6 m; Table 3.2). It could not be determined whether any animals entered the water.

Elephant Seals.—During the daytime, ~40 elephant seals were hauled out at Dos Coves South. During the nighttime launch, the camera was not focused on any elephant seals on the beach (Table 3.3). At Bachelor Beach North, ~1000 elephant seals were hauled out during the day. During the nighttime launch, all 100 elephant seals in the FOV of the camera looked up, and at least three seals moved a short distance along the beach (0.5–3 m; Table 3.3). At Redeye Beach, ~100 elephant seals were hauled out during the day. At nighttime, ~14 elephant seals could be seen briefly when the vehicle was launched; however, the light diminished quickly, and the responses of most seals could not be determined. At least one seal moved a short distance along the beach, and at least one other seal looked up in response to the launch (Table 3.3).

TABLE 3.2. Details of vehicle launches, SELs, and California sea lion reactions at SNI during 2009. All launches occurred from the 807 Launch Complex.

Launch Date in 2009	Launch Time (local)	Vehicle Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	3-D CPA distance (m)	SEL [dB re 20 µPa^2 · s] flat-/ M_{pa}-weighted	Behavioral Reaction of Animals to Launch
6 June	22:16	Terrier-Lynx	260°	70° / 366 m	Dos Coves South[n]	622	N/A; launch sound audible on audio channel	Number of sea lions on beach during launch unknown, but at least 5 sea lions startled and moved along the beach. Could not determine if any animals entered water.
13 June	22:31	Terrier-Lynx	260°	70° / 366 m	Dos Coves South[n]	558	120 / 118	At least 6 sea lions in FOV during launch; all startled and moved along beach. 4 sea lions moved out of FOV (at least 6 m). Could not determine if any animals entered water.
10 August	20:50	Terrier-Black Brant	258.1°	71.1° / 381 m	Dos Coves South[n]	602	121 / 118	50 sea lions monitored; all looked and moved along beach. One entered FOV. Could not determine if any animals entered water.
"	"	"	"	"	The "Y"[n]	1342	109 / 107	100 sea lions monitored; all looked and moved along beach. One entered FOV. Could not determine if any animals entered water.

[n] monitoring site was located north of the launch azimuth. N/A = not available, FOV = field of view of camera.

TABLE 3.3. Details of vehicle launches, SELs, and northern elephant seal reactions at SNI during launches in 2009. All launches occurred from 807 Launch Complex.

Launch Date in 2009	Launch Time (local)	Vehicle Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	3-D CPA distance (m)	SEL [dB re 20 µPa$^2 \cdot$ s] flat-/ M_{pa}-weighted	Behavioral Reaction of Animals to Launch
6 June	22:16	Terrier-Lynx	260°	70° / 366 m	Dos Coves South[n]	622	N/A; launch sound audible on audio channel	Number of seals on beach during launch unknown; none in FOV.
"	"	"	"	"	Bachelor Beach North[s]	846	116 / 113	During launch, ~100 seals in FOV; all looked up and at least 3 moved 0.5-3 m.
"	"	"	"	"	Redeye Beach[a]	1692	106 / 102	During launch, ~13 in FOV; all looked up. Too dark to see if any seals moved along beach.
13 June	22:31	Terrier-Lynx	260°	70° / 366 m	Dos Coves South[n]	558	120 / 118	No elephant seals in FOV during launch, but were hauled out on beach during the day.
					Bachelor Beach North[s]	215	116 / 113	During launch, ~100 seals in FOV; all looked up and at least 3 moved 0.5-3 m.
					Redeye Beach[a]	1698	106 / 102	During launch, ~15 seals in FOV, but too dark to see details. At least one seal moved a short distance, and one more looked up.
10 August	20:50	Terrier-Black Brant	258.1°	71.1° / 381 m	Dos Coves South[n]	602	121 / 118	No elephant seals in FOV during launch, but were hauled out on beach during the day.
"	"	"	"	"	Bachelor Beach South[s]	916	115 / 111	2 elephant seals monitored; both looked up but did not move in response to launch

[n] monitoring site was located north of the launch azimuth. [s] monitoring site was located south of the launch azimuth. [a] monitoring site was located away from/behind azimuth. N/A = not available, FOV = field of view of camera.

3.4.3 Terrier-Black Brant Launch, 10 August 2009

A Terrier-Black Brant was launched from the 807 Launch Complex, with an azimuth of 258.1º and a 71.1º elevation angle (Fig. 3.1C). Video recordings of California sea lions were made at The "Y" (CPA = 1.3 km) and Dos Coves South (CPA = 0.6 km). Video recordings of elephant seals were also attempted at Dos Coves South and Bachelor Beach South (CPA = 0.9 km) (Table 3.1). During this launch, four illuminators were used per camera, so lighting conditions were improved during the recordings compared to the other two launches. However, the video quality was poor at Dos Coves South and the "Y".

ATARs were deployed at three sites (Dos Coves South, Bachelor Beach South, The "Y") where video recordings of pinnipeds were made, as well as near (55 m from) the launcher (Fig. 3.1C; Tables 2.2 and 2.3). The sounds from the launch were loudly audible on the audio channel of all video recordings.

California Sea Lions.—At Dos Coves South, ~200 sea lions (including adult males and females, and pups) were hauled, and many pups were in the water. Just before the nighttime launch, ~50 sea lions were in the FOV of the camera, and some were moving around on the beach. During the launch, all 50 sea lions looked up and moved along the beach, and one sea lion entered the FOV (Table 3.3). However, it could not be determined whether any animals entered the water. Approximately 50 min later during a post-launch scan, there were only 5–10 sea lions hauled out at Dos Coves South (Table 3.2). During the daytime, ~100 sea lions (including adult males and females, and pups) were hauled out at The "Y". Just before the nighttime launch, ~100 sea lions were observed on the beach, and some were moving around. During the launch, all 100 sea lions startled and scattered along the beach (Table 3.2). It could not be determined whether any animals entered the water.

Elephant Seals.—A few elephant seals were hauled out at Dos Coves South during the day, but no seals were captured on video during the nighttime launch (Table 3.3). During the daytime, ~40 elephant seals were hauled out at Bachelor Beach South. During the nighttime launch, two elephant seals were observed; both looked up in response to the launch but did not move along the beach (Table 3.3).

3.6 Implementation of Mitigation Measures

Table 3.4 shows a summary of the mitigation measures that were specified by NMFS in the LOA, and how they were implemented during the current monitoring period.

3.7 Summary

Although low-light conditions during nighttime launches in 2009 hindered detailed behavioral observations, pinniped responses to launches appeared to be similar to those observed during previous monitoring periods (see Holst et al. 2008). In general, northern elephant seals exhibited little reaction to the launches, whereas California sea lions responded more strongly. Harbor seals were not observed during the present monitoring period.

During the nighttime launches at SNI, most northern elephant seals merely raised their heads briefly during the launches. However, some elephant seals did move a short distance (0.5–3 m) away from their resting site. All California sea lions that were observed during the launches exhibited startle responses and moved around on the beach. Movement into the water could not be determined during the nighttime launches due to low-light conditions.

No evidence of injury or mortality was observed during or immediately succeeding the launches.

TABLE 3.4. Implementation of mitigation measures during the June–December 2009 monitoring period.

Mitigation Measure	Implementation
No personnel at haul-out sites 2 hr before launch	Personnel were prohibited from accessing the haul-out sites at least 2 hr before all launches.
Avoid launches during harbor seal pupping season	None of the launches occurred during the harbor seal pupping season.
Limit launch activities during other pinniped pupping season	All three launches occurred during the California sea lion pupping season. These launches were part of ABL testing program; thus, the timing of these launches could not be changed.
No launches of missiles at low elevation from Alpha Launch Complex	No missiles were launched from the Alpha Launch Complex during the monitoring period. In addition, vehicles from 807 Launch Complex passed over haul out beaches at altitudes >365 m.
Avoid multiple launches in quick succession, especially when pups present	No multiple launches in quick succession occurred during the present monitoring period.
Limit launches during nighttime	As the launches were part of the ABL testing program, they had to take place at night.
Ensure aircraft maintain an altitude of 1000 ft from haul outs	No aircraft were flown near haul-out areas.
Review launch procedure and monitoring methods with NMFS if pinniped injury or mortality are discovered.	No injured or dead pinnipeds were seen during the monitoring period.

4. ESTIMATED NUMBERS OF PINNIPEDS AFFECTED BY VEHICLE LAUNCHES DURING 2009

This chapter provides estimates of the numbers of pinnipeds affected by the Navy's vehicle nighttime launches on SNI during 2009, based mainly on information provided in previous chapters of this report.

4.1 Pinniped Behavioral Reactions to Noise and Disturbance

Some of the pinnipeds on the beaches at SNI show disturbance reactions to vehicle launches, but others do not. The levels, frequencies, and types of noise that elicit a response are known or expected to vary between and within species, individuals, locations, and seasons. Also, 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 vehicle launch. Furthermore, pinnipeds may, at times, react to the sight and sound of seabirds 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. 2008).

For pinnipeds hauled out on land, behavioral changes range from a momentary alert reaction or an upright posture to movement – either deliberate or abrupt – 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. 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).

Although it is possible that pinnipeds exposed to launch noise might "stampede" from the haul-out sites in a manner that causes injury or mortality, this was judged unlikely prior to the monitoring program. Review of video records of pinnipeds during launches at SNI indicates that this assumption was generally correct. However, monitoring conducted during 2002–2003 showed that, in some cases, several harbor seal pups were knocked over by adult seals as both pups and adults moved toward the water in response to the launch (Holst 2004a). However, no injuries were observed. Similarly, during the 2004–2005 monitoring period, several 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 2006b). The pups were momentarily startled, but did not appear to be injured. No such cases have been observed since 2005.

Since no injuries or deaths were observed during the monitored launches in either the present monitoring period or earlier monitoring back to August 2001, disturbance rather than injury or mortality is the primary concern in this project. The minimum numbers of pinnipeds on the monitored beaches that might have been affected significantly by the launches were estimated. The Navy, consistent with 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. 2005, 2008; Holst and Greene 2006a,b), we have assumed that only those animals that met the following criteria would be counted as affected by the launches:

1. pinnipeds that were injured or killed during launches (e.g., by stampedes);
2. pinnipeds exposed to launch sounds strong enough to cause TTS; and
3. pinnipeds that left the haul-out site, or exhibited prolonged movement or prolonged behavioral changes (such as pups separated from mothers) relative to their behavior immediately prior to the

launch.

In practice, no pinnipeds are known or suspected to have been injured or killed during the monitored launches (i.e., since August 2001), 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 current monitoring period was based on criterion (3) – the number that left the haul-out site, or exhibited prolonged movement or other behavioral changes.

The numbers of such affected pinnipeds were calculated for the periods during and immediately following the three launches on three separate days during 2009. Disturbance reactions (if any) were short-lived for northern elephant seals and California sea lions and did not appear to extend into subsequent days. Harbor seals commonly leave their haul-out sites during a launch, but occasionally haul out again at the same site as soon as several minutes after a launch, and often start to haul out again within 1–2 hr after a launch (Holst et al. 2008).

4.2 Possible Effects on Pinniped Hearing Sensitivity

Temporary or perhaps 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).

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: 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). 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 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) propose 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; those levels are not expected to elicit TTS in elephant seals or California sea lions (Southall et al. 2007).

The sounds received from vehicle launches on SNI are sometimes impulse sounds (e.g., when there is a sonic boom [not the case for 2009 launches] or near the launcher). At other times and locations they are non-impulsive. During past monitoring of vehicle launches from SNI during 2001–2008, few if any pinnipeds were exposed to sound levels above 122 dB SEL-M (Holst et al. 2008). 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 150 dB (Holst et al. 2008). During the current monitoring period, SEL-M at pinniped beaches reached up to 118 dB, and peak pressure levels were as high as 131 dB re 20 μPa. However, near the launcher which was located close to a beach, SEL-M reached 130 dB, and the peak pressure level was 146 dB. Thus, it is possible that a few pinnipeds, particularly harbor seals, may incur TTS during some vehicle launches (especially of larger missiles and targets) from SNI. Because of their higher TTS thresholds, it is likely that fewer California sea lions and elephant seals may incur TTS as compared to harbor seals. During the current monitoring period, it is unlikely that any animals incurred TTS. Although northern elephant seals are known to haul out on the beach near the launcher, harbor seal haul-out sites are located at least 1 km from the launch complex.

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 TTS threshold let alone the PTS threshold. Even measurements taken close to the launcher were <144 dB re 20 $\mu Pa^2 \cdot s$.

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). During the 2001–2008 monitoring period, peak pressure levels received near pinniped beaches close to the vehicle trajectory were generally less than 149 dB re 20 μPa (Holst et al. 2008). However, during three launches that produced a sonic boom (impulse), peak pressure levels were 149–150 dB (Holst et al. 2008). However, given the higher TTS thresholds in 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 sea lions or elephant seals during those launches. Harbor seal haul-out sites are located at least 1 km from the launch complexes at SNI; thus, peak levels at haul-out locations will be lower than near the launcher. Thus, harbor seals are also unlikely to incur PTS during launches at SNI. During the current monitoring period, none of the sounds were strong enough at pinniped haul-out sites to have induced PTS in any pinniped species.

4.2.2 Conclusions Regarding Effects on Pinniped Hearing Sensitivity

Overall, the results to date indicate that there is little potential for appreciable TTS or especially PTS in pinnipeds hauled out near the vehicle launch azimuths during the launch operations at SNI. 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 (i.e., no PTS). 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.

If there is any reason to be concerned about auditory effects, it would be during either of two types of launches: (1) When artillery shots occur at beach locations and pinnipeds are present nearby, should this ever occur, and (2) When a large vehicle travels at supersonic speed over a pinniped beach at relatively low altitude (i.e., when the elevation angle at launch was low). These cases should be reconsidered when specific noise exposure criteria become available for possible PTS in pinnipeds in air exposed to impulse sounds.

4.3 Estimated Numbers of Pinnipeds Affected by Launches

The approach to estimating the numbers of pinnipeds affected by launches during 2009 was based on video observations of pinnipeds, combined with estimates of the numbers of hauled out pinnipeds not videotaped but exposed to the same launches. The latter animals are presumed to have reacted in the same manner as those whose responses were videotaped. The total numbers of such affected pinnipeds were calculated for the periods during and immediately following the three launches. Disturbance reactions for most northern elephant seals and California sea lions appeared to be short-lived and were not expected to extend into subsequent days. Also, any undocumented disturbance reactions by harbor seals were expected to be short-lived.

For pinniped groups that extended farther along the beach than encompassed by the FOV of the video camera, an estimate of the total number of individuals that were hauled out at the monitored site was made based on a pre-launch video pan of the area. The proportions of animals in the focal subgroups that were affected during each launch (based on the disturbance criteria listed in § 4.1) were then extrapolated to the estimated total number of individuals hauled out in this area (Table 4.1). It was not possible to extrapolate the proportions of animals affected on the monitored beaches to unmonitored haul-out sites, because it was generally unknown which beaches were used as haul-out sites on specific launch dates and how many animals may have been hauled out. Thus, the estimates of the numbers of pinnipeds affected by launches are likely underestimates.

For pinniped species that were not monitored on certain launch dates, the number of animals affected by launches was estimated based on data from the 2001–2008 monitoring periods. That is, the number of affected animals for the corresponding season and vehicle type was used, if possible.

Navy biologists did not sight any northern fur seals (*Callorhinus ursinus*) or Guadalupe fur seals (*Arctocephalus townsendi*) on SNI during the current monitoring period, and none were evident in the video segments that were analyzed.

Observations from the 2001–2002 monitoring period showed that all of the haul-out sites continued to be occupied on subsequent days following the launches (Holst and Lawson 2002).

There was no evidence of injury or mortality during any of the launches.

TABLE 4.1. Minimum estimated numbers of pinnipeds potentially (poten.) affected by launches from the Navy's vehicle launch program on SNI, June–December 2009. Some individuals were probably affected during more than one launch on a given day.

Launch Date in 2009	Vehicle Type	Monitoring Site	Total # in Area	# of Focal Animals Poten. Affected	Total # Poten. Affected in Area
Number of California sea lions potentially affected					
6 June	Terrier-Lynx	Dos Coves South	50	5	50
"	"	The "Y"	-	-	*100*
13 June	Terrier-Lynx	Dos Coves South	200	6	200
"	"	The "Y"	-	-	*100*
10	Terrier-Black Brant	Dos Coves South	200	50	200
"	"	The "Y"	100	100	100
	Total number of sea lions potentially affected				**750**
Number of northern elephant seals potentially affected					
6 June	Terrier-Lynx	Dos Coves	200	-	0
"	"	Bachelor Beach N.	1000	100	0
"	"	Redeye Beach	200	13	0
13 June	Terrier-Lynx	Dos Coves	40	-	0
"	"	Bachelor Beach N.	1000	100	0
"	"	Redeye Beach	100	14	0
10	Terrier-Black Brant	Dos Coves South	~20	-	0
"	"	Bachelor Beach N.	-	-	*0*
"	"	Bachelor Beach S.	40	2	0
"	"	Redeye Beach	-	-	*0*
	Total number of elephant seals potentially affected				**0**
Number of harbor seals potentially affected					
6 June	Terrier-Lynx	Unmonitored sites	-	-	*20*
13 June	Terrier-Lynx	Unmonitored sites	-	-	*20*
10	Terrier-Black Brant	Unmonitored sites	-	-	*20*
	Total number of harbor seals potentially affected				**60**

Note: Numbers in italics are estimates derived from data previously collected during the 2001–2008 monitoring programs (Lawson 2002; Holst 2004b; Holst et al. 2005, 2008; Holst and Greene 2006a,b), as well as the current monitoring period, for launch dates when monitoring of certain pinniped species did not occur. A dash (-) shows that unknown numbers or no pinnipeds were observed at that site during the launch. N = North; S = South.

4.4 Summary

No evidence of pinniped injuries or fatalities related to launch noises or other launch operations was evident, nor was it expected. Few if any pinnipeds were exposed to received levels of sound energy above 118 dB re (20 µPa)^2·s M_{pa}-weighted. The specific received levels of transient airborne sound that cause the onset of TTS in pinnipeds are not well documented. However, near the launcher, the recorded peak pressure levels and the SEL-M exceeded the estimated values at which mild TTS may occur in the harbor seal (143 dB re 20 µPa and 129 dB, respectively). As harbor seals are not known to haul out on the beach closest to the launcher, TTS is considered to have been unlikely during the current monitoring period. In the unlikely event that TTS did occur, it would have been presumably mild and quickly recoverable.

Approximately 750 California sea lions, 60 harbor seals, and no northern elephant seals were estimated to have been affected during the monitoring period. These figures are very approximate, because they (a) include extrapolations for pinnipeds on beaches that were not monitored on any given launch day, (b) very likely count some of the same individuals more than once, and (c) also exclude pinnipeds on some beaches that were not monitored. The pinnipeds included in these estimates left the haul-out site in response to the launch, or exhibited prolonged movement or behavioral changes relative to their behavior immediately prior to the launch.

The results from the current monitoring period (and those from previous monitoring periods) suggest that any effects of the launch operations were minor, short-term, and localized, at least for California sea lions and especially elephant seals. In the case of harbor seals, some harbor seals may have left their haul-out site until the following low tide, but numbers occupying haul-out sites shortly after a launch or the next day, are generally similar to pre-launch levels. It is not likely that any of the pinnipeds on SNI were adversely impacted by such behavioral reactions. In the unlikely case that any pinnipeds did incur TTS during launches at SNI, this would have presumably been mild and recoverable.

5. ACKNOWLEDGEMENTS

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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 of Greeneridge analyzed the recordings and prepared the figures of launch-by-launch acoustic results. Steve Schwartz, Grace Smith, Gina Smith, and Lisa Thomas-Barnett at SNI were responsible for setting out the ATARs and video cameras, and for transferring the sound and video data to Greeneridge and LGL, respectively.

At LGL, Ted Elliott assisted with mapping of launches and audio/video recording sites, and Valerie Moulton provided valuable advice on video analysis approaches. Dr. Jack Lawson was principally responsible for the project design and initial project reports. Dr. W. John Richardson of LGL helped with project design and administration, and reviewed the draft report.

We are grateful to all concerned.

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APPENDIX A:
LETTER OF AUTHORIZATION FOR 4 JUNE 2009 – 3 JUNE 2010

Letter of Authorization[3]

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 216, Subpart N—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 4, 2009, through June 3, 2010.

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, Conservation, and Education Division, Office of Protected Resources, National Marine Fisheries Service (NMFS) at (301) 713-2289 and to the Southwest 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). Additionally, the National Stranding Network must be notified immediately (telephone: (526) 980-4017). Every attempt will be made to collect pinniped carcasses discovered within 48 hours following a launch, provided that the collection does not result in the disturbance (flushing) of other animals on the site. Any carcasses collected will be transferred to Long Marine Laboratory in Santa Cruz, California for complete necropsy.

4. Cooperation:

The holder of this Authorization is required to cooperate with NMFS and any other Federal, state or local agency monitoring the impacts of the activity on marine mammals. The holder must notify the Administrator, Southwest 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

[3] This is a verbatim copy (retyped) of the LOA.

Authorization).

5. The marine mammal species authorized for taking by incidental harassment are: northern elephant seals (*Mirounga angustirostris*), harbor seals (*Phoca vitulina*); and California sea lions (*Zalophus californianus*).

6. <u>Mitigation Requirements:</u> The Holder of this Authorization must ensure the least practicable adverse impacts on Pacific harbor seals, California sea lions, and northern elephant seals, 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 feet (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 feet (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 feet (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 proposed 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 Southwest 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 initial report must be submitted to the Office of Protected Resources, NMFS, and the Southwest Regional Office, NMFS, at least 60 days prior to the expiration of this Letter of Authorization. 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 Southwest Regional Office, NMFS, 180 days prior to the expiration of this Authorization 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 final 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.

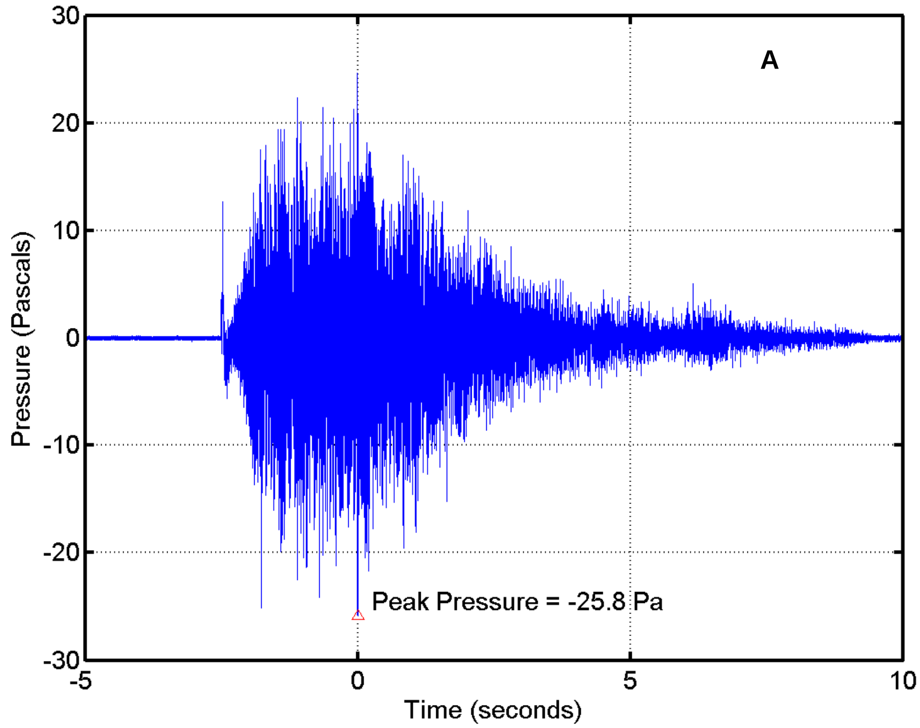
10. Failure to comply with the terms and conditions contained in Subpart N-Taking of Marine Mammals Incidental to Missile Launch Operations from San Nicolas Island, CA (50 CFR 216.150-216.159) may result in the modification, suspension or revocation of this Authorization

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.

for James H. Lecky
Director, Office of Protected Resources,
National Marine Fisheries Service

6/3/09
Date

APPENDIX B:
ACOUSTIC DATA FROM THE VEHICLE LAUNCHES IN 2009



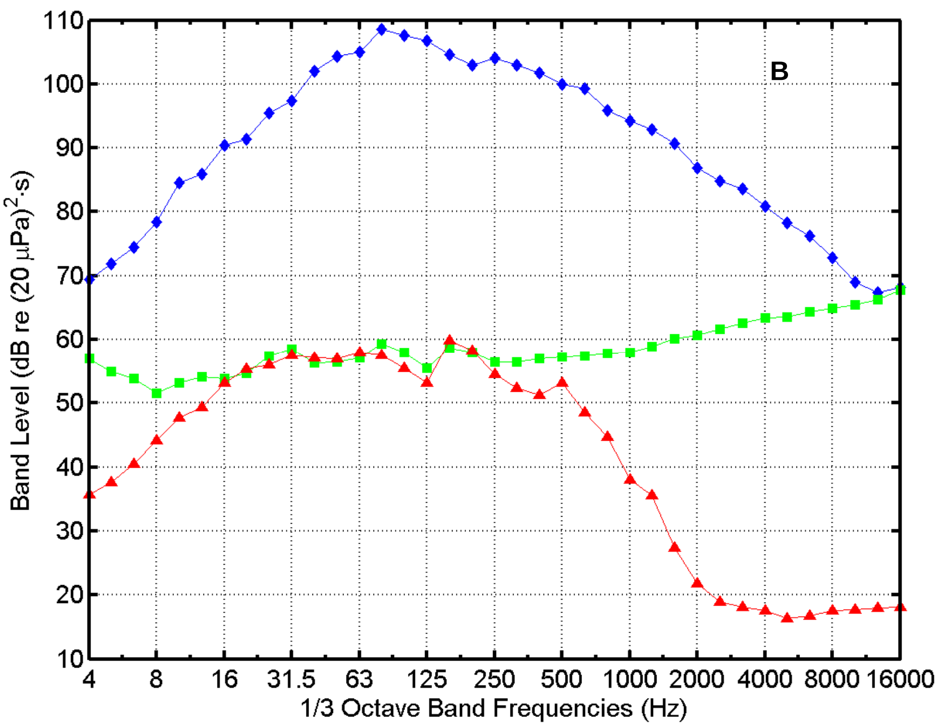


FIGURE B-1. (A) Pressure waveform and (B) one-third octave band levels for a Terrier-Lynx flight at 22:16 on 6 June 2009 recorded at Bachelor Beach North. In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

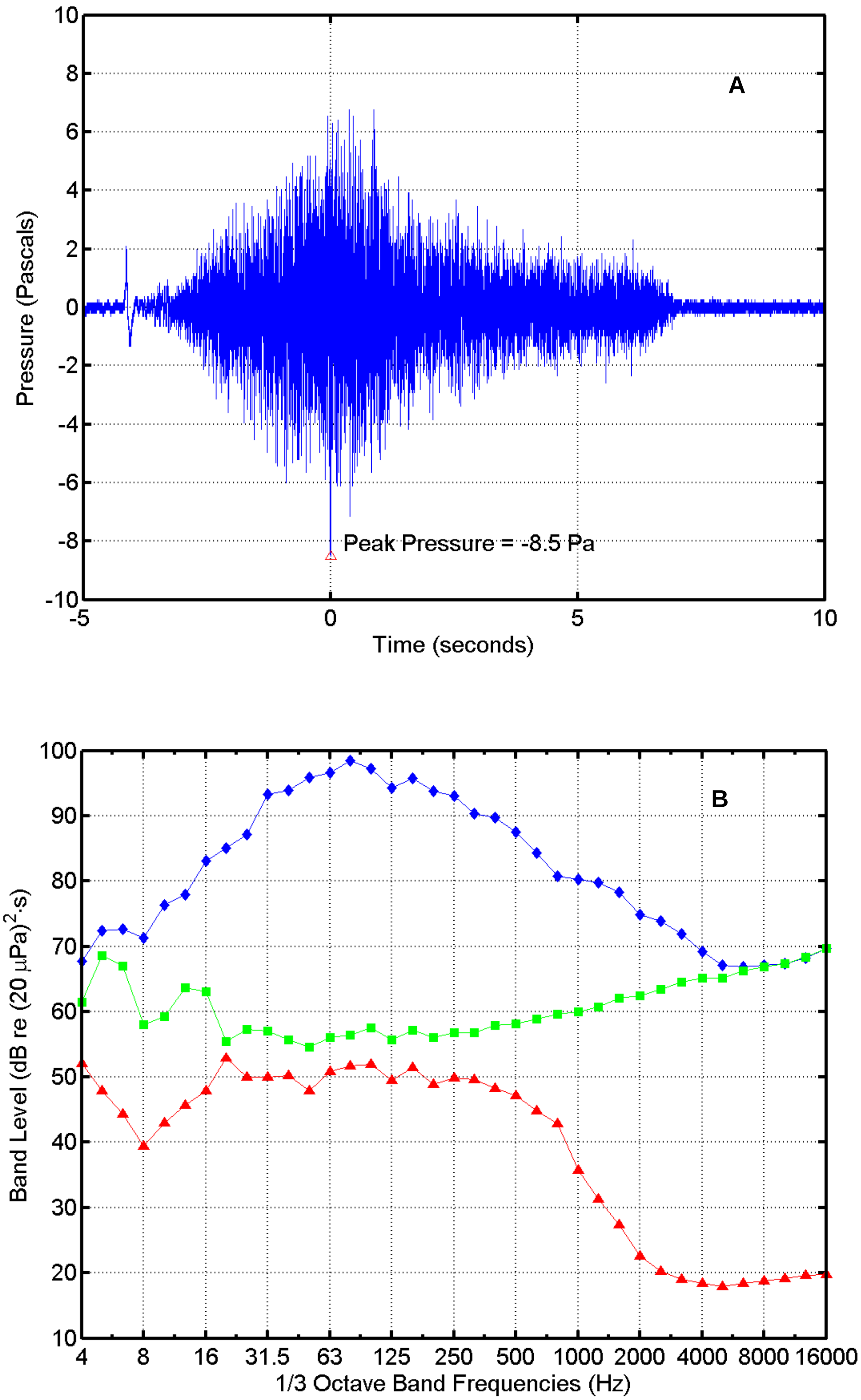
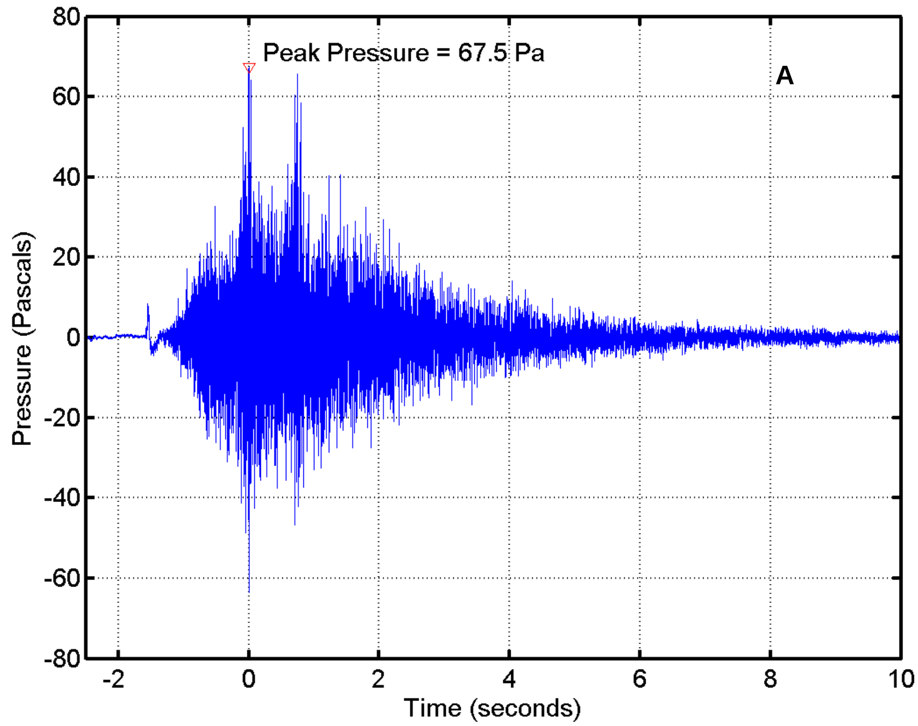


FIGURE B-2. (A) Pressure waveform and (B) one-third octave band levels for a Terrier-Lynx flight at 22:16 on 6 June 2009 recorded at Redeye Beach. In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).



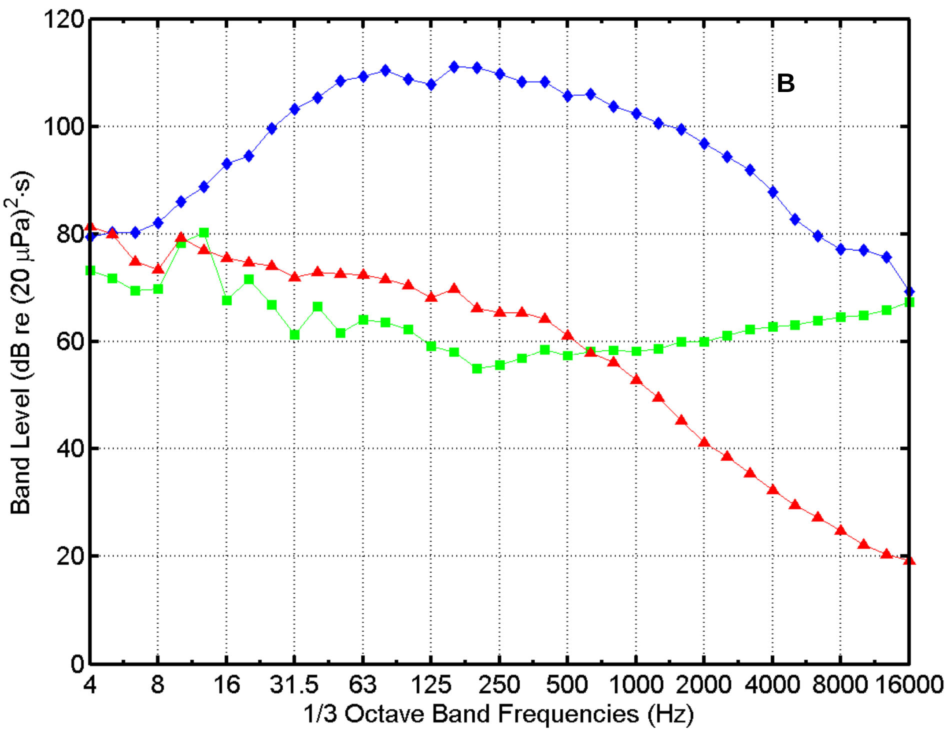


FIGURE B-3. (A) Pressure waveform and (B) one-third octave band levels for a Terrier-Lynx flight at 22:31 on 13 June 2009 recorded at Dos Coves South. In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

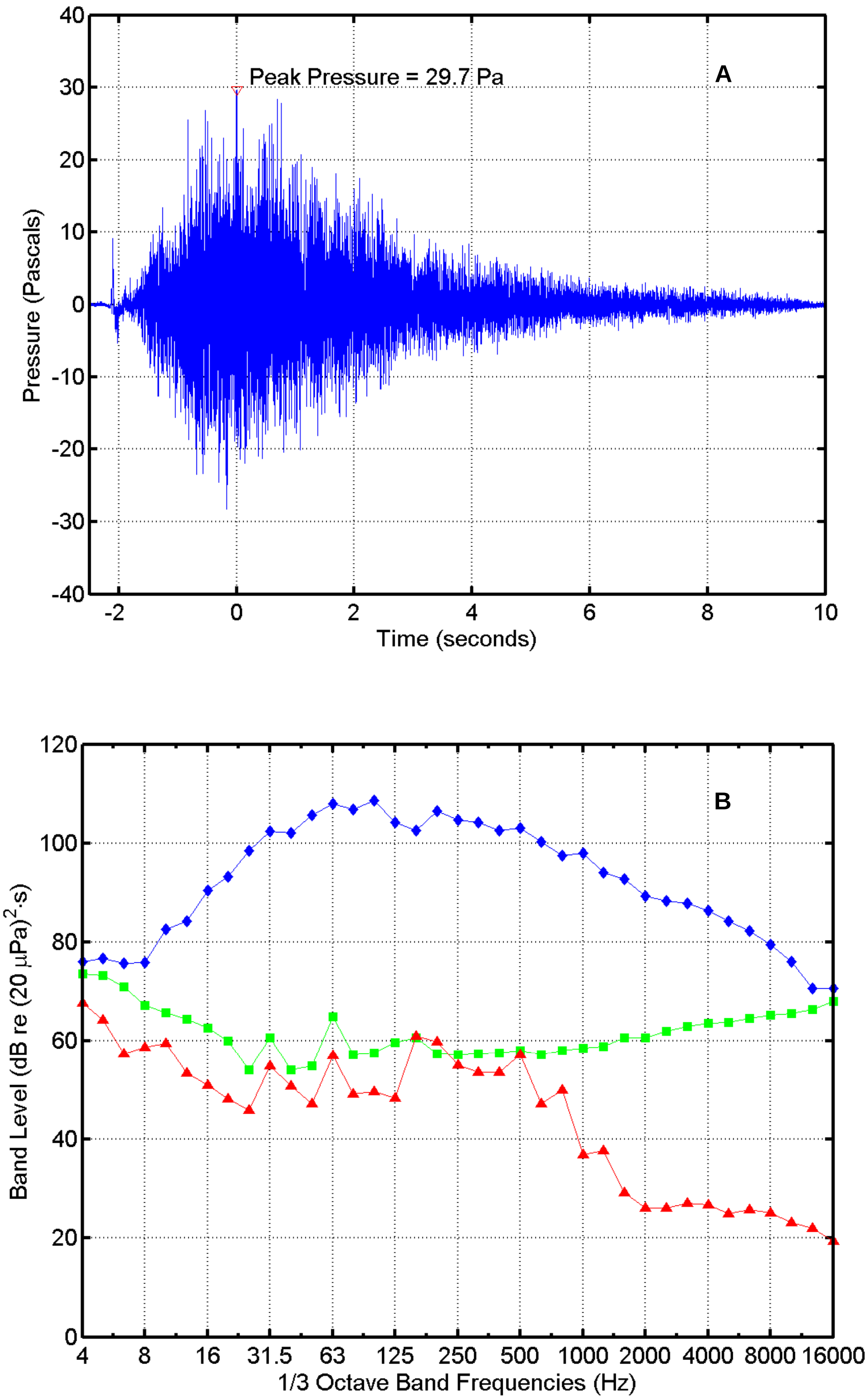
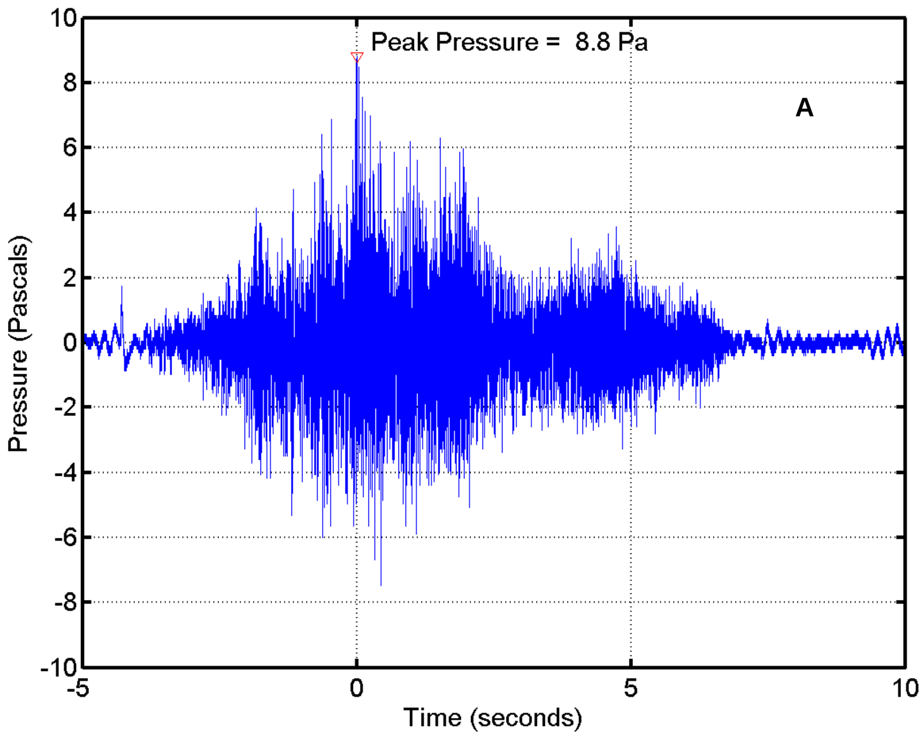


FIGURE B-4. (A) Pressure waveform and (B) one-third octave band levels for a Terrier-Lynx flight at 22:31 on 13 June 2009 recorded at Bachelor Beach North. In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).



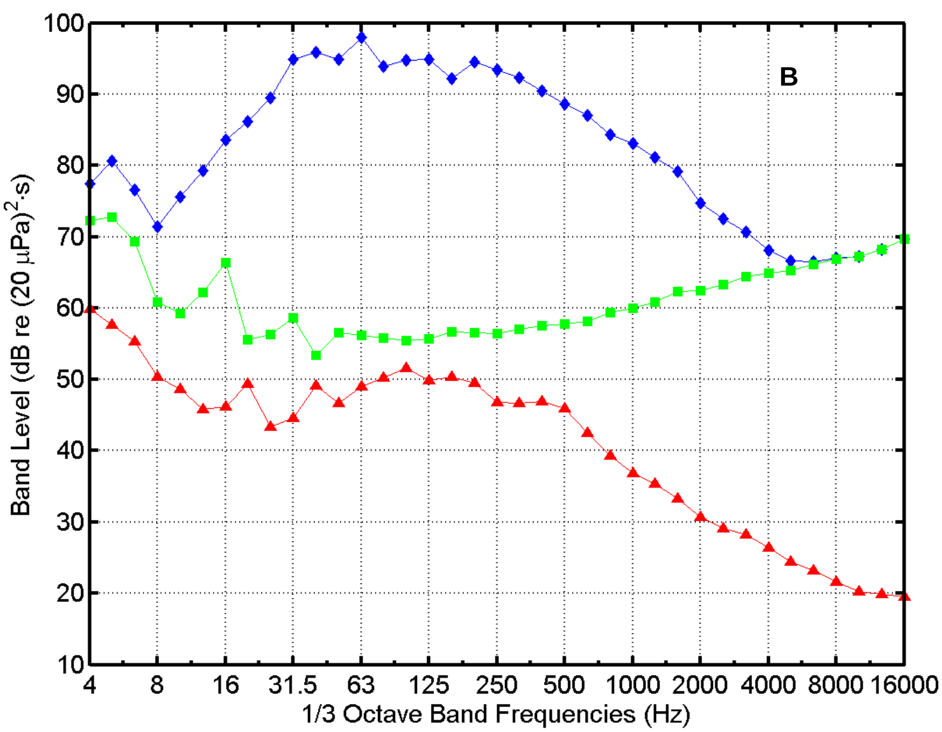
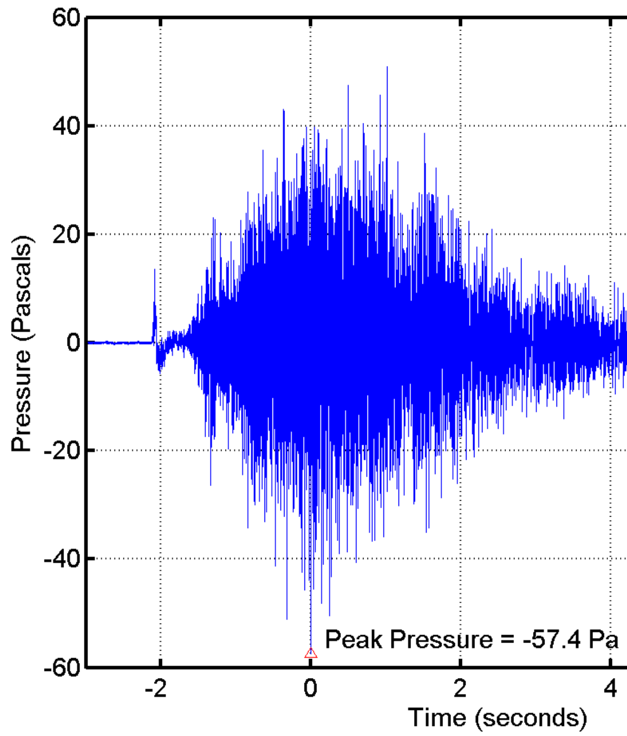


FIGURE B-5. (A) Pressure waveform and (B) one-third octave band levels for a Terrier-Lynx flight at 22:31 on 13 June 2009 recorded at Redeye Beach. In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).



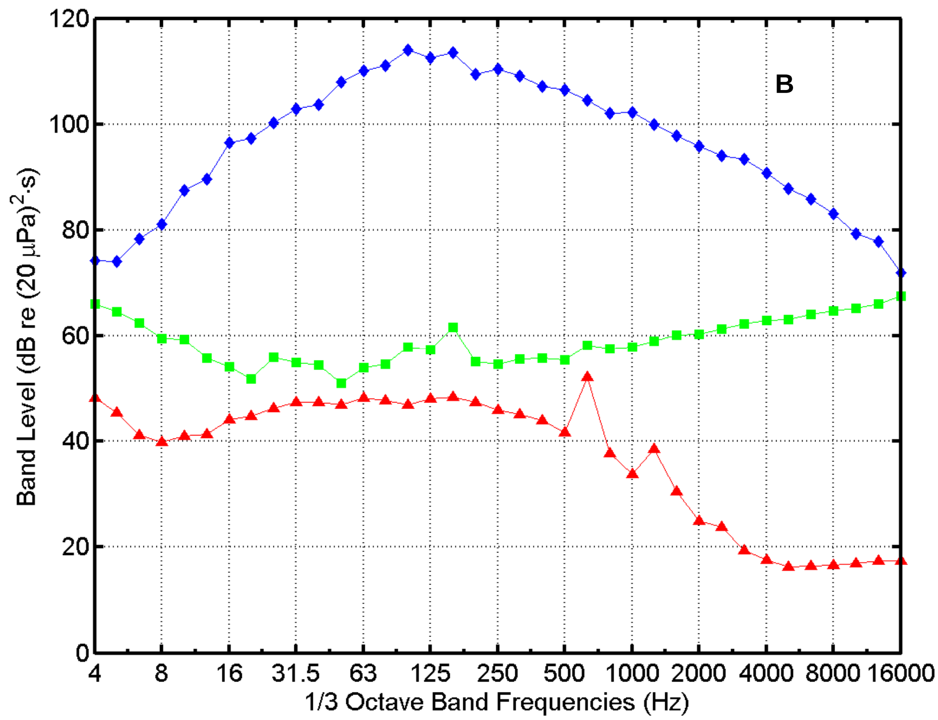


FIGURE B-6. (A) Pressure waveform and (B) one-third octave band levels for a Terrier-Black Brant flight at 20:50 on 10 August 2009 recorded at Dos Coves South. In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

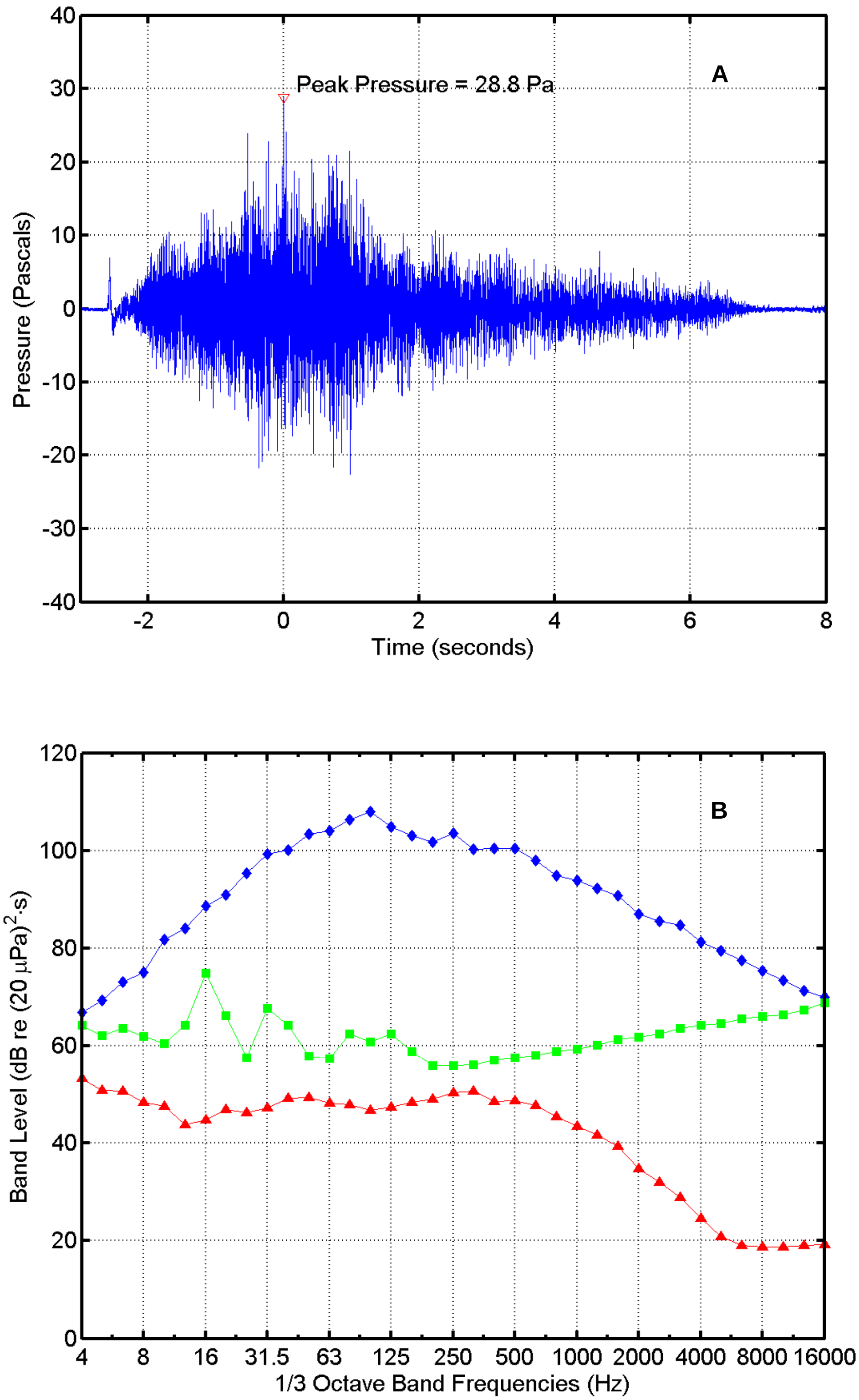


FIGURE B-7. (A) Pressure waveform and (B) one-third octave band levels for a Terrier-Black Brant flight at 20:50 on 10 August 2009 recorded at Bachelor Beach South. In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

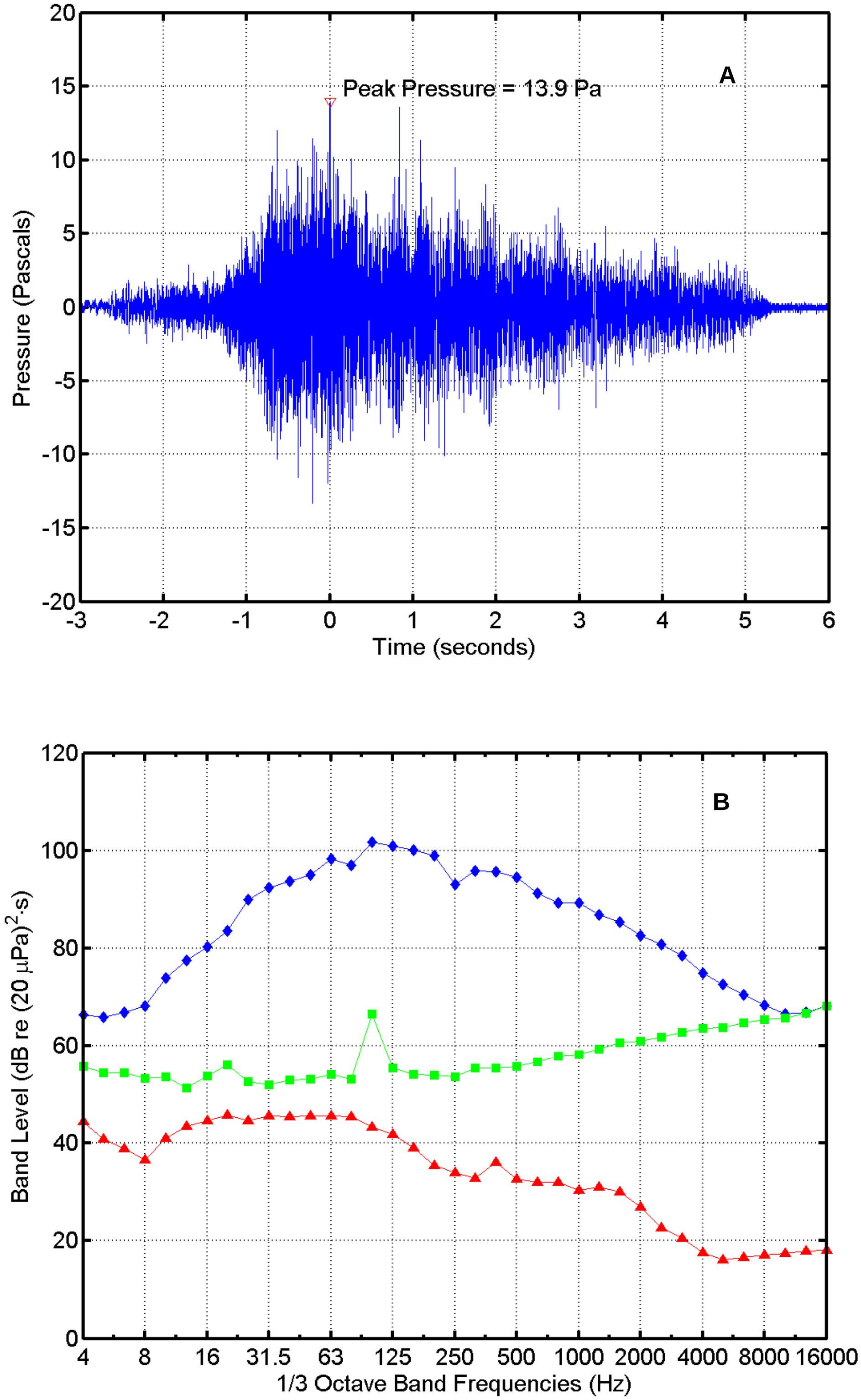


FIGURE B-8. (A) Pressure waveform and (B) one-third octave band levels for a Terrier-Black Brant flight at 20:50 on 10 August 2009 recorded at The "Y". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

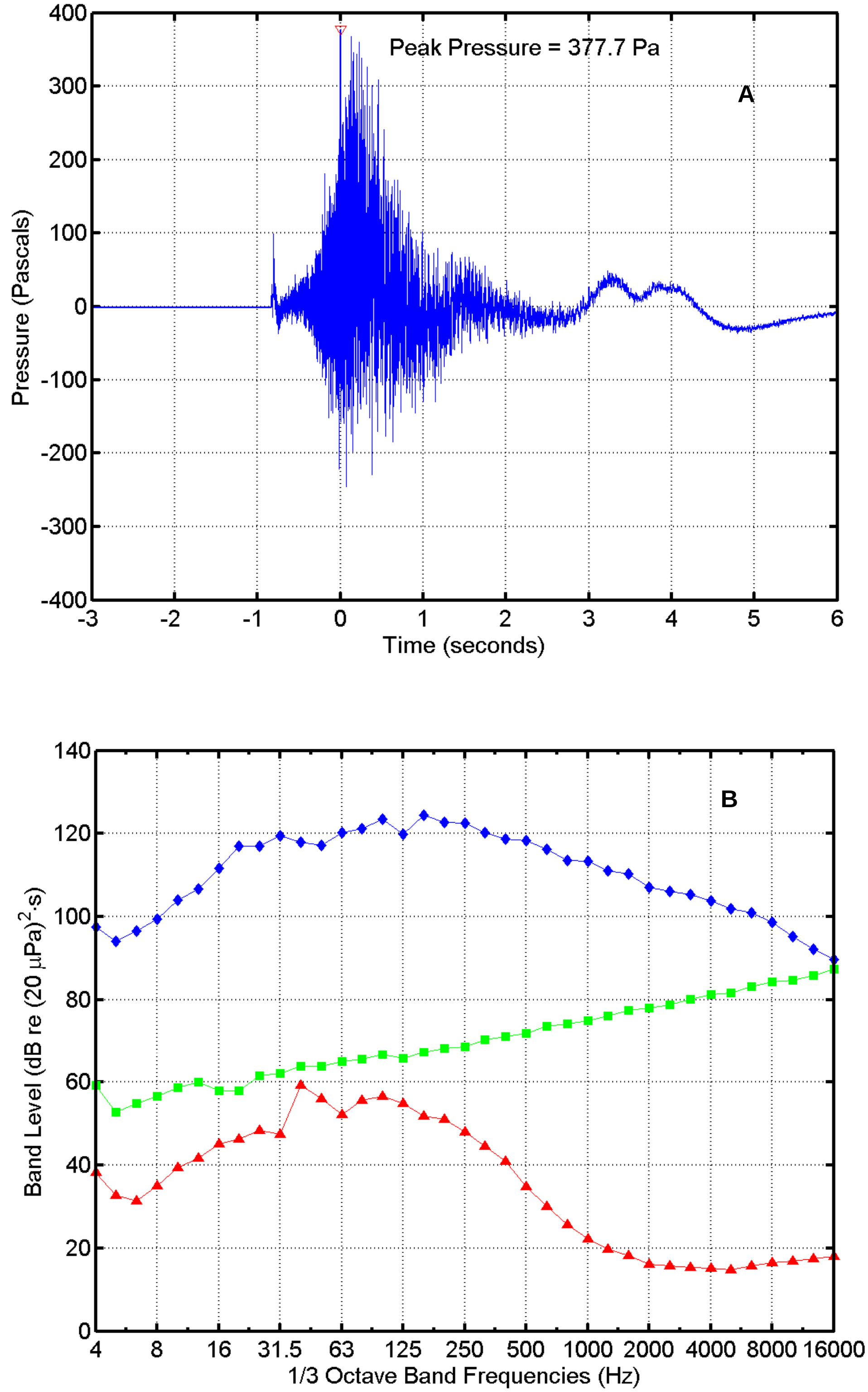


FIGURE B-9. (A) Pressure waveform and (B) one-third octave band levels for a Terrier-Black Brant flight at 20:50 on 10 August 2009 recorded near the Launcher. In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).