Marine Mammal and Acoustical Monitoring of Missile Launches on San Nicolas Island, California, August 2001 – May 2005

submitted by

LGL LIMITED
environmental research associates

for

Naval Air Warfare Center Weapons Division
Point Mugu, California

to

National Marine Fisheries Service
Silver Spring, Maryland, and Long Beach, California

LGL Report TA2665-5

June 2005

Marine Mammal and Acoustical Monitoring of Missile Launches on San Nicolas Island, California, August 2001 – May 2005

by

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Naval Air Warfare Center Weapons Division
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Suggested format for citation:

Holst, M. and C.R. Greene, Jr., with W.J. Richardson, T.L. McDonald, K. Bay, R.E. Elliott, and V.D. Moulton. 2005. Marine mammal and acoustical monitoring of missile launches on San Nicolas Island, California, August 2001 – May 2005. LGL Rep. TA2665-5. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for Naval Air Warfare Center Weapons Division, Point Mugu, CA, and Nat. Mar. Fish. Serv., Silver Spring, MD, and Long Beach, CA. 165 p.

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

3-D	3-dimensional
AGS	Advanced Gun System
AIC	Akaike's Information Criterion
ASCM	Anti-Ship Cruise Missile
ASL	above sea level
ATAR	Autonomous Terrestrial Acoustic Recorder
avg.	average
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
DR	Ducted Rocket (pertains to GQM-163A "Coyote" SSST)
ft	feet
hr	hour
Hz	hertz
IHA	Incidental Harassment Authorization
in.	inch
kg	kilogram
kHz	kilohertz
km	kilometer (1 km = 3281 ft, 0.62 mi, or 0.54 n.mi)
kt	knots
lb	pound
LOA	Letter of Authorization
m	meter (1 m = 1.09 yards or 3.28 feet)
mi	statute mile
min	minute
mm	millimeter
MMPA	Marine Mammal Protection Act
NAWCWD	Naval Air Warfare Center Weapons Division
NMFS	National Marine Fisheries Service, U.S. Dept of Commerce
n.mi	nautical mile (1 n.mi = 1.15 mi or 1.85 km)
PTS	Permanent Threshold Shift
RAM	Rolling Airframe Missile
rms	root mean square (a type of average)
s	seconds
SEL	sound exposure level, a measure of the energy content of a transient sound
SNI	San Nicolas Island
SPL	sound pressure level
SSST	GQM-163A "Coyote" Supersonic Sea-Skimming Target
TTS	Temporary Threshold Shift
USC	United States Code
V/µPa	volts per micropascal
µPa	micropascal
WOSA	Weighted Overlapped Segment Averaging

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 missile launch operations on San Nicolas Island (SNI), California. The LOA is valid from 8 October 2004 through 7 October 2005. The LOA was issued pursuant to 50 Code of Federal Regulations (CFR) 216.107, 50 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). The LOA allows 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, an LOA was issued for this purpose for the period October 2003 to October 2004, and two separate Incidental Harassment Authorizations (IHAs) were issued 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 launch activities on pinnipeds hauled out at SNI. This report provides results concerning the marine mammal and associated acoustic monitoring program for launches from SNI during the October 2003 to May 2005 period (Year 3 and the early part of Year 4), including detailed results from 16 launches on nine different days in October 2003 through January 2005. In Year 3 (October 2003–October 2004), this included four single launches, a dual launch (in quick succession), one double launch (two vehicles launched sequentially), and three triple launches (three vehicles launched sequentially) from October 2003 through October 2004 (Year 3). Also included are detailed results from three launches in January 2005 (beginning of Year 4). Five additional launches that occurred in February–April 2005 are described, but the acoustic data and pinniped observations have not yet been analyzed.

Previous reports have provided corresponding results concerning 12 launches (including 2 dual launches) during August 2002 to July 2003 and 19 launches (including 1 dual launch) during August 2001 through July 2002 (see Lawson et al. 2002; Holst and Greene 2003a,b). Those launch data are summarized but not described in detail in this report. However, data from all years of monitoring (2001 to 2005) were used for data analyses described in this report. The following subsections briefly summarize the monitoring program for August 2001–May 2005.

Description of Missile Launches and Monitoring Program Described

From October 2003 to January 2005 (Year 3 and early part of Year 4), 16 launches occurred from SNI on nine different days. The launches included one "dual launch" of two Rolling Airframe Missiles (RAM) in quick succession, as well as three RAM launches on the same day; six Advanced Gun System (AGS) slugs and two AGS missiles; two GQM-163A Supersonic Sea-Skimming Targets (SSST); and two Arrow missiles. The dual RAM launch on 5 May 2004 consisted of two missiles that were launched within seconds of each other. Each dual launch is counted here as a single launch. On another occasion, 3 June 2004, two AGS slugs and one AGS missile were launched sequentially on the same day; those were counted as separate launches. On 26 July 2004, two AGS slugs were launched sequentially, 33 min apart, and were also counted as separate launches. The triple RAM launch occurred on 22 September 2004. On 27 January 2005, two AGS slugs and one AGS missile were launched sequentially on the same day. On four other launch dates, single vehicles were launched. More recently, there were two launches of AGS vehicles on 24 February 2005, a dual Vandal launch on 11 March 2005, and single SSST launches on 24 March and 22 April 2005. However, the acoustic data and pinniped observations for these launches have not yet been analyzed. Additional AGS launches are anticipated to occur in June, July, and August 2005, and additional Vandal launches are expected to occur in June, July, and September 2005. However, the expected launch schedule is subject to change.

During the August 2002 to August 2003 monitoring period, 12 launches occurred from SNI on 11 different days. The launches included one Tactical Tomahawk, a dual RAM launch, six Vandals (including one dual launch), two AGS missiles, and two SSSTs. During the August 2001 to July 2002 monitoring period, 19 launches were conducted on 14 days. These launches involved 14 Vandals, one Terrier Orion, an AGS missile and two slugs, and a dual RAM launch.

Overall, during the August 2001 to January 2005 period for which detailed data on the launches are available, there were 47 launches of 51 vehicles (of which four were dual launches in quick succession) on 34 different days. These involved 21 Vandals, 4 SSSTs, 13 AGS vehicles, 9 RAMs, 2 Arrows, 1 Terrier Orion, and 1 Tactical Tomahawk.

Vehicles were launched from one of two launch complexes on SNI. The Tomahawk and RAMs were launched from the Building 807 Launch Complex. This site is located close to shore on the western end of SNI, ~35 ft (11 m) above sea level (ASL). Vandals, Terrier Orion, SSSTs, and Arrows were launched from the Alpha Launch Complex. This launch site is 625 ft (190.5 m) ASL on the west-central part of SNI, 1.1 mi (1.8 km) inland from the closest part of the shoreline. From August 2001 through June 2004, AGS missiles and slugs were launched from the Alpha Launch Complex. Starting in July 2004, AGS vehicles were launched from the Building 807 Complex, to which the AGS launcher had been relocated.

The vehicles launched from the Alpha Launch Complex had launch elevation angles ranging from 8–90º above horizontal (Arrows were launched vertically), and were directed generally westward (azimuths 232° to 305°). They crossed the west end of SNI at altitudes up to 17,300 ft (5273 m). From Building 807 Launch Complex, RAMs were launched at elevation angles of 8–10º and crossed the beach at an altitude of 50 ft (15 m). AGS missiles and slugs were launched from the Building 807 Launch Complex on azimuths of 287–300º and at an elevation angle of 50º, crossing the beach at an altitude of 4500 ft (1372 m). The Tactical Tomahawk was launched at an elevation angle of 90º and crossed the beach at 1000 ft (305 m).

Acoustic Measurements During Vehicle Launches

Vehicle flight sounds were measured as received at various locations on the periphery of SNI during launches conducted from August 2001–January 2005. At distances of 0.3 mi (0.5 km) or more from the closest point of approach (CPA) of the vehicle, all measures of sound level were higher for Vandals than for AGS and RAM vehicles, with “other large” vehicles (e.g., SSST, Arrow, Terrier, Tomahawk) being quite variable. Although sounds from the AGS vehicles were weaker than those from Vandals at distances beyond 0.3 mi (0.5 km), the levels recorded close to the AGS launcher were equal to or greater than those from the Vandal.

A multiple regression model for several sound measures showed that, after allowing for distance and other factors, Vandals had the highest average sound levels compared with all other vehicle types. Vandals produced flat-weighted sound pressure levels (SPL-f) as high as 137 decibels (dB) re 20 micropascal (μPa) near the launcher and 142 dB at a nearshore site located 400 m from the CPA of the vehicle. AGS vehicles produced SPL-f of 156 dB near the launcher and 126 dB at a nearshore site 442 m from the CPA. RAMs resulted in SPL-f up to 130 dB near the launcher and 99 dB at a nearshore site located 1555 m from the CPA. Near the launcher, SSSTs produced SPL-f up to 126 dB, and at a site 1614 m from the CPA, the SPL-f was 133 dB. Arrows produced SPL-f up to 90 dB at a site 1821 m from the CPA. A single Tomahawk was launched, which produced an SPL-f of 93 dB 529 m from the CPA, and the only Terrier Orion that was launched resulted in an SPL-f of 91 dB 2433 m from the CPA.

The regression models also showed a decrease in all measures of sound level with increasing CPA distance, and an increase in A-weighted SPL (SPL-A) and sound exposure level (SEL-A) with increasing elevation angle from the receiving location to CPA. The sound measures were not significantly related to the wind component along the CPA-to-receiver axis.

Behavior of Pinnipeds During Missile Launches

Behavior of pinnipeds around the periphery of western SNI during missile launches was monitored by unattended video cameras 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 in some cases following the launches. Monitoring was typically attempted at up to three sites during each launch, with launch-to-launch variation in the locations monitored. Videotaped behavioral data from the launches for February–April 2005 have not yet been analyzed, and the following discussion addresses the launches in August 2001–January 2005.

For each launch, 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. The proportions of the animals on a given beach that moved, or that moved into the water, were examined in relation to distance from the CPA of the vehicle, and to various other variables characterizing conditions during the launch. A logistic regression approach was used for the latter analyses.

No evidence of injury or mortality was observed during or immediately succeeding the launches for any pinniped species. However, on three occasions, harbor seal pups were knocked over by adult seals as both pups and adults moved toward the water in response to the launch. Seal pups were momentarily startled, but did not appear to be injured, and continued to move towards the water. On two occasions (not during launches), adult sea lions were seen knocking over sea lion pups when they moved along the beach, but no injuries were evident.

California Sea Lions

California sea lions were observed during seven of the nine launch dates during October 2003 to January 2005, with observations at one to three sites during each launch (total of 25 site-launch combinations monitored). From August 2001 to August 2003, monitoring occurred in another 34 situations on 17 dates. Responses of sea lions to the launches varied by individual. Some sea lions exhibited startle responses, whereas others hardly reacted to the launch. During 43 of 59 monitoring occasions, sea lions reacted more vigorously by moving along the beach; on these occasions, 3–100% (avg. 65%) of the sea lions present moved. On 17 of 57 occasions, sea lions entered the water in response to the launch. On 11 of these 17 occasions, less than 50% of the sea lions entered the water, but 60–100% entered the water on the remaining 6 occasions. Although sea lions showed increased vigilance for a short period after each launch, all age classes settled back to pre-launch behavior patterns within 1 or 2 min of the launch time.

Responses of sea lions to launches were related to sound levels and CPA angle. More sea lions moved or entered the water with decreasing CPA angle and increasing sound exposure levels (SELs). Sea lion responses to CPA distance, vehicle type, and season were more variable.

Northern Elephant Seals

Elephant seals were observed at one to three sites during six of the nine launch dates during October 2003 to January 2005, with a total of 17 monitored site-launch combinations. During August 2001 to August 2003, monitoring occurred on another 18 occasions on 13 dates. Most elephant seals exhibited little reaction to launch sounds; they merely raised their heads for a few seconds and then returned to their previous activity pattern (e.g., sleeping, resting). During several launches (16 of 35 occasions), a small proportion (avg. 23%) of elephant seals on the beach repositioned or moved a small distance (<6 ft [<2 m]) away from their resting site. The proportion of elephant seals that entered the water was typically zero. A single elephant seal entered the water on two occasions.

Elephant seals tended to be more responsive (a greater proportion moved) when larger vehicles, such as Vandals, were launched. Elephant seal response was also related to CPA distance and SEL. A greater proportion of elephant seals moved with decreasing CPA distance and increasing SEL. Wind and season were not related to proportion of seals responding.

Harbor Seals

Harbor seals were observed at one or two sites during five of the nine launch dates in October 2003 to January 2005, with a total of seven site-launch combinations monitored. During August 2001 to August 2003, 23 site-launch combinations were monitored on 11 dates. During the majority of these launches, most harbor seals left their haul-out sites and entered the water. Individuals that left the site typically did not return during the duration of the video-recording period, which lasted for an additional 1 to 2 hr. On 26 of 30 occasions, 7–100% (avg. 78%) of seals moved in response to the launch, and on 24 of 30 occasions, 7–100% (avg. 69%) entered the water.

Harbor seals were more responsive during launches of larger vehicles (e.g., Vandals, SSST, etc.) and showed stronger reactions during the pupping/breeding season. Harbor seal response increased with increasing CPA angle but was not strongly related to distance or sound level. Wind was not related to the proportion of seals responding.

Estimated Numbers of Pinnipeds Affected by Missile Launches

No evidence of pinniped injuries or fatalities related to missile launches was evident, nor was it expected. During all years of monitoring (August 2001 to January 2005), few if any pinnipeds were exposed to sound levels above 129 dB SEL on a flat-weighted basis (SEL-f), or 118 dB SEL on an A-weighted basis (SEL-A). However, small numbers were exposed to peak pressures as high as 149–150 dB re 20 µPa when a Vandal flying over the beach created a sonic boom.

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 the previous launches were used to estimate the number of pinnipeds affected during launch days when no recordings were possible. We considered pinnipeds that left the haul-out site, or exhibited prolonged movement or prolonged behavioral changes, as being affected.

Approximately 530 California sea lions, 13 northern elephant seals, and 193 harbor seals are estimated to have been affected by launch sounds during the October 2003 to October 2004 period. In January 2005, an additional 80 California sea lions and 25 harbor seals are estimated to have been affected. Of the sea lions, most were young animals such as pups or juveniles. These numbers are probably 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. Given the lack of evidence of any serious effects on pinnipeds at the sites that were monitored, it is not likely that many (if any) of the pinnipeds on SNI were adversely impacted by the launches.

Behavior of some pinnipeds occurring near the launch azimuths during the launch operations was affected in subtle ways. However, the results suggest that any effects of these launch operations were minor, short-term, and localized, with no consequences for local pinniped populations. Any localized displacement of pinnipeds was of short duration (although some harbor seals may have left their haul-out sites until the following low tide). Previous monitoring from August 2001 to July 2002 showed that numbers of pinnipeds occupying haul-out sites the day after a launch were similar to pre-launch levels.

1. MISSILE LAUNCHES AND MONITORING PROGRAM DESCRIBED

Missiles and targets are launched from one of two land-based launch complexes on the western part of San Nicolas Island (SNI), California (Fig. 1.1). The Building 807 Launch Complex is located on the west coast of SNI at ~35 ft (11 m) above sea level (ASL), and the Alpha Launch Complex is located 625 ft (190.5 m) ASL on the west-central part of SNI (Fig. 1.2). The vehicles missiles pass over or near pinniped haul-out sites located around the periphery of SNI. The pinniped species that occur commonly on SNI are northern elephant seals (*Mirounga angustirostris*), harbor seals (*Phoca vitulina*), and California sea lions (*Zalophus californianus*).

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 missile launch operations on SNI for the period from 8 October 2004 through 7 October 2005 (Appendix A). That is the fourth annual incidental take authorization issued to the Navy concerning launches from SNI. Previously, two separate Incidental Harassment Authorizations (IHAs) were issued for the periods August 2001–July 2002 and August 2002–August 2003 (Years 1, 2), and an LOA was issued for the period October 2003–October 2004 (Year 3). These authorizations, issued by NMFS under the Marine Mammal Protection Act (MMPA), allowed the 'take by harassment' of small numbers of elephant seals, harbor seals, and sea lions during routine launches from Navy-owned SNI.

A Marine Mammal Monitoring Plan was proposed in the initial IHA application and slightly updated in the Petition for Regulations under which the LOAs have been issued. The purpose of the monitoring was to characterize any effects of launch activities on pinnipeds hauled out at SNI. This report describes the results of the marine mammal and associated acoustic monitoring program for launches from SNI during the October 2003–January 2005 period (Year 3 and initial part of Year 4). During the October 2003–October 2004 monitoring period (Year 3), 13 launches (including one dual launch) occurred at SNI on eight different days within the 5 May to 22 September 2004 period. Another three launches that occurred on 27 January 2005 (Year 4) are also described in detail in this report. The more recent launches on 24 February, 11 March, 24 March, and 22 April 2005 are described, but the acoustic data and pinniped observations for these launches are not yet available.

Corresponding results concerning 12 launches (including two dual launches) during August 2002–July 2003 (Year 2), and 19 launches (including one dual launch) during August 2001–July 2002 (Year 1) are summarized in this report, and used in analyses of all results to date. However, those early results are not described in detail in this report; they were described by Lawson et al. (2002) and Holst and Greene (2003a,b), and summarized in Holst et al. (2005).

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. This report includes four chapters: (1) background, introduction, and description of the Navy's missile launches in the period October 2003–May 2005, as well as for the overall monitoring period from 2001 to 2005 [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].

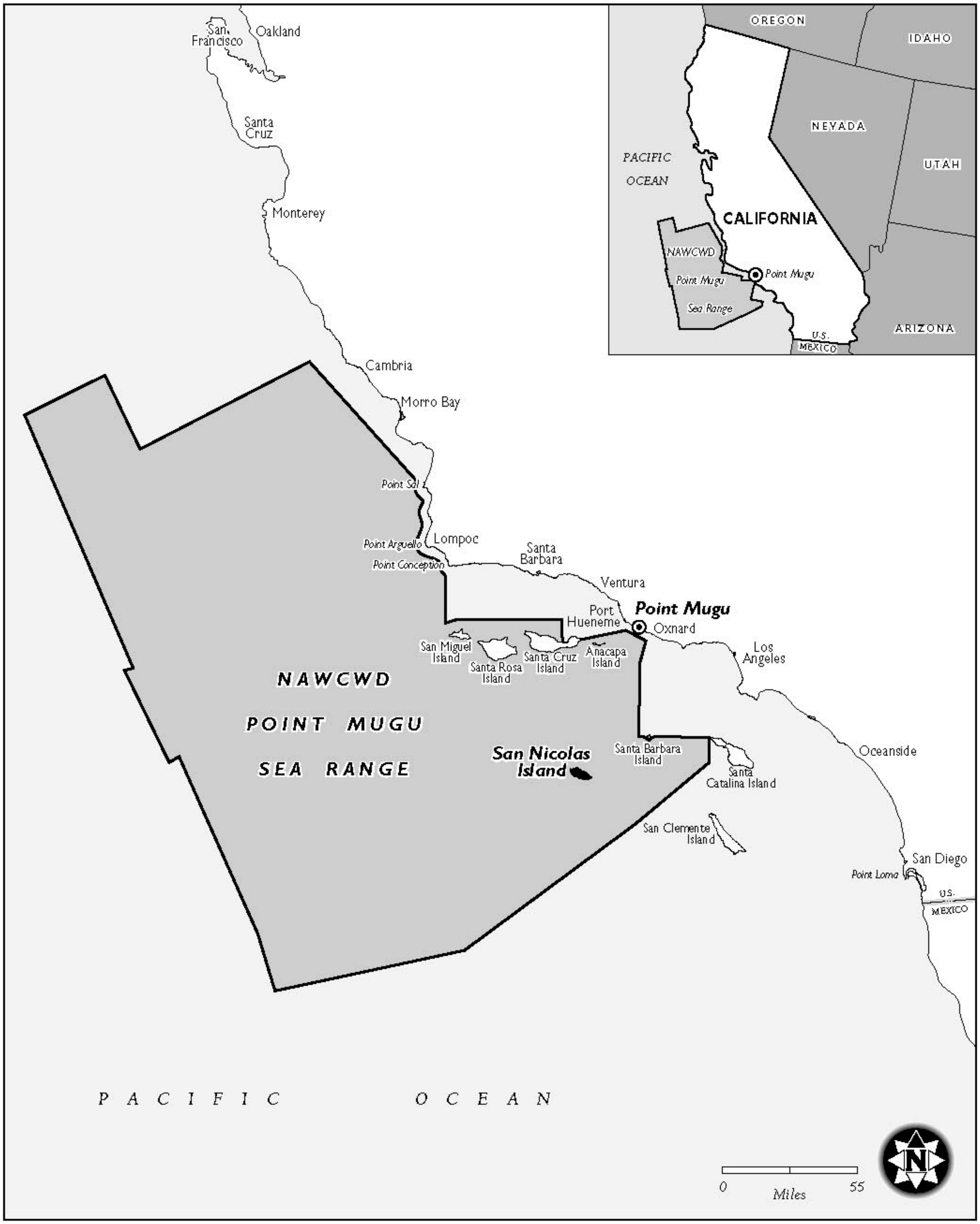

FIGURE 1.1. Regional site map of the Point Mugu Sea Range and San Nicolas Island (map by TEC Inc.).

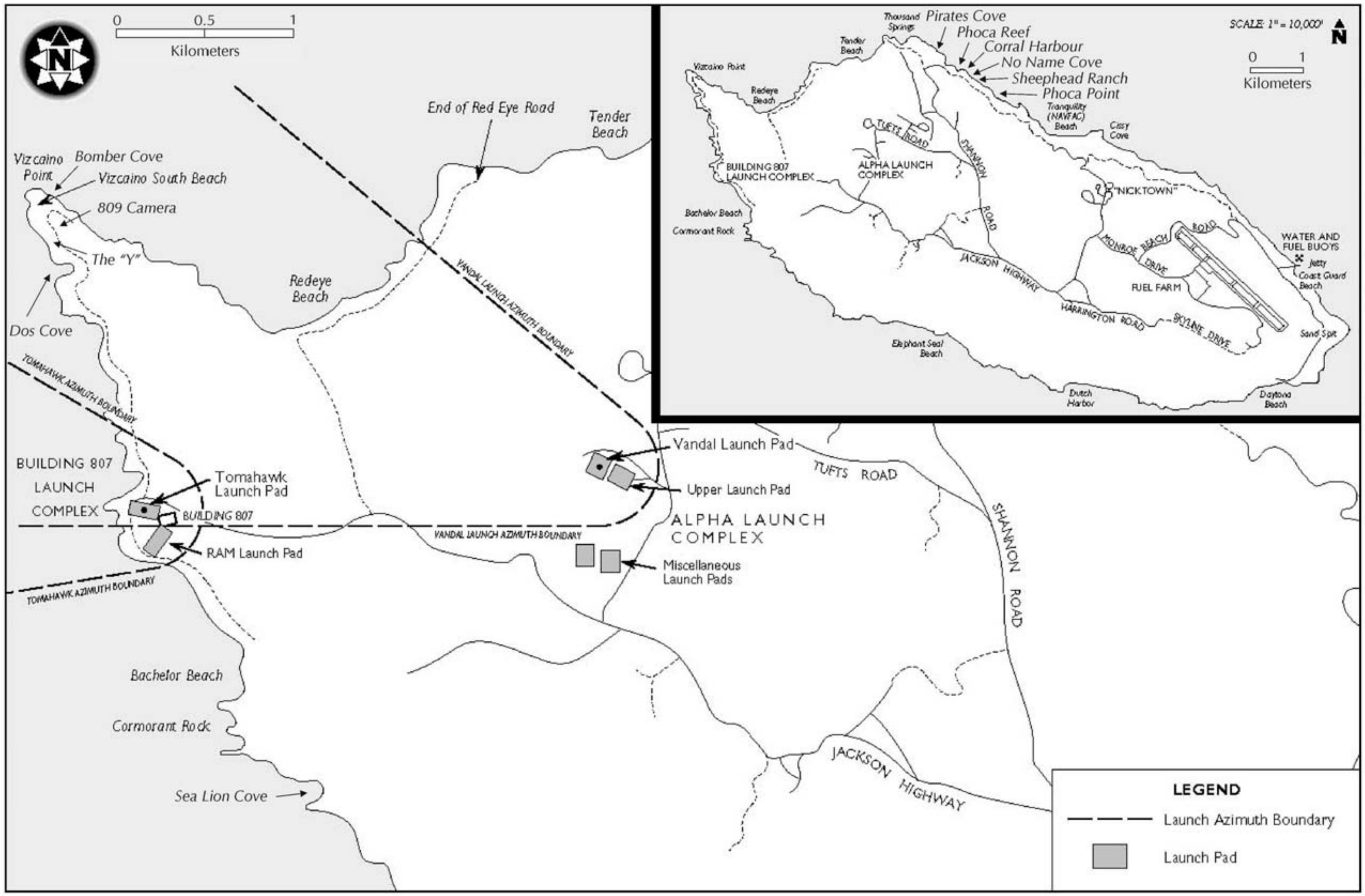

FIGURE 1.2. View of vehicle launch sites on San Nicolas Island. Shown are the Alpha Launch Complex and the Building 807 Launch Complex (at lower elevation near the shoreline). Also shown are the maximum predicted extent of the launch azimuths for vehicles leaving the two launch sites.

1.1 Vandal

The Vandal, designated MQM-8G, is a relatively large, air-breathing (ramjet) vehicle designed to provide a realistic simulation of the midcourse and terminal phase of a supersonic anti-ship missile (Fig. 1.3). The Vandal is an evolved version of the (former) Talos missile. The Vandal is 25.2 ft (7.7 m) long, excluding the booster, and 28 in. (71 cm) in diameter. There are three variants of the Vandal, the standard (no longer used), ER, and EER. The EER variant, including booster, weighs 8100 lb (3674 kg). The variants differ primarily in their operational range.

Vandals have no explosive warhead. At launch, the Vandal is accelerated for several seconds by a solid propellant rocket booster, to a speed sufficient for the ramjet engine to start. After several seconds of thrust, the booster is discarded, and the missile continues along its flight path at supersonic speed under ramjet power. The expended booster rocket drops into the water west of SNI.

Vandals are remotely controlled, non-recoverable missiles that are launched from the Alpha Launch Complex (Fig. 1.2). Vandal launch trajectories can vary from near-vertical liftoff, crossing the west end of SNI at an altitude of about 13,000 ft (3962 m), to a nearly horizontal launch profile crossing the west end of SNI at an altitude of about 1000 ft (305 m). With a launch angle ≤13º, the Vandal can descend to a sea-skimming altitude several nautical miles out at sea, or it can continue offshore at higher altitude.

The Vandal is often launched singly, but in some cases, two Vandals are launched sequentially, spaced closely in time. If launched sequentially, two Vandals are launched in succession from the same pad (Fig. 1.4).

1.2 GQM-163A "Coyote" Supersonic Sea-Skimming Target (SSST)

The Navy/Orbital Sciences Corp. GQM-163A "Coyote" Supersonic Sea-Skimming Target (SSST) is an expendable target powered by a ducted-rocket ramjet. It is capable of flying at low altitudes (13 ft or 4 m cruise altitude) and supersonic speeds (Mach 2.5) over a flight range of 45 n.mi or 83 km (Fig. 1.5). This vehicle is designed to provide a ground launched aerial target system to simulate a supersonic, sea-skimming Anti-Ship Cruise Missile (ASCM) threat. The SSST is being developed as a replacement for the Vandal.

The SSST vehicle assembly consists of two primary subsystems: MK 12 or MK 70 solid propellant booster, and the GQM-163A target vehicle. The solid-rocket booster is about 18 in. (46 cm) in diameter and is of the type used to launch the Navy's Standard surface-to-air missile. The GQM-163A target vehicle is 18 ft (5.5 m) long and 14 in. (36 cm) in diameter, exclusive of its air intakes. It consists of a solid-fuel Ducted Rocket (DR) ramjet subsystem, Control and Fairing Subassemblies, and the Front End Subsystem (FES). Included in the FES is an explosive destruct system to terminate flight if required.

The SSST utilizes the unmodified Vandal launcher, currently installed at the Alpha Launch Complex on SNI, with a Launcher Interface Kit (LIK; Fig. 1.5). A modified AQM-37C Aerial Target Test Set (ATTS) is utilized for target checkout, mission programming, verification of the vehicle's ability to perform the entire mission, and homing updates while the vehicle is in flight.

During a typical launch, booster separation would occur about 5.5 s after launch and about 1.4 n.mi downrange, at which time the vehicle would have a speed of about Mach 2.35 (Orbital Sciences Corp; www.orbital.com). Following booster separation, the GQM-163A's DR ramjet ignites, the vehicle

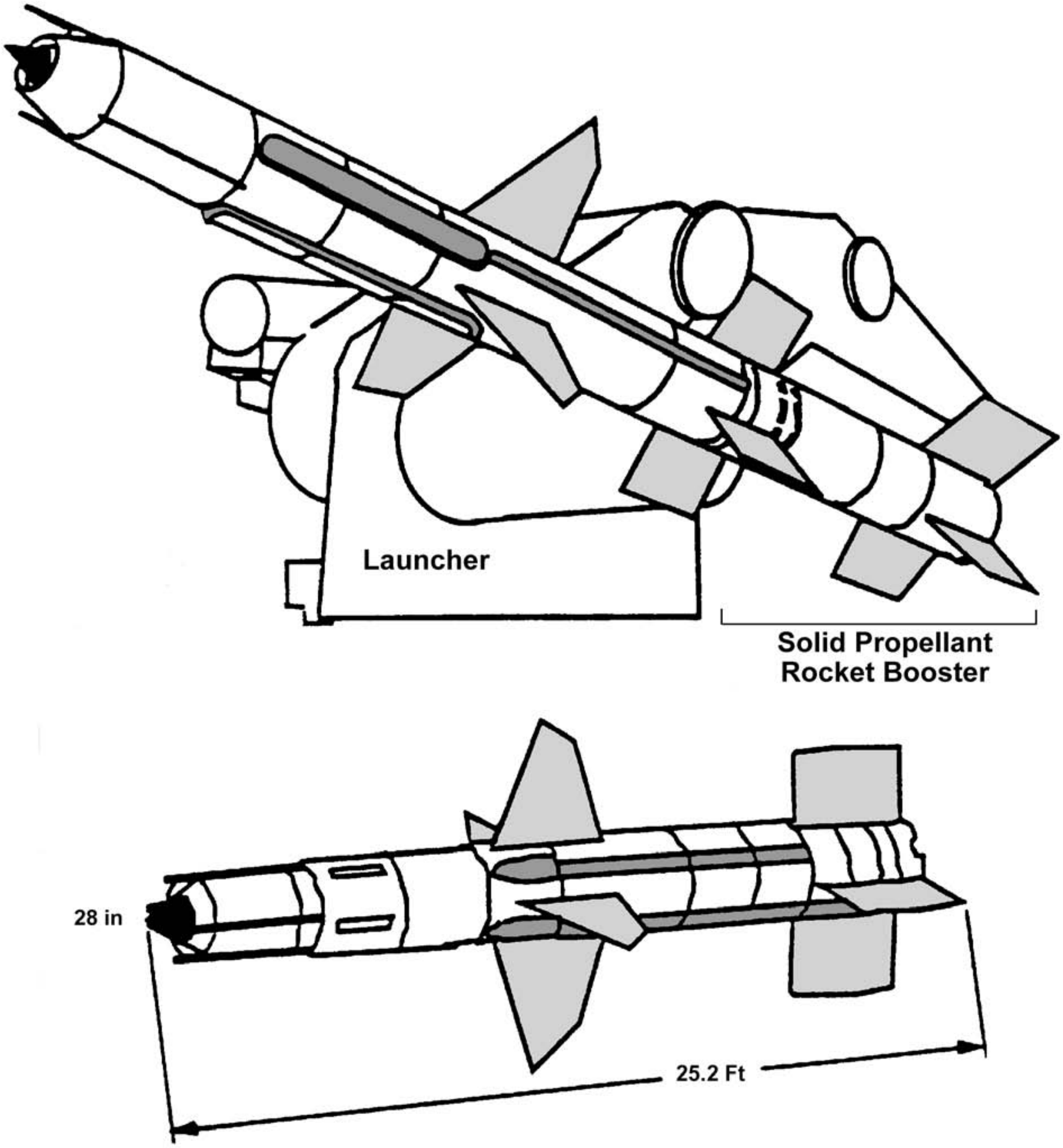

FIGURE 1.3. The Vandal is a supersonic vehicle that is accelerated to ramjet operational speed by a solid propellant rocket booster. The ER (top) and EER (bottom) Vandal variants are identical in dimensions, with the EER having greater range and weight. The Vandal is launched from a dedicated launcher system at the Alpha Launch Complex on San Nicolas Island.

FIGURE 1.4. View of two Vandals mounted on the launch pad at the Alpha Complex on San Nicolas Island; solid rocket booster is visible at rear of closer Vandal (photograph by U.S. Navy).

FIGURE 1.5. View of the GQM-163A SSST with booster and launcher at the Alpha Launch Complex on San Nicolas Island (photograph by U.S. Navy).

reaches its apogee, and then dives to 16 ft (5 m) altitude while maintaining a speed of Mach 2.5. During launches from SNI, the low-altitude phase occurs over water west of the island. The target performs pre-programmed maneuvers during the cruise and terminal phases, as dictated by the loaded mission profile, associated waypoints, and mission requirements. During the terminal phase, the SSST settles down to an altitude of 13 ft (4 m) and Mach 2.3 until DR burnout.

1.3 Tactical Tomahawk

The Tactical Tomahawk is a long range, subsonic cruise missile (Fig. 1.6). It has a speed of about 550 mph (880 km/h) and a range of 870 n.mi (1609 km). It is designed to fly at extremely low altitudes at high subsonic speeds, and it is piloted by several mission-tailored guidance systems. Radar detection of this missile is extremely difficult because of the small radar cross-section and low altitude flight profile. Operational Tomahawks have one of two warhead configurations: a 1000-lb (454 kg) blast/fragmentary unitary warhead, or a general-purpose submunition dispenser with combined effect bomblets. The Tactical Tomahawk can be reprogrammed in-flight to strike any of 15 pre-programmed alternate targets or to redirect the missile to any Global Positioning System (GPS) target coordinates. It can also loiter over a target area, and it has an on-board camera.

The Tactical Tomahawk is 18.25 ft (5.6 m) long with a 20.5 ft (6.3 m) long booster. It weighs 2900 lb (1315 kg) without the booster or 3500 lb (1588 kg) with the booster. It has a diameter of 20.4 in. (51.8 cm) and a wing span of 8.75 ft (2.7 m). At SNI, Tomahawk missiles are launched from the Building 807 Launch Complex.

1.4 Terrier Orion

As compared with the Vandal, the Terrier Orion is a slightly smaller rocket, and it flies ballistic trajectories. The Terrier Orion missile is a two-stage, unguided, fin-stabilized, solid propellant rocket system designed to provide a realistic simulation of a medium-range ballistic missile (Fig. 1.7). The two-stage Terrier vehicle has an overall length of ~33 ft (10 m), body diameter of 18 in. (45.7 cm; first stage) and 14 in. (35.6 cm; second stage), and a total weight at lift off of 3976 lb (1804 kg).

The Navy launched one Terrier Orion missile at SNI during Year 1, but it had no explosive warhead when it was launched at SNI. At launch, the Terrier is accelerated for 6.4 s by a solid propellant rocket booster. After 13.6 s of coasting, the booster is discarded and the missile continues along its ballistic flight path at supersonic speed under second stage rocket power for 27 s. The expended booster rocket dropped into the water west of SNI, and the second stage and forebody impacted ~5 min after launch.

The Terrier Orion is a non-recoverable missile that was launched from the same launch site (Alpha Launch Complex) on the western part of SNI as the Vandals. The Terrier's launch trajectory was near-vertical (64.6 º), crossing the west end of SNI at an altitude of ~13,000 ft (3962 m).

1.5 Rolling Airframe Missile (RAM)

The Navy/Raytheon Rolling Airframe Missile (RAM) is a supersonic, lightweight, quick-reaction missile. This relatively small missile, designated RIM 116, uses the infrared seeker of the Stinger missile and the warhead, rocket motor, and fuse from the Sidewinder missile. It has a high-tech radio-to-infrared frequency guidance system.

FIGURE 1.6. View of the Tactical Tomahawk missile and launcher at the Building 807 Launch Complex on San Nicolas Island (photograph by U.S. Navy).

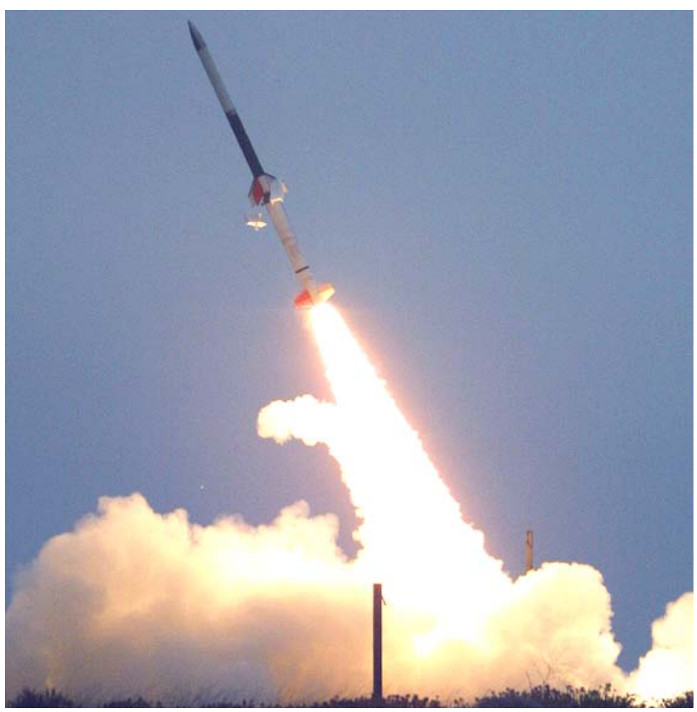

FIGURE 1.7. View of Terrier Orion launch from the pad at the Alpha Complex on San Nicolas Island (photograph by U.S. Navy).

The RAM is a solid-propellant rocket 5 in. (12.7 cm) in diameter and 9.2 ft (2.8 m) long. Its launch weight is 162 lb (73.5 kg), and operational versions have warheads that weigh 25 lb (11.4 kg). At SNI, RAMs are launched from the Building 807 Launch Complex (Fig. 1.8).

1.6 Advanced Gun System (AGS)

The Advanced Gun System (AGS) is a gun designed for a new class of Destroyer; it will be used to launch both small missiles and ballistic shells. It is to be a fully integrated gun weapon system, including a 155-mm gun, integrated control, an automated magazine, and a family of advanced guided and ballistic projectiles, propelling charges, and auxiliary equipment. The operational AGS will have a magazine with a capacity for 600 to 750 projectiles and associated propelling charges. The regular charge for the gun will replace the booster that is usually associated with a missile. The gun gets the missile up to speed, at which point the missile's propulsion takes over. The missile itself is relatively quiet, as it does not have a booster, and it is fairly small. However, the gun blast is rather strong.

At SNI, a howitzer (Fig. 1.9) has been used to launch test missiles, as the AGS gun is still being developed. The launcher was located at the Alpha Launch Complex until June 2004, and the vehicles there were launched at azimuths of 282–305°. In July 2004, the launcher was moved to the Building 807 Launch Complex, where vehicles were launched at azimuths of 287–300°.

1.7 Arrow Self-Defense Missile

The Arrow (Fig. 1.10) is a theater missile defense weapon, or anti-ballistic missile (ABM). It was developed in Israel and is designed to intercept tactical ballistic missiles. It is about 22.3 ft (6.8 m) long and 2 ft (0.6 m) in diameter. It travels at hypersonic speed, and it has high and low altitude interception capabilities. The Arrow consists of three main components: a phased array radar (known as Green Pine), a fire control center (called Citron Tree), and a high-altitude interceptor missile that contains a powerful fragmentation warhead. It also has two solid propellant stages, including a booster and sustainer. The array radar is capable of detecting incoming missiles at a distance of 310 mi (500 km). Once a missile is detected, the fire control center launches the interceptor missile. The interceptor travels at nine times the speed of sound and reaches an altitude of 31 mi (50 km) in less than 3 min. The first test of an Arrow in the United States was conducted at SNI on 29 July 2004, and another Arrow was launched on 26 August 2004. At SNI, Arrows have been launched near the Alpha Launch Complex, within the area labeled on Figure 1.2 as “Miscellaneous Launch Pads”, at an azimuth of 285°.

1.8 Missile Launches during the Monitoring Period

During the period from October 2003 to January 2005, there were a total of 16 launches from SNI on nine separate days (Table 1.1). A dual RAM launch occurred on 5 May 2004; single SSSTs were launched on 18 May and 27 August 2004; multiple AGS slugs and missiles were launched sequentially on 3 June and 26 July 2004, as well as 27 January 2005; single Arrows were launched on 29 July and 26 August 2004; and three RAMs were launched sequentially on 22 September 2004.

During the August 2001 to July 2002 monitoring period (Year 1), 19 launches were conducted on 14 days (Table 1.1). These launches involved 14 Vandals, 1 Terrier Orion, 1 AGS missile and 2 AGS slugs, and a dual launch of RAMs. During Year 2, August 2002 to July 2003, 12 launches were conducted on 11 days (Table 1.1). These launches involved seven Vandals (including one dual launch of two Vandals), one Tomahawk, two AGS missiles, two SSSTs, and one dual launch of RAMs.

FIGURE 1.8. View of the Rolling Airframe Missile (RAM) launcher at the Building 807 Launch Complex on San Nicolas Island (photograph by U.S. Navy).

FIGURE 1.9. View of the Advanced Gun Projectile System launcher at the Alpha Complex on San Nicolas Island (photograph by U.S. Navy).

FIGURE 1.10. View of the Arrow interceptor and launcher at the Alpha Complex on San Nicolas Island (photograph by U.S. Navy).

All launches occurred during daylight hours (between 08:30 and 17:02 local time). Weather during the launches ranged from cool to warm, with variable winds, clear and sunny to partly cloudy or overcast (Table 1.1).

All RAM launches occurred from the Building 807 Launch Complex (Fig. 1.2, 1.7); they had a launch azimuth of 240º and an elevation angle ranging from 8 to 10º. The Tomahawk was also launched from the Building 807 Launch Complex, at an elevation angle of 90°, transitioning to an azimuth of 285°. AGS vehicles were launched on azimuths of 282–305° from the Alpha Launch Complex (Fig. 1.2) until June 2004. In July 2004, the AGS launcher was moved to the Building 807 Launch Complex, where AGS vehicles were launched at azimuths of 287–300°. AGS slugs and missiles were launched at elevation angles of 50–63°.

TABLE 1.1. Details of all launches at San Nicolas Island from August 2001 through May 2005, including 19 launches during August 2001–July 2002, 12 launches during August 2002–August 2003, 13 launches during October 2003–October 2004, 3 launches on 27 January 2005, and 5 launches from February to April 2005. The weather data were collected at the San Nicolas Island airport, which is located at an elevation of 500 ft (152 m) ASL toward the east end of San Nicolas Island; therefore weather conditions at haul-out sites may have differed somewhat. Times are local time.

Launch Date	Launch Time	Vehicle Type	Launch Complex	Launch Azimuth (true)	Elevation Angle/Altitude Over Beach	Weather at SNI Airport	Tide State	Video Quality	Audio Quality
YEAR 1									
15 Aug. 2001	12:56	Vandal	Alpha	270°	8° / 1280 ft	20°C; winds 310° at 12 kt; low tide; fog at ~100 m	Low at 12:51	Good, 3 cameras	2 of 3 ATARs over-loaded
"	13:17	Vandal	Alpha	270°	8° / 1280 ft	20°C; winds 310° at 12 kt; low tide; fog at ~100 m	Low at 12:51	Good, 3 cameras	2 of 3 ATARs over-loaded
20 Sept. 2001	08:30	Vandal	Alpha	270°	8° / 1280 ft	14°C; winds 300° at 6 kt; overcast	Low at 06:03	Good, 3 cameras	1 of 3 ATARs failed
"	17:02	Terrier Orion	Alpha	232.3°	64.6° / 13,000 ft	14°C; winds 300° at 6 kt; overcast	Low at 06:03	Good, 3 cameras	3 ATARs OK
5 Oct. 2001	13:37	Vandal	Alpha	273.3°	8° / 1300 ft	16°C; winds 290° at 9 kt; overcast with drizzle	Low at 18:09	Good, 3 cameras	2 of 3 ATARs failed
19 Oct. 2001	09:00	Vandal	Alpha	270°	8° / 1280 ft	17°C; winds 320° at 10 kt; overcast	Low at 05:15	Good, 3 cameras	2 of 3 ATARs over-loaded
19 Dec. 2001	15:22	Vandal	Alpha	273°	8° / 1300 ft	15°C; clear and sunny	Low at 19:09	Good, 2 cameras	1 of 3 ATARs failed
14 Feb. 2002	11:33	Vandal	Alpha	273°	8° / 1300 ft	20°C; winds 5 kt; overcast	Low at 17:03	Good, 2 cameras	1 of 3 ATARs overloaded
22 Feb. 2002	12:13	Vandal	Alpha	270°	42° / 9600 ft	27°C; winds 3 kt; sunny and warm	Low at 12:44	Good, 3 cameras	1 of 3 ATARs failed
"	14:56	Vandal	Alpha	270°	42° / 9600 ft	27°C; winds 3 kt; sunny and warm	Low at 12:44	Good, 3 cameras	1of 3 ATARs failed

TABLE 1.1. Continued.

Launch Date	Launch Time	Vehicle Type	Launch Complex	Launch Azimuth (true)	Elevation Angle/Altitude Over Beach	Weather at SNI Airport	Tide State	Video Quality	Audio Quality
6 Mar. 2002	11:20	Vandal	Alpha	273.1°	8° / 1300 ft	17°C; winds 270° at 9 kt; overcast	Low at 11:03	Good, 4 cameras	3 ATARs OK
1 May 2002	15:53	Vandal	Alpha	273°	6.5° / malfunctioned & hit land	18°C; winds 300° at 20 kt; windy but clear	Low at 07:09	Good, 2 cameras	2 of 3 ATARs failed
"	17:00	Vandal	Alpha	273°	42° / 9600 ft	18°C; winds 300° at 20 kt; windy but clear	Low at 07:09	Good, 2 cameras	1 of 3 ATARs failed
8 May 2002	14:54	Vandal	Alpha	273°	8° / 1300 ft	18°C; winds 270° at 10 kt; sunny and clear	Low at 13:15	Good, 4 cameras	3 ATARs OK
19 June 2002	15:07	AGS Test Slug	Alpha	305°	63° / malfunctioned & hit land	15°C; winds 290° at 15 kt; overcast	Low at 11:42	Good, 2 cameras	1 of 2 ATARs failed
21 June 2002	12:53	Dual RAM	Building 807	240°	8° / 50 ft	16°C; winds 270° at 12 kt; overcast	Low at 13:18	Good, 2 cameras	1 ATAR used; OK
26 June 2002	11:20	AGS Test Slug	Alpha	300°	62.5° / 500 ft	17°C; winds 290° at 16 kt; foggy and overcast	Low at 05:50	Good, 2 cameras	3 ATARs OK
"	12:51	AGS Missile	Alpha	300°	62.5° / 5300 ft	17°C; winds 290° at 16 kt; foggy and overcast	Low at 05:50	Good, 2 cameras	3 ATARs OK
18 July 2002	11:54	Vandal	Alpha	273°	8° / 1300 ft	19°C; winds 340° at 4 kt; foggy and overcast	Low at 10:04	Good, 1 camera	2 of 3 ATARs failed
YEAR 2									
23 Aug. 2002	14:09	Tactical Tomahawk	Building 807	305°	90° / 1000 ft	15.6°C; winds 285° at 8.7-13.0 kt; overcast and partly cloudy	Low at 16:31	Good, 2 cameras	2 of 3 ATARs failed
18 Nov. 2002	11:03	Dual RAM	Building 807	240°	10° / 50 ft	23.9°C; winds 125° at 1.7 kt; clear and sunny	Low at 7:52	Good, 1 of 2 cameras	1 of 3 ATARs failed

TABLE 1.1. Continued.

Launch Date	Launch Time	Vehicle Type	Launch Complex	Launch Azimuth (true)	Elevation Angle/Altitude Over Beach	Weather at SNI Airport	Tide State	Video Quality	Audio Quality
10 Dec. 2002	8:49	Vandal	Alpha	273°	8° / 1300 ft	18.3°C; winds 285° at 21.7 kt; clear	Low at 8:33	Good, 1 of 2 cameras	1 of 3 ATARs failed
18 Dec. 2002	14:30	AGS	Alpha	282°	50° / 4500 ft	12.8°C; winds 285° at 17.4 kt; overcast to partly cloudy	Low at 15:15	None	2 ATARs used; OK
"	16:15	AGS	Alpha	282°	50° / 4500 ft	12.8°C; winds 285° at 17.4 kt; overcast to partly cloudy	Low at 15:15	None	1 of 2 ATARs failed
24 Jan. 2003	14:20	SSST	Alpha	270°	20° / 3400 ft	18.3°C; winds 293° at 8.7-13.0 kt; clear and windy	Low at 20:09	Good, 2 of 3 cameras	2 of 3 ATARs failed
14 Mar. 2003	09:13	Vandal	Alpha	273°	8° / 1300 ft	13.9°C; winds 225° at 3.5 kt; calm, overcast at shore, fog inland	Low at 13:34	Good, 2 of 2 cameras	3 ATARs OK
16 Mar. 2003	13:04	Vandal	Alpha	273°	8° / 1300 ft	15°C; winds 315° at 13.9-20.0 kt; gusty, few clouds	Low at 14:36	Good, 2 of 2 cameras	2 of 3 ATARs failed
4 Apr. 2003	15:20	Dual Vandal	Alpha	273°	8° / 1300 ft	12.8°C; winds 315° at 14.8 kt; clear	Low at 16:18	Good, 2 of 2 cameras	3 ATARs OK
4 June 2003	12:35	SSST	Alpha	270°	22° / 3500 ft	17.2°C; winds 210° at 7.0 kt; haze; few clouds	Low at 7:41	Good, 3 cameras	3 ATARs OK
26 June 2003	13:27	Vandal	Alpha	285°	42° / 17,277 ft	23°C; winds 230° at 7.0 kt; clear but some haze; fog	Low at 13:37	Good, 3 cameras	1 of 3 ATARs failed
28 July 2003	16:27	Vandal	Alpha	270°	8° / 1280 ft	20°C; winds 300° at 11kt; few clouds	Low at 15:16	Good, 3 cameras	2 of 3 ATARs failed

TABLE 1.1. Continued.

Launch Date	Launch Time	Vehicle Type	Launch Complex	Launch Azimuth (true)	Elevation Angle/Altitude Over Beach	Weather at SNI Airport	Tide State	Video Quality	Audio Quality
YEAR 3									
5 May 2004	11:46	Dual RAM	Building 807	240°	8° / 50 ft	17°C; winds 315° at 6 kt; clear and sunny	Low at 16:02	Good - 2 cameras, Poor - 1	3 ATARs OK
18 May 2004	12:40	SSST	Alpha	300°	18° / 3300 ft	18°C; winds 315° at 15 kt; sunny and windy	Low at 15:11	Good - 2 cameras, Fair - 1	1 of 3 ATARs OK; 2 overloaded
3 June 2004	11:31	AGS Slug	Alpha	282°	50° / 4500 ft	17°C; winds 270° at 6 kt; partly cloudy	Low at 15:40	Good - 1 cameras, Poor - 2	3 ATARs OK
"	13:22	AGS Slug	Alpha	282°	50° / 4500 ft	17°C; winds 270° at 6 kt; partly cloudy	Low at 15:40	Good - 2 cameras, Fair - 1	3 ATARs OK
"	15:08	AGS Missile	Alpha	282°	50° / 4500 ft	17°C; winds 270° at 6 kt; partly cloudy	Low at 15:40	Good - 2 cameras, Fair - 1	3 ATARs OK
26 July 2004	15:10	AGS Slug	Building 807	300°	50° / 4500 ft	19°C; winds 310° at 14 kt; scattered clouds	Low at 10:31	Good, 3 cameras	3 ATARs OK
"	15:43	AGS Slug	Building 807	300°	50° / 4500 ft	19°C; winds 310° at 14 kt; scattered clouds	Low at 10:31	Good, 3 cameras	3 ATARs OK
29 July 2004	10:20	Arrow	Alpha	285°	90°/ ~7000 ft	16°C; winds 320° at 7 kt; overcast	Low at 13:57	Good, 4 Cameras	3 ATARs OK
26 Aug. 2004	10:08	Arrow	Alpha	285°	90°/ ~7000 ft	18°C; winds 320° at 5 kt; overcast	Low at 13:10	Good - 2 cameras, Poor - 1	3 ATARs OK

TABLE 1.1. Continued.

Launch Date	Launch Time	Vehicle Type	Launch Complex	Launch Azimuth (true)	Elevation Angle/Altitude Over Beach	Weather at SNI Airport	Tide State	Video Quality	Audio Quality
27 Aug. 2004	16:30	SSST	Alpha	300°	18° / 3300 ft	20°C; winds 4 kt; scattered clouds	Low at 20:05	Good, 3 cameras	3 ATARs OK
22 Sept. 2004	09:56	RAM	Building 807	240°	10° / 50 ft	27°C; winds 60° at 8 kt; overcast	N/A	Good, 3 cameras	3 ATARs OK
"	10:57	RAM	Building 807	240°	10° / 50 ft	27°C; winds 60° at 8 kt; overcast	N/A	Good, 3 cameras	3 ATARs OK
"	11:19	RAM	Building 807	240°	10° / 50 ft	27°C; winds 60° at 8 kt; overcast	N/A	Good, 3 cameras	3 ATARs OK
YEAR 4									
27 Jan. 2005	08:59	AGS Slug	Building 807	287°	50° / 4500 ft	10.6°C; winds 370° at 6 kt; broken clouds	Low at 3:57	Good, 3 cameras	2 ATARs OK; 1 malfunctioned
"	11:41	AGS Slug	Building 807	287°	50° / 4500 ft	10.6°C; winds 370° at 6 kt; broken clouds	Low at 3:57	Good, 3 cameras	2 ATARs OK; 1 malfunctioned
"	13:29	AGS Missile	Building 807	287°	50° / 4500 ft	10.6°C; winds 370° at 6 kt; broken clouds	Low at 3:57	Good, 3 cameras	2 ATARs OK; 1 malfunctioned
24 Feb. 2005	09:05	AGS	Building 807	240°	50° / 4500 ft	N/A	N/A	Good, 3 cameras	3 ATARs OK
"	13:16	AGS	Building 807	240°	50° / 4500 ft	N/A	N/A	Good, 3 cameras	3 ATARs OK

TABLE 1.1. Continued.

Launch Date	Launch Time	Vehicle Type	Launch Complex	Launch Azimuth (true)	Elevation Angle/Altitude Over Beach	Weather at SNI Airport	Tide State	Video Quality	Audio Quality
11 Mar. 2005	09:30	Dual Vandal	Alpha	273°	8° / 1300 ft	winds 130° at 12 kt; overcast	Low at 3:54	Good, 3 cameras	3 ATARs OK
24 Mar. 2005	08:35	SSST	Alpha	270°	14° / 3000 ft	23°C; winds 203° at 8kt; overcast	Low at 14:56	Good, 3 cameras	3 ATARs OK
22 April 2005	16:43	SSST	Alpha	270°	14° / 3000 ft	winds 315° at < 8kt; variable cloud cover	Low at 15:06	Good, 3 cameras	3 ATARs OK

Note: N/A means not available or unknown.

All other vehicles were launched from the Alpha Launch Complex (Fig. 1.2). The Terrier Orion was launched at an azimuth of 232º and an elevation angle of 64.6º. Vandals were launched at azimuths of 270–285º, and at low (6.5–8º) to high (42º) elevation angles. SSSTs (Fig. 1.5) were launched at azimuths of 270–300º, with elevation angles of 18–22º. The Arrows (Fig. 1.9) were launched at the Alpha Launch Complex at elevation angle of 90°, transitioning to an azimuth of 285°.

These launch azimuths caused the vehicles to pass over or near various acoustic measurement sites and pinniped monitoring sites where Autonomous Terrestrial Acoustic Recorders (ATARs) and video systems had been deployed. The latter consisted of several wagon- or tripod-mounted cameras, as well as a remotely-controlled fixed video camera ("809 Camera") near Building 809 (Fig. 1.2).

In addition to the launches in August 2001 through January 2005 for which detailed monitoring results are provided in this or previous reports, there were two launches of AGS vehicles on 24 February 2005, a dual Vandal launch on 11 March 2005, and single SSST launches on 24 March and 22 April 2005 (Table 1.1). The acoustic data and pinniped observations for these launches are not yet available. Additional AGS launches are anticipated to occur in June, July, and August 2005, and Vandal launches are expected to occur in June, July, and September 2005. However, the launch schedule is subject to change.

1.9 Acoustical Monitoring of the Missile Launches

Audio recordings were obtained to document launch sounds at several distances from the launch trajectories of the vehicles. In addition, these recordings provided measures of 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 detect (or not) 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.

Based on a review of the literature (Lawson et al. 1998), it is evident that the sound levels that might cause notable disturbance for each of the pinniped species are variable and context-dependent. Lawson et al. (1998) estimated the minimum received level (on an A-weighted “Sound Exposure Level” or SEL-A basis) that might elicit substantial disturbance as 100 dBA. The 100-dBA level pertains to exposure to prolonged sounds, i.e., those that lasted at least several seconds. It is arguable whether the launch sounds should be considered to be “prolonged” from the perspective of a pinniped at a fixed location on a beach. Measured durations range much less than 1 to ~5 s (Greene and Malme 2002; see also Chapter 2 of this report). In any event, the assumption that reactions might occur at distances up to those where received levels diminished to 100 dBA SEL was one factor in selecting acoustic (and video) monitoring sites during Year 1. Sites at distances up to ~2.5 mi (4 km) from the launcher and/or launch trajectory were monitored in Year 1.

After reviewing video recordings of launches at SNI during 2001–2002 (also see Holst and Lawson 2002), the 100-dBA SEL still seemed reasonable as a minimum received level that might elicit disturbance for California sea lions. However, 90 dBA SEL-A 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-A. 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 during Year 1, indicated that levels at or above 90 dBA SEL-A could be expected out to distances of ~2.5 mi (4 km) from the launch trajectory (see Fig. 2.39 *in* Greene and Malme 2002). This determined where acoustic (and video) monitoring was done during subsequent years. Sites at distances up to ~2.5 mi (4 km) from the launcher and/or launch trajectory were monitored in Years 2–4.

1.10 Visual Monitoring of Pinnipeds During Missile Launches

The Navy conducted continued video and visual monitoring of marine mammals during the missile launches from SNI in the October 2003 to May 2005 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 was expected to provide the data required to characterize the extent and nature of disturbance effects. In particular, it would provide 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.

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. 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;
3. ascertain periods or launch conditions when pinnipeds are most and least responsive to launch activities, and
4. document numbers of pinnipeds affected by vehicle launch sounds and, although unlikely, any mortality or injury.

Data from all monitoring years were pooled in order to meet the objectives. Additional data will be collected during future monitoring. A detailed description of the methods for the visual monitoring can be found in Section 3.2 of Chapter 3.

1.11 Letter of Authorization (LOA)

The monitoring programs for the Navy’s vehicle launches in 2001–2005 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 TTS might have occurred as a result of a launch, or if biologically significant behavioral patterns of

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

pinnipeds are disrupted. NMFS (2000) defines 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." Consistent with NMFS (2002), "…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".

The first LOA authorized possible harassment takes of pinnipeds hauled out at SNI during vehicle launches from 2 October 2003 to 1 October 2004 (Year 3; NMFS 2003). A second LOA is currently held and was issued to the Navy on 8 October 2004; the LOA concerns the period 8 October 2004 through 7 October 2005 (Year 4; NMFS 2004; Appendix A). Previously, in Years 1 and 2, IHAs were issued for the same purpose. Acoustic and visual monitoring has been conducted during launches from SNI from August 2001 to the present (2005). The current report summarizes the results from all monitoring years, including launches conducted from August 2001–January 2005, including launch-specific details for launches in the October 2003 through January 2005 period.

1.12 Summary

From October 2003 through October 2004, NAWCWD conducted a total of 13 launches from SNI, on eight different days. In addition, three launches took place on 27 January 2005. Vehicles were launched from the Building 807 Launch Complex near the beach on the west-central part of SNI and from the Alpha Launch Complex farther inland on SNI.

An acoustic and visual monitoring program was conducted during these launches to assess the effects of these operations on the pinniped species on the island. Monitoring procedures were consistent with those during 31 previous launches in the August 2001 through August 2003 period (see Lawson et al. 2002; Holst and Greene 2003a,b; Holst et al. 2005). Monitoring procedures and results of the acoustic and visual monitoring during October 2003 to January 2005 are described in Chapters 2 and 3. Those chapters also summarize key results from August 2001 through August 2003, and use the combined data from all monitoring years to characterize the launch sounds and pinniped responses. Results from the launches during February–April 2005 will be reported later.

2. ACOUSTICAL MEASUREMENTS OF MISSILE LAUNCHES, AUGUST 2001–JANUARY 2005

2.1 Introduction

A total of 51 vehicles were launched from SNI during the period from 15 August 2001 through 27 January 2005. Of these, 13 launches of 14 vehicles were during the October 2003 through October 2004 period, and an additional 3 launches (3 vehicles) took place on 27 January 2005. Also, 19 launches (20 vehicles) occurred during the August 2001 through July 2002 period, and 12 launches (14 vehicles) took place during August 2002 through August 2003. Four launches were dual launches in quick succession, including dual RAM launches on 21 June 2002, 18 November 2002, and 5 May 2004, and a dual Vandal launch on 4 April 2003. On 7 days (15 August and 20 September 2001; 22 February, 1 May, 26 June and 18 December 2002; and 26 July 2004), two vehicles were launched sequentially at intervals ranging from 21 min to 8.5 hr apart. On 3 June and 22 September 2004, and 27 January 2005, three vehicles were launched sequentially, varying from 22 min to 2.7 hr apart. More recently in 2005, there were two launches of AGS vehicles on 24 February, a dual Vandal launch on 11 March, and single SSST launches on 24 March and 22 April, but the acoustic data for these launches have not yet been analyzed. Table 2.1 lists the launch dates, times, and types of vehicles. Maps of the launch azimuths and monitoring locations for launches in 2004 and January 2005 can be found in Chapter 3, and for earlier years in Appendix B.

The acoustic measurement program during the October 2003–January 2005 period was consistent in approach and methodology with that used during the preceding years (see Greene and Malme 2002; Holst and Greene 2003a,b). The sounds of each vehicle, as well as background sounds, were recorded at up to three sites on the island during each vehicle flight. ATARs, described below, were used to record the launch sounds at places and times where launch safety considerations required that no operator could be present. Of the 141 possible recordings over the period from August 2001 through January 2005 (47 launches × 3 recording sites per launch), 136 recordings were attempted and 98 recordings were obtained and analyzed (Table 2.1). During 26 launches, one or two ATARs did not operate successfully.

2.2 Field Methods

2.2.1 Deployment of ATARs

During each vehicle launch within the present monitoring period, the three ATARs were all positioned near pinniped haul out sites at varying distances from the planned launch azimuth. During each of these launches, at least one ATAR was within a horizontal distance of 1968 ft (600 m) of the planned azimuth or the launcher itself. The other ATARs were positioned to the sides of that azimuth at other locations where pinniped responses were to be monitored by video methods (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.

TABLE 2.1. Vehicle launches recorded at San Nicolas Island from August 2001 to January 2005.

Date	Local Time	Vehicle	Elevation Angle (°)	Acoustic Recording Sites	Acoustic Data
Year 1					
15 Aug. 01	12:56	Vandal	8	3	1 OK*
"	13:17	Vandal	8	3	1 OK*
20 Sept. 01	08:30	Vandal	8	3	2 OK†
"	17:02	Terrier Orion	64.6	3	1 OK†
5 Oct. 01	13:37	Vandal	8	3	1 OK†
19 Oct. 01	09:00	Vandal	8	3	1 OK*
19 Dec. 01	15:22	Vandal	8	3	2 OK†
14 Feb. 02	11:33	Vandal	8	3	2 OK*
22 Feb. 02	12:13	Vandal	42	3	2 OK†
"	14:56	Vandal	42	3	2 OK†
6 Mar. 02	11:20	Vandal	8	3	3 OK
1 May 02	15:53	Vandal	6.5	3	1 OK†
"	17:00	Vandal	42	3	2 OK†
8 May 02	14:54	Vandal	8	3	3 OK
19 June 02	15:07	AGS Test Slug	63	2	1 OK†
21 June 02	12:53	Dual RAM	8	1	1 OK
26 June 02	11:20	AGS Test Slug	62.5	3	3 OK
"	12:51	AGS Missile	62.5	3	3 OK
18 July 02	11:54	Vandal	8	3	1 OK†
Year 2					
23 Aug. 02	14:09	Tomahawk	90	3	1 OK†
18 Nov. 02	11:03	Dual RAM	10	3	2 OK†
10 Dec. 02	08:49	Vandal	8	3	2 OK†
18 Dec. 02	14:30	AGS	50	2	2 OK
"	16:15	AGS	50	2	1 OK†
24 Jan. 03	14:20	SSST	20	3	1 OK†
14 Mar. 03	09:13	Vandal	8	3	3 OK
16 Mar. 03	13:04	Vandal	8	3	1 OK†
4 Apr. 03	15:20	Dual Vandal	8	3	3 OK
4 June 03	12:35	SSST	22	3	3 OK
26 June 03	13:27	Vandal	42	3	2 OK†
28 July 03	16:27	Vandal	8	3	1 OK†
Year 3					
5 May 04	11:46	Dual RAM	8	3	3 OK
18 May 04	12:40	SSST	18	3	1 OK*
3 June 04	11:31	AGS Slug	50	3	3 OK
"	13:22	AGS Slug	50	3	3 OK
"	15:08	AGS Missile	50	3	3 OK
26 July 04	15:10	AGS Slug	50	3	3 OK
"	15:43	AGS Slug	50	3	3 OK
29 July 04	10:20	Arrow	90	3	3 OK
26 Aug. 04	10:08	Arrow	90	3	3 OK
27 Aug. 04	16:30	SSST	18	3	3 OK
22 Sept. 04	09:56	RAM	10	3	3 OK
"	10:57	RAM	10	3	3 OK
"	11:19	RAM	10	3	3 OK
Year 4					
27 Jan. 05	08:59	AGS Slug	50	3	2 OK†
"	11:41	AGS Slug	50	3	2 OK†
"	13:29	AGS Missile	50	3	2 OK†

* Other ATARs overloaded; † ATAR malfunctioned or data could not be interpreted.

ATARs were set up at the recording locations on the launch day well before the launch time and were retrieved later the same day. The three ATAR units were deployed by Navy biologists at sites as close as practical to three pinniped haul-out sites at various distances from the launch site and launch trajectory. These three ATAR sites included the following locations: (1) as close as possible to the vehicle's planned flight path, (2) where the received sound levels were estimated to reach an SEL (Sound Exposure Level) of ~90 to 100 dBA re $(20\ \mu Pa)^2 \cdot s$, as shown in Greene and Malme (2002), and (3) midway between sites 1 and 2. Over the period since monitoring started (August 2001), the Navy has distributed the ATARs such that, for types of targets or missiles that are launched commonly at SNI, recordings have been made at a variety of different distances and locations relative to the flight trajectories.

2.2.2 ATAR Design

The ATARs were designed to record continuously and unattended for up to 48 hr. It was necessary to use autonomous extended-duration recorders because safety considerations required all personnel to leave the monitoring sites 1 hr prior to the planned launch. With the 48-hr recording capability, an ATAR can still make recordings of flight sounds even if prolonged launch delays occur. The extended recording capabilities of the ATAR units, as compared with Digital Audio Tape (DAT) recording units used previously (e.g., Greene 1999), were important in accommodating any launch delays and periods between launches on the same day.

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 Hz. The principal components of an ATAR are two calibrated dissimilar microphones, two adjustable gain amplifiers (signal conditioners), a two-channel audio interface and analog-to-digital converter, and a laptop computer on whose hard disk the digitized sound samples are recorded. 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 in each ATAR 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. 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 kHz and digitized to a 16-bit two-byte integer.

At each of the monitoring sites, the microphones were placed in hemispherical windscreens and positioned so they were 0.08–0.12 in. (2–3 mm) from the flat side of the hemisphere. The windscreens were then each affixed to the center of an aluminum base plate 0.25 in. (0.63 cm) thick and 22 in. (55.9 cm) in diameter. The two base plates were set on the ground or sand in an area generally free of vegetation (Fig. 2.2). 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, just as an animal would near the ground (Greene 1999).

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

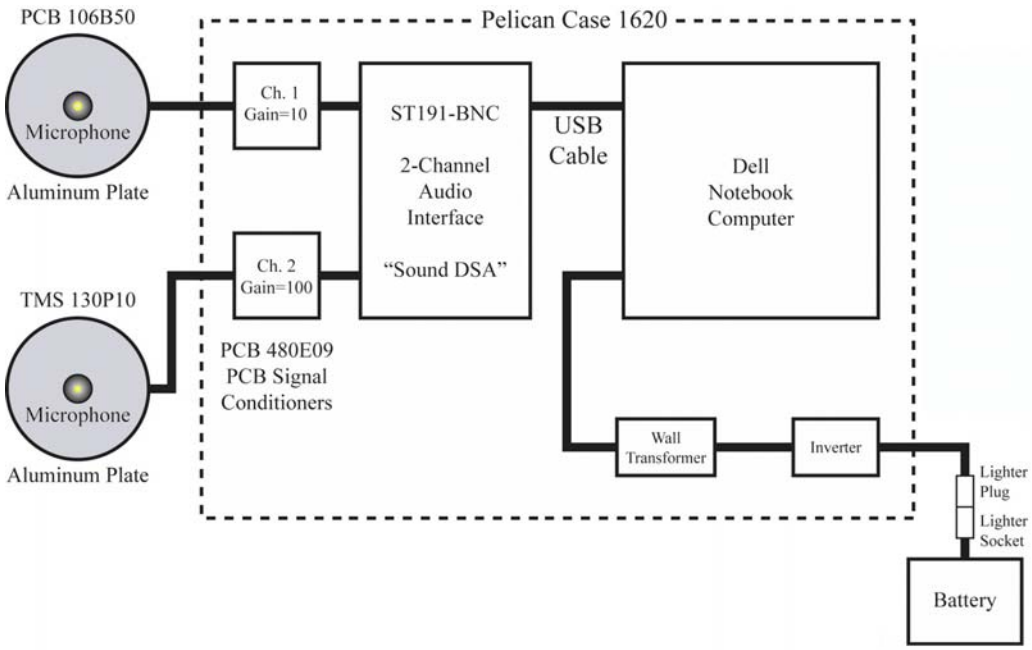

FIGURE 2.1. Block diagram of an Autonomous Terrestrial Acoustic Recorder (ATAR).

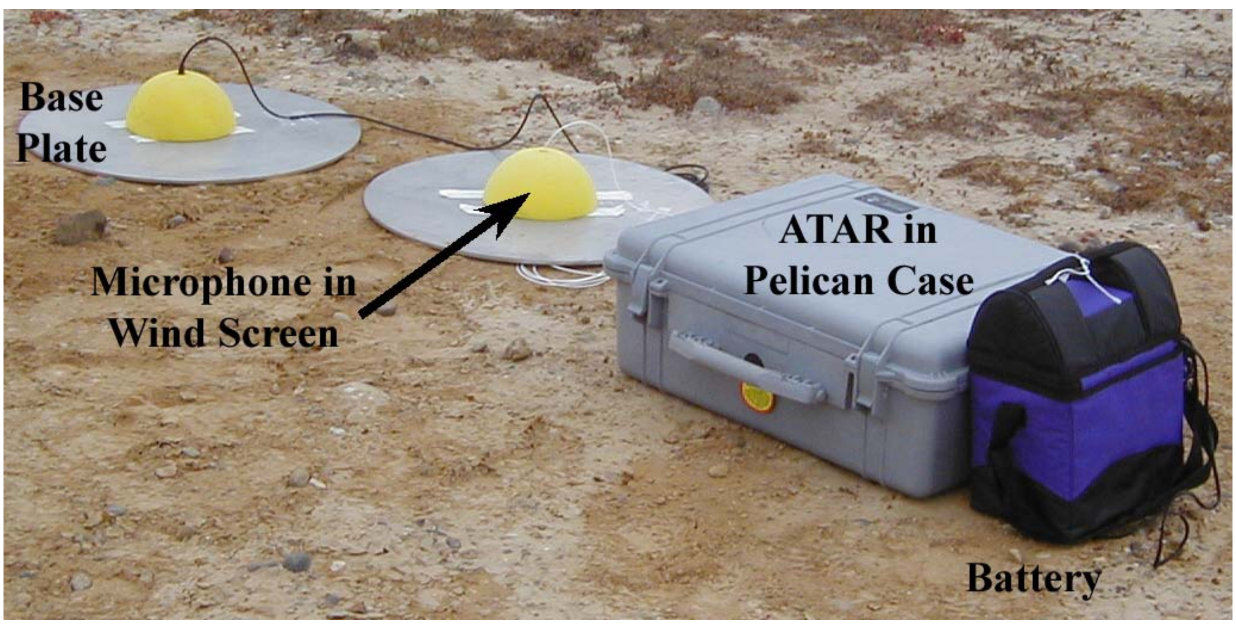

FIGURE 2.2. Typical field installation of an Autonomous Terrestrial Acoustic Recorder (ATAR) at the west end of San Nicolas Island, California (photograph by J. Lawson, LGL).

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.

The ATARs did not record successfully during several deployments. Typically, the recording program aborted prematurely, before the vehicle was launched. The problem appeared to be associated with an input/output software driver, either between the sound card and the recording program, or between the recording program and hard disk. Evidence indicated a problem in the interaction of a manufacturer-supplied low-level software driver and the operating system (Windows 2000 Professional). The problem did not occur frequently in a laboratory environment, making it difficult to diagnose. The software driver was upgraded and the operating system was replaced by Windows XP Professional just before the 4 April 2003 recordings. Although all three ATARs worked on that date, at one site an operator discovered a failure and corrected it before leaving for the launch. Additional failures occurred during several subsequent launches (Table 2.2).

In addition, a number of ATARs overloaded during launches, particularly during Year 1. The overloading occurred because the ATAR recording gains were inadvertently set higher than required. Thus, the overloading was not necessarily indicative of unusually high received levels, and the average received levels at the overloaded ATARs would not necessarily have been greater than those at non-overloaded ATARs.

During Year 2, it was observed that an ATAR would not operate at one site despite repeated attempts, but after being moved a fraction of a mile away, it operated successfully on the first try. It was 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. This observation is consistent with the fact that the ATARs do not fail when tested either in the lab at SNI or in Santa Barbara. Shielding and grounding was installed during subsequent launches, which seemed to alleviate this problem.

2.3 Audio and Data Analysis Methods

The ATARs recorded digital data directly onto a hard drive within the ATAR. The digital data on the hard drives were copied to a recordable CD-ROM after the recording period and returned to the acoustical contractor, Greeneridge Sciences Inc., 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) on a flat- (SPL-f) or A-weighted (SPL-A) basis, and SEL on a flat- (SEL-f) or A-weighted (SEL-A) basis. Frequency-domain results included estimation of sound pressure levels in one-third octave bands for center frequencies from 4 to 16,000 kHz. This section describes how these values are defined and calculated.

2.3.1 Time-Series Analysis

All analyses required identification of a signal's beginning and termination. 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

TABLE 2.2. Locations of ATAR recording devices (also Figure 3.1 in Chapter 3 and Appendix B).

Launch Date	Vehicle	ATAR Locations
Year 1		
15 Aug. 01	Vandal	End of Redeye Road; 809 Cameraº; Dos Covesº
20 Sep. 01	Terrier	Alpha Launch Complex*; Building 807*; Cormorant Rock Blind
20 Sep. 01	Vandal	809 Camera; Tender Beach; Dos Coves*
5 Oct. 01	Vandal	Phoca Reef; 809 Camera*; Vizcaino Point*
19 Oct. 01	Vandal	NAVFAC Beach; 809 Cameraº; Bachelor Beach Southº
19 Dec. 01	Vandal	809 Camera; Building 807; Dos Coves*
14 Feb. 02	Vandal	809 Camera; Bachelor Beach North; Alpha Launch Complexº
22 Feb. 02	Vandal	809 Camera; Redeye Beach; Dos Coves*
6 Mar. 02	Vandal	809 Camera; Dos Coves; Sheephead Ranch
1 May 02	Vandal	809 Camera†; Bachelor Beach South; Dos Coves*
8 May 02	Vandal	Pirates Cove; Sea Lion Cove; Vizcaino Point
19 June 02	AGS Test Slug	Redeye II; Alpha Launch Complex*
21 June 02	RAM	Building 807 Launch Complex
26 June 02	AGS Test Slug & Missile	809 Camera; Launch Pad; Redeye Beach
18 July 02	Vandal	809 Camera*; Dos Coves; Tender Beach*
Year 2		
23 Aug. 02	Tomahawk	Dos Coves, 50 ft from Launcher*, Bachelor Beach South*
18 Nov. 02	Dual RAM	75 ft from Launcher, Bachelor Beach North, Dos Coves*
10 Dec. 02	Vandal	Dos Coves, Bachelor Beach North, Launcher*
18 Dec. 02	AGS	50 ft from Launcher, Near 809 Camera‡
24 Jan. 03	SSST	Redeye I, Bachelor Beach South*, Dos Coves*
14 Mar. 03	Vandal	Pirates Cove, Sheephead Ranch, 100 ft from Launcher
16 Mar. 03	Vandal	Corral Harbor, Launcher*, Pirates Cove*
4 Apr. 03	Dual Vandal	NAVFAC Beach, No Name Cove, Phoca Point
4 June 03	SSST	Sheephead Ranch, Near 809 Camera, 100 ft from Launcher
26 June 03	Vandal	The "Y", Near 809 Camera, Bomber Cove*
28 July 03	Vandal	Near 809 Camera, Bachelor Beach North*, Dos Coves*
Year 3		
5 May 04	Dual RAM	Dos Coves, Bachelor Beach North, Bachelor Beach South
18 May 04	SSST	Pirates Cove, Harbor Seal Overlookº, Redeye Iº
3 June 04	AGS slugs and missile	Dos Coves South, Harbor Seal Overlook, Near 809 Camera
26 July 04	AGS slugs	Bachelor Beach North, Dos Coves South, Vizcaino Point
29 July 04	Arrow	Dos Coves South, Bachelor Beach North, Vizcaino Point
26 Aug. 04	Arrow	Dos Coves South, Phoca Reef, Vizcaino Point
27 Aug. 04	SSST	Dos Coves South, Phoca Reef, Vizcaino Point
22 Sept. 04	RAM	Dos Coves South, The “Y”, Vizcaino Point
Year 4		
27 Jan. 05	AGS slugs and missiles	Redeye I, Bachelor Beach North, Bachelor Beach South*

º ATAR overloaded; * ATAR malfunctioned or sound could not be analyzed; † ATAR malfunctioned at this location only during the first launch at 15:53:20; ‡ Sound recorded for AGS launch at 14:30 only.

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:

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

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·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·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·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. The acoustical contractor used Welch's (1967) "Weighted Overlapped Segment Averaging" (WOSA) method 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 broadband time series analysis) as follows:

- for duration > 1 s, use 32,768-sample blocks of total length 0.74 s with Blackman-Harris minimum three-term window (Harris 1978), 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 < 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 Hz 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, resulting 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 sound pressure levels 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 A-Weighting

Time-series results for the full 3 to 20,000 Hz bandwidth were calculated both for A- and flat-weighted data. With A-weighting, the signal's spectrum is multiplied by the standard A-weighting spectrum (Kinsler et al. 1982:280; Richardson et al. 1995:99). This multiplication 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 weighting applied by the human ear and is a standard method of presenting data on airborne sounds. Flat-weighting, on the other hand, 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. The relative sensitivity of pinnipeds listening in air to different frequencies is generally similar to that of humans (Richardson et al. 1995), so A-weighting may also be relevant to pinnipeds. However, measurement data from each launch are presented by one-third octave band, so other weighting methods (e.g., C-weighting or species-specific weighting functions) could be applied to these data. Only flat weighting was used for frequency-domain analyses. The concept of A-weighting is not useful when reporting results for specific frequencies or narrow frequency bands.

2.3.4 Data Analysis

From physical considerations, one expects the acoustic measures of a vehicle flight to be related to several potential predictor variables. The sound level is expected to diminish with increasing distance, but some other factors are also likely to affect the received sound. The primary measure of distance used here was the 3-dimensional (3-D) distance of the ATAR from the closest point of approach (CPA) of the vehicle. The simple bivariate relationships of various measures of sound to the 3-D CPA distance was first examined using scatter plots and Spearman Rank Order Correlations. One-sided *P*-values are appropriate, since the direction of the effect was predictable (i.e., sound levels were expected to diminish with increasing distance from the vehicle flight path). Then, a process of stepwise multiple linear regression was conducted to investigate the simultaneous relationships of received sound to several potential predictor variables.

For all analyses, data from August 2001 to January 2005 were used. For each launch, several potential predictor variables were calculated. These included the 3-D distance from the ATAR recording site to the CPA of the vehicle (in km), the angle above the horizon from recording site to the 3-D CPA (in degrees), and the wind component along the axis from the CPA to the ATAR location (in knots). The wind component equaled the wind speed if the wind was blowing directly from the CPA location to the ATAR, – (wind speed) if blowing along that axis but in the opposite direction (ATAR to CPA), and zero if perpendicular to that axis. For these and other angles, the component was calculated as the cosine of the angle between wind direction and the CPA-to-ATAR axis, multiplied by the wind speed. The relationship between 3-D distance and the measured vehicle sound variables was examined for each vehicle type using scatter plots.

Multiple regression models were run to predict seven measured acoustic levels. The linear regression models were all of the form

$$y = \beta_0 + \beta_1 x_1 + ... + \beta_p x_p + \varepsilon, \qquad [1]$$

where y was the acoustic measurement, $x_1, ..., x_p$ were a set of predictor variables, $\beta_0, \ldots, \beta_p$ were parameters to be estimated, and ε was a random error term that was assumed to follow a normal distribution with mean 0 and unknown variance σ^2 (Neter et al. 1996). A "best" set of predictor variables to include in [1] was selected by fitting all possible combinations of predictor variables (excluding interactions) and ranking the resulting model set by Akaike's Information Criterion (AIC; Burnham and Anderson 2002). AIC for a model was defined as

$$AIC = n \ln\left(\hat{\sigma}^2\right) + 2K \qquad [2]$$

where n was the number of observations, K was the number of parameters in the model + 1 (for $\hat{\sigma}^2$), and $\hat{\sigma}^2$ was the maximum likelihood estimate of σ^2, estimated by

$$\hat{\sigma}^2 = \frac{\sum \hat{\varepsilon}_i^2}{n}. \qquad [3]$$

Regression models with low AIC values are, in theory, better representations of the actual relationships than are models with high AIC (Burnham and Anderson 2002). The model with minimum AIC among those fitted was chosen as our "best" model given the available data and the set of models fitted. The coefficient of multiple determination (R^2) for each model, student's t statistic for each coefficient, and P-value associated with the t statistics were also calculated. Estimation of all possible models and ranking by AIC was carried out using SAS Proc REG (SAS Institute 2000).

A total of either 80 or 84 sets of launch sound measurements were available for analysis, depending upon the sound variable being considered. The seven sound measurements used as response variables were Peak, SEL-f, SEL-A, SPL-f, SPL-A, and the logarithm (base 10) of duration with flat-weighting (logDur-f) and A-weighting (logDur-A). Predictor variables considered for inclusion in [1] were as follows: (1) vehicle type, (2) the 3-D distance to the CPA (CPADist; in km), (3) the logarithm (base 10) of 3-D distance from recording site to CPA (logCPADist), (4) the angle above the horizon from the recorder to the vehicle CPA (CPA_Angle; in degrees), plus (5) the wind component in kt.

In general, sound propagation is characterized both by spreading loss, which is logarithmically related to distance, and by absorption/scattering loss, which is linear with distance. Therefore both logarithmic (logCPADist) as well as a linear functions of 3-D CPA distance were considered as potential predictors of the acoustic measures.

Vehicle type was coded as a discrete variable with 4 levels: 1 ="other large" (Arrow, SSST, Tomahawk, and Terrier), 2 = AGS missile or AGS slug, 3 = "other small" (RAM), and 4 = Vandal. Level 4 (Vandal) was used as the reference level in all regression models. This is the standard method for handling categorical data in a multiple regression analysis. With this method, the coefficients derived by the multiple regression for each of the three vehicle type variables indicate the degree to which sounds from each of those vehicles differed from Vandal sounds.

Both 3-D distance variables (non-log and log) were allowed in the same model even though they were highly correlated (r = 0.77). As a result, slight multicolinearity (Neter et al. 1996) may exist in models containing both distance variables. Coefficients of all predictor variables were inspected in models both with and without distance variables. If coefficients were similar, multicolinearity was deemed inconsequential and no corrections were made. Assuming interactions between predictor variables were nil, it was possible to fit a total of 31 models to each of the seven response variables.

The results of the regressions are presented in Tables 2.6 and 2.7 (later). The best-fitting models are summarized in Table 2.6, where it can be seen that the sound level measures were more closely related to logCPADist and CPA_Angle, whereas durations were more closely related to linear distance. The models including all predictor variables are presented in Table 2.7. The nominal significance levels associated with each included predictor variable are also presented Tables 2.6 and 2.7, as an indication of its relative utility in predicting the acoustic measure.

2.4 Results

Measurements of the vehicle flight sounds are reported based both on flat-weighting and on A-weighting. The background sound levels are also reported based on each of these weighting methods.

2.4.1 Vehicle Flight Sounds

Four parameters are reported for the vehicle flight sounds: peak pressure level (peak), SPL, SEL, and duration. These parameters are explained in Section 2.3.

Recent Results.—Table 2.3 shows the results for acoustic monitoring from October 2003 through January 2005 based on both flat- and A-weighting. It was to be expected that A-weighted levels would almost always be less than flat-weighted levels because sonic booms include strong components at freq-uencies below 1000 Hz, which are de-emphasized with A-weighting. The flight sound durations are sometimes long because of rocket noise reverberation or because the launch was at a high elevation angle, resulting in a relative prolonged period when the vehicle was well above the horizon.

During the October 2003 to January 2005 monitoring period, sounds from various vehicles were recorded at a variety of 3-D CPA distances:

- The RAM launches resulted in flat-weighted SPLs ranging from 86 dB re 20 µPa at Dos Coves, located ~1901 ft (580 m) from the CPA, to 99 dB recorded at “The Y” 5099 ft (1555 m) from the CPA (see Fig. 3.1A,I in Chapter 3; Table 2.3). SELs ranged from 84 to 97 dB re (20 µPa)^2·s.
- The AGS vehicles, when launched from the Alpha Launch Complex, resulted in an SPL of 100–105 dB at Dos Coves, located ~4418 ft (1.3 km) from the CPA (Fig. 3.1C,D,E,F,J,K in Chapter 3; Table 2.3). Levels received at the same location were higher (125–126 dB) when the AGS launcher was re-located to Building 807 and the CPA was ~1450 ft (440 m). SELs received during AGS launches ranged from 90 to 114 dB.
- The SSSTs produced SPLs ranging from 82 dB at Phoca Reef, 1.5 mi (2.4 km) from the CPA, to 133 dB at Vizcaino Point, located 1 mi (1.6 km) from the CPA (Fig. 3.1B,I in Chapter 3; Table 2.3). SELs ranged from 92 to 119 dB.
- The Arrows produced SPLs ranging from 84 to 90 dB at sites 5839 ft (1.8 km) to 1.6 mi (2.7 km) from the CPA (Fig. 3.1G,H in Chapter 3; Table 2.3). SELs ranged from 96 to 102 dB.

TABLE 2.3. Pulse parameters for flat- and A-weighted sound from vehicle flights at SNI during October 2003 to January 2005. The peak levels and SPLs are in dB relative to 20 µPa, the SELs (energy levels) are in dB relative to (20 µPa)^2·s, and the durations (Dur.) are in s. The 3-D CPA distance of the vehicle from the monitoring site is given in m. Broadband (10-20,000 Hz) flat- and A-weighted sound levels for each site as recorded before the launch by the high-sensitivity sensor designed to measure ambient sounds are also given (dB re 20 µPa). See Figure 3.1 in Chapter 3 for maps of monitoring locations.

				CPA	Flat-weighted sound				A-weighted sound			Ambient sound	
Date	Time	Vehicle	Site	(m)	Peak	SPL	SEL	Dur.	SPL	SEL	Dur.	Flat-wt	A-wt
5 May 04	11:46:00	RAM[a]	Dos Coves	581	111	86	93	4.5	80	86	3.9	64	47
“	11:46:12	RAM[a]	Dos Coves	581	114	87	93	4.0	79	85	3.7	64	47
“	11:46:00	RAM[a]	Bachelor Beach North	693	116	90	97	4.2	85	91	3.7	67	57
“	11:46:12	RAM[a]	Bachelor Beach North	693	116	91	96	3.0	84	90	3.6	67	57
“	11:46:10	RAM[a]	Bachelor Beach South	992	117	90	96	3.5	85	91	4.0	78	67
“	11:46:12	RAM[a]	Bachelor Beach South	992	115	88	94	3.8	82	88	4.2	77	67
18 May 04	12:40	SSST[b]	Pirates Cove	2397	106	93	105	15.8	71	79	6.7	N/A	N/A
“	12:40	SSST[b]	Harbor Seal Overlook*†	1292	>136	>128	>117	0.1	>106	>103	0.5	79	37
“	12:40	SSST[b]	Redeye I *†	1061	>136	>130	>119	0.1	>111	>103	0.1	78	45
3 June 04	11:31	AGS Slug[c]	Dos Coves South	1347	117	105	98	0.2	88	78	0.1	71	53
“	13:22	AGS Slug[c]	Dos Coves South	1347	113	100	94	0.2	82	73	0.1	76	54
“	15:08	AGS Missile[c]	Dos Coves South	1347	114	105	98	0.2	81	73	0.1	72	56
“	11:31	AGS Slug[c]	Harbor Seal Overlook†	1164	124	110	103	0.2	88	80	0.2	N/A	N/A
“	13:22	AGS Slug[c]	Harbor Seal Overlook†	1164	115	101	95	0.3	85	76	0.1	N/A	N/A
“	15:08	AGS Missile[c]	Harbor Seal Overlook†	1164	125	111	103	0.2	87	79	0.2	N/A	N/A
“	11:31	AGS Slug[c]	Near 809 Camera	1268	127	110	103	0.2	107	89	0.0	66	40
“	13:22	AGS Slug[c]	Near 809 Camera	1268	128	109	103	0.3	94	88	0.3	64	41
“	15:08	AGS Missile[c]	Near 809 Camera	1268	120	108	102	0.2	82	75	0.2	73	42
26 July 04	15:10	AGS Slug[c]	Bachelor Beach North	781	123	115	101	0.05	93	82	0.1	64	54
“	15:43	AGS Slug[c]	Bachelor Beach North	773	125	116	103	0.1	94	82	0.1	61	53
“	15:10	AGS Slug[c]	Dos Coves South	438	133	125	112	0.1	100	88	0.1	66	56
“	15:43	AGS Slug[c]	Dos Coves South	442	135	126	114	0.1	102	90	0.1	74	61
“	15:10	AGS Slug[c]	Vizcaino Point	1584	117	110	98	0.1	69	61	0.2	78	47
“	15:43	AGS Slug[c]	Vizcaino Point	1589	116	110	98	0.1	65	58	0.2	72	38
29 July 04	10:20	Arrow[d]	Dos Coves South	1780	105	89	100	12.2	78	87	9.0	67	56
“	10:20	Arrow[d]	Bachelor Beach North	1820	107	90	102	14.3	83	92	8.5	71	48
“	10:20	Arrow[d]	Vizcaino Point	2082	101	88	99	12.7	73	83	10.6	65	41
26 Aug. 04	10:08	Arrow[d]	Dos Coves South	1779	103	88	98	11.0	78	87	8.8	72	58
“	10:08	Arrow[d]	Phoca Reef	2656	101	86	98	15.7	72	82	10.3	22	22
“	10:08	Arrow[d]	Vizcaino Point	2262	100	84	96	15.6	72	82	10.4	57	40

TABLE 2.3. Continued.

Date	Time	Vehicle	Site	CPA (m)	Flat-weighted sound				A-weighted sound			Ambient sound	
					Peak	SPL	SEL	Dur.	SPL	SEL	Dur.	Flat-wt	A-wt
27 Aug. 04	16:30	SSST[b]	Dos Coves South[†]	1920	136	118	114	0.4	102	96	0.3	62	52
“	16:30	SSST[b]	Phoca Reef	2413	100	82	92	9.9	67	76	7.0	55	38
“	16:30	SSST[b]	Vizcaino Point[†]	1614	136	133	117	0.02	103	100	0.4	59	39
22 Sept. 04	09:56	RAM[e]	Dos Coves South	580	109	92	97	3.0	87	91	2.4	68	52
“	10:57	RAM[e]	Dos Coves South	580	110	90	96	4.5	84	90	3.9	62	47
“	11:19	RAM[e]	Dos Coves South	580	114	89	95	3.4	82	87	3.3	61	50
“	09:56	RAM[e]	The “Y”	1555	116	99	95	0.4	83	82	0.8	62	40
“	10:57	RAM[e]	The “Y”	1555	109	93	87	0.3	75	70	0.4	60	36
“	11:19	RAM[e]	The “Y”	1554	111	97	89	0.1	79	71	0.2	65	37
“	09:56	RAM[e]	Vizcaino Point	2013	105	92	87	0.4	77	73	0.4	69	39
“	10:57	RAM[e]	Vizcaino Point	2013	104	94	84	0.1	73	65	0.2	70	41
“	11:19	RAM[e]	Vizcaino Point	2013	107	93	84	0.1	72	64	0.2	74	39
27 Jan. 05	08:59	AGS Slug[c]	Redeye I[†]	1492	108	103	91	0.1	65	56	0.1	73	65
“	11:41	AGS Slug[c]	Redeye I[†]	1492	108	103	90	0.1	No signal after A-weighting			72	N/A
“	13:29	AGS Missile[c]	Redeye I[†]	1492	108	103	90	0.1	53	50	0.5	70	60
“	08:59	AGS Slug[c]	Bachelor Beach North[†]	753	125	116	103	0.05	84	80	0.4	65	54
“	11:41	AGS Slug[c]	Bachelor Beach North[†]	753	123	114	101	0.1	79	77	0.5	68	55
“	13:29	AGS Missile[c]	Bachelor Beach North[†]	753	123	112	101	0.1	78	76	0.7	65	54
“	08:59	AGS Slug[c]	Bachelor Beach South*						N/A				
“	11:41	AGS Slug[c]	Bachelor Beach South*						N/A				
“	13:29	AGS Missile[c]	Bachelor Beach South*						N/A				

N/A: data not available. [†]Sonic boom evident. *ATAR malfunctioned or overloaded (clipped signal). [a]Vehicle launched at an 8° angle. [b]Vehicle launched at an angle of 18°. [c]Vehicle launched at an angle of 50°. [d]Vehicle launched at an angle of 90°. [e]Vehicle launched at an angle of 10°.

Sonic booms were evident on four occasions during the October 2003 to January 2005 period:

- SSST on 18 May 2004 as received at Harbor Seal Overlook (4236 ft or 1.3 km from CPA), and at Redeye I (3482 ft or 1.1 km from the CPA),
- AGS slug on 3 June 2004 as received at Harbor Seal Overlook (3818 ft or 1.2 km from the CPA),
- SSST on 27 August 2004, as received at Dos Coves South (1.2 mi or 1.9 km from the CPA) and at Vizcaino Point (1 mi or 1.6 km from the CPA), and
- AGS vehicles on 27 January 2005, as received at Redeye I, located 4895 ft (1.5 km) from the CPA, and Bachelor Beach North (2470 ft or 753 m from the CPA).

Two graphs are presented in Appendix C for each flight recording from October 2003 through January 2005. For each launch, both graphs are based on flat-weighted data; no graphs are presented for A-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) 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.

Prior-Year Results.—Table 2.4 shows the standard acoustic measurements for the August 2001 through July 2002 monitoring period (Year 1; from Greene and Malme 2002). Table 2.5 presents those results from each launch during the August 2002 to August 2003 period (Year 2; from Holst and Greene 2003a). Appendix B shows the monitoring sites relative to the launch azimuth for each launch in Years 1 and 2. Graphs depicting pressure signatures and one-third octave data for each launch during Years 1 and 2 are shown in Greene and Malme (2002) and in Holst and Greene (2003a,b). The earlier reports describe notable features of the results from specific launches in Years 1 and 2.

2.4.2 Vehicle Sounds in Relation to Distance

Scatter plots of broadband pulse parameters relative to 3-D CPA distance between the vehicles and the receiving location are shown in Figures 2.3-2.6, considering all available data from August 2001 to January 2005.

Peak pressure level, SPL, and SEL generally decreased with increasing CPA distance from the vehicle (Fig. 2.3-2.6). The data from the Vandals spanned a wider range of distances (0–2.5 mi or 0 to 4 km) than available for other vehicle types. The Vandal data showed that, at the longer distances (>1.25 mi or >2 km), the loss rate when plotted against a linear distance scale tended to “flatten out”, at least in the case of peak pressure and SPL (Fig. 2.3). This was expected, given that attenuation of sound tends to be logarithmically related to distance.

The scatter diagrams for the various received level measurements vs. distance reveal several additional patterns:

- As expected, flat-weighted levels were always stronger than A-weighted levels at corresponding CPA distances, with increasing divergence between the two at the longer CPA distances.

TABLE 2.4. Pulse parameters for flat- and A-weighted sound from vehicle flights at SNI during August 2001 to July 2002 (Year 1). The peak levels and SPLs are in dB relative to 20 µPa, the SELs (energy levels) are in dB relative to $(20\ \mu Pa)^2 \cdot s$, and the durations (Dur.) are in s. The 3-D CPA distance of the vehicle from the monitoring site is given in m. Broadband (10-20,000 Hz) flat- and A-weighted sound levels for each site as recorded before the launch by the high-sensitivity sensor designed to measure ambient sounds are also given (dB re 20 µPa). Vehicles were launched at low elevation (8º) angles unless otherwise specified. See Figure B-1 in Appendix B for maps of monitoring locations.

				CPA	Flat-weighted sound				A-weighted sound			Ambient sound	
Date	Time	Vehicle	Site	(m)	Peak	SPL	SEL	Dur.	SPL	SEL	Dur.	Flat-wt	A-wt
15 Aug. 01	12:55	Vandal	End of Redeye Road	1763	109	95	100	3.3	84	90	3.6	60	44
"	12:55	Vandal	Dos Coves			Overloaded			Overloaded			52	35
"	12:55	Vandal	809 Camera			Overloaded			Overloaded			62	40
15 Aug. 01	13:16	Vandal	End of Redeye Road	1763	112	96	100	2.6	85	89	2.4	61	43
"	13:16	Vandal	Dos Coves			Overloaded			Overloaded			53	36
"	13:16	Vandal	809 Camera			Overloaded			Overloaded			74	48
20 Sept. 01	08:29	Vandal	Tender Beach	2256	116	102	107	3.7	89	95	4.1	65	55
"	08:29	Vandal	809 Camera †	1046	140	133	119	0.04	100	101	1.3	55	41
20 Sept. 01	17:00	Terrier[a]	Building 807					N/A				59	42
"	17:00	Terrier[a]	100 ft from Launcher					N/A				69	55
"	17:00	Terrier[a]	Cormorant Rock Blind	2433	104	91	96	2.8	78	83	3.4	59	38
5 Oct. 01	13:36	Vandal	Phoca Reef	2424	109	90	94	2.9	No signal after A-weighting			48	43
19 Oct. 01	08:59	Vandal	Bachelor Beach South			Overloaded			Overloaded			51	41
"	08:59	Vandal	809 Camera			Overloaded			Overloaded			48	39
"	08:59	Vandal	NAVFAC Beach	3911	133	121	120	0.8	No signal after A-weighting			32	21
19 Dec. 01	15:20	Vandal	Building 807 †	823	144	136	123	0.05	107	106	0.8	69	51
"	15:20	Vandal	809 Camera †	897	142	134	121	0.05	106	103	0.5	69	48
14 Feb. 02	11:33	Vandal	150 ft from Launcher			Overloaded			Overloaded			34	29
"	11:33	Vandal	809 Camera †	897	134	123	116	0.2	105	91	0.04	63	55
"	11:33	Vandal	Bachelor Beach North †	1206	144	135	123	0.07	118	107	0.08	59	45
22 Feb. 02	12:13	Vandal[b]	809 Camera	2372	110	93	97	2.5	80	85	2.8	55	36
"	12:13	Vandal[b]	Redeye Beach	1718	111	96	101	3.3	87	92	2.7	53	45
22 Feb. 02	14:56	Vandal[b]	809 Camera	2372	109	92	99	4.6	82	88	3.6	54	44
"	14:56	Vandal[b]	Redeye Beach	1718	111	96	102	3.7	87	92	3.0	52	44
6 Mar. 02	11:20	Vandal	Dos Coves †	399	149	142	129	0.05	119	113	0.2	71	46
"	11:20	Vandal	Sheephead Ranch	2909	109	98	95	0.6	No signal after A-weighting			45	29
"	11:20	Vandal	809 Camera †	897	143	133	121	0.06	119	106	0.05	65	46
1 May 02	15:53	Vandal[c]	Bachelor Beach South	N/A	110	102	102	1.0	No signal after A-weighting			80	68
1 May 02	17:00	Vandal[b]	Bachelor Beach South	2318	115	95	104	6.9	86	92	4.0	69	46
"	17:00	Vandal[b]	809 Camera	2312	112	96	103	5.4	85	90	3.2	76	49

TABLE 2.4. Continued.

Date	Time	Vehicle	Site	CPA (m)	Flat-weighted sound Peak	Flat-weighted sound SPL	Flat-weighted sound SEL	Flat-weighted sound Dur.	A-weighted sound SPL	A-weighted sound SEL	A-weighted sound Dur.	Ambient sound Flat-wt	Ambient sound A-wt
8 May 02	14:54	Vandal	Vizcaino Point †	1121	144	131	122	0.1	117	104	0.05	66	40
"	14:54	Vandal	Sea Lion Cove	2139	104	85	92	5.8	73	80	4.6	55	33
"	14:54	Vandal	Pirates Cove	2388	111	96	96	1.0	60	67	4.9	57	33
19 June 02	15:07	AGS Test Slug[a]	Redeye II	N/A	111	95	97	1.4	68	72	2.5	67	55
21 June 02	12:53	RAM	50 ft from Launcher	2	147	126	131	3.2	124	130	3.2	68	52
26 June 02	11:20	AGS Test Slug[a]	50 ft from Launcher	N/A	158	150	137	0.05	137	125	0.06	59	37
"	11:20	AGS Test Slug[a]	Redeye Beach	N/A	110	100	96	0.4	57	62	2.9	59	48
"	11:20	AGS Test Slug[a]	809 Camera	N/A	109	97	96	0.8	59	64	2.9	61	47
26 June 02	12:51	AGS Missile	50 ft from Launcher	22	157	148	136	0.06	133	122	0.07	57	29
"	12:51	AGS Missile	Redeye Beach	1536	108	102	93	0.1	57	64	4.9	62	49
"	12:51	AGS Missile	809 Camera	2115	107	98	94	0.4	72	64	0.12	59	45
18 July 02	11:54	Vandal	Dos Coves †	399	149	139	128	0.07	122	110	0.07	54	42

Note: Some ATARs overloaded. N/A means data are unavailable (missiles malfunctioned; CPA could not be calculated). †Sonic boom evident. [a]Vehicles launched at angles of 62.5-64.6°. [b]Vehicles launched at a 42° angle. [c]Vehicle launched at an angle of 6.5°.

TABLE 2.5. Pulse parameters for flat- and A-weighted sound from vehicle flights at SNI during August 2002 to August 2003 (Year 2). The peak levels and SPLs are in dB relative to 20 µPa, the SELs (energy levels) are in dB relative to $(20\ \mu Pa)^2 \cdot s$, and the durations (Dur.) are in s. The 3-D CPA distance of the vehicle from the monitoring site is given in m. Broadband (10-20,000 Hz) flat- and A-weighted sound levels for each site as recorded before the launch by the high-sensitivity sensor designed to measure ambient sounds are also given (dB re 20 µPa). Vehicles were launched at low elevation (8º) angles unless otherwise specified. See Figure B-2 in Appendix B for maps of monitoring locations.

				CPA	Flat-weighted sound				A-weighted sound			Ambient sound	
Date	Time	Vehicle	Site	(m)	Peak	SPL	SEL	Dur.	SPL	SEL	Dur.	Flat-wt	A-wt
23 Aug. 02	14:09	Tomahawk [‡,a]	Dos Coves	539	111	93	105	16.3	91	102	10.8	72	58
18 Nov. 02	11:03	RAM[b]	75 ft from Launcher **	4	146	124	129	3.3	122	128	3.2	68	61
"	11:03	RAM[b]	75 ft from Launcher *	4	146	130	126	0.4	130	125	0.3	65	50
"	11:03	RAM[b]	Bachelor Beach North **	693	112	90	97	5.2	84	92	5.8	71	54
"	11:03	RAM[b]	Bachelor Beach North *	693	112	90	94	2.6	84	89	3.1	N/A	N/A
10 Dec. 02	08:49	Vandal	Dos Coves †	421	150	140	128	0.06	131	118	0.05	91	60
"	08:49	Vandal	Bachelor Beach North †	1206	136	123	117	0.3	108	102	0.3	86	60
18 Dec. 02	14:30	AGS[c]	50 ft from Launcher	12	166	155	141	0.05	143	130	0.06	82	72
"	14:30	AGS[c]	Near 809 Camera	1196	130	109	119	9.0	78	88	8.1	71	44
"	16:15	AGS[c]	50 ft from Launcher	12	165	156	143	0.05	143	131	0.07	71	70
24 Jan. 03	14:20	SSST[d]	Redeye I †	1034	134	123	118	0.3	104	98	0.3	74	55
14 Mar. 03	09:13	Vandal	Pirates Cove	2388	112	88	98	10.7	58	66	6.6	51	35
"	09:13	Vandal	Sheephead Ranch	2909	112	90	98	6.0	51	60	8.5	52	42
"	09:13	Vandal	100 ft from Launcher	27	156	137	136	0.8	119	118	0.8	61	28
16 Mar. 03	13:04	Vandal	Corral Harbor	2590	115	98	100	1.6	64	71	4.7	61	41
4 Apr. 03	15:20	Vandal	NAVFAC Beach	3911	108	92	95	2.1	58	59	1.2	62	41
"	15:20	Vandal	No Name Cove	3506	116	104	101	0.5	62	67	3.6	47	35
"	15:20	Vandal	Phoca Point	3273	115	106	101	0.3	58	63	3.6	69	36
4 Apr. 03	15:20	Vandal	NAVFAC Beach	3911	107	95	95	1.0	55	51	0.4	74	49
"	15:20	Vandal	No Name Cove	3506	115	98	101	2.0	63	68	3.7	68	34
"	15:20	Vandal	Phoca Point	3273	115	98	101	2.0	60	66	3.8	69	36
4 June 03	12:35	SSST[d]	Near 809 Camera	1397	136	115	116	1.4	99	99	0.9	69	41
"	12:35	SSST[d]	Sheephead Ranch †	2906	116	101	102	1.2	90	87	0.5	59	42
"	12:35	SSST[d]	100 ft from Launcher	72	142	126	128	1.5	113	115	1.5	60	32
26 June 03	13:27	Vandal[e]	The "Y"	2948	112	93	101	7.2	80	89	7.4	62	51
"	13:27	Vandal	Near 809 Camera	2757	113	97	103	3.6	83	90	5.2	70	42
28 July 03	16:27	Vandal	Near 809 Camera †	1045	143	137	122	0.03	121	106	0.04	78	43

‡Chase planes preceded and followed the missile. †Sonic boom evident. *One missile (signature from the second missile was analyzed). **Two missiles (signatures from 2 missiles were analyzed together). N/A = data not available. [a]Vehicle launched at a 90° angle. [b]Vehicle launched at an angle of 10°. [c]Vehicles launched at an angle of 50°. [d]Vehicles launched at an angle of 20-22°. [e]Vehicle launched at an angle of 42°.

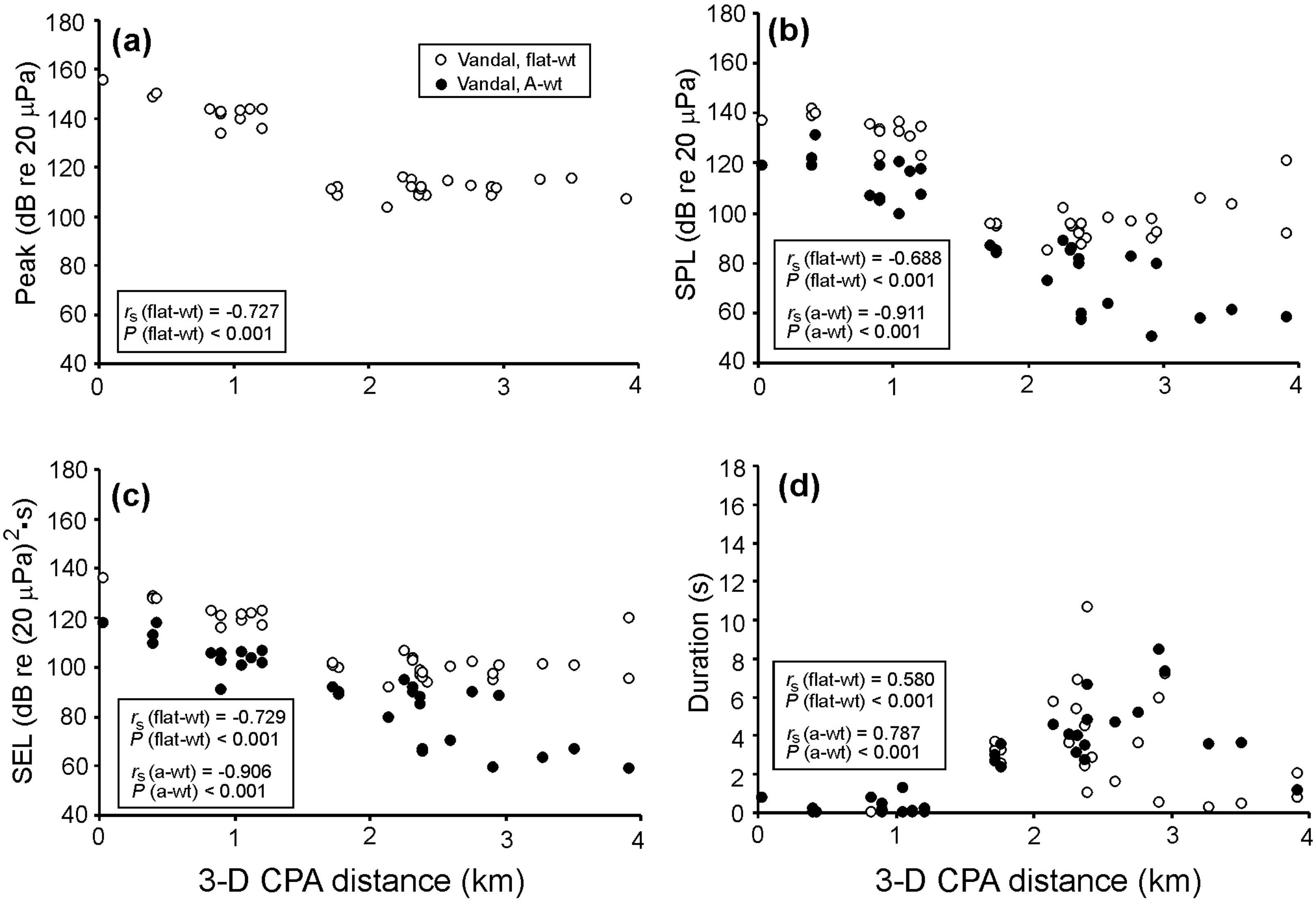

FIGURE 2.3. Sounds from launches of Vandal missiles relative to the 3-D CPA distance: **(a)** Peak sound pressure, **(b)** SPL, **(c)** SEL, and **(d)** Duration. For SPL, SEL, and Duration, both flat-weighted (open symbols) and A-weighted (closed symbols) measurements are shown. Also shown are Spearman rank order correlation coefficients (r_s) along with 1-sided P-values.

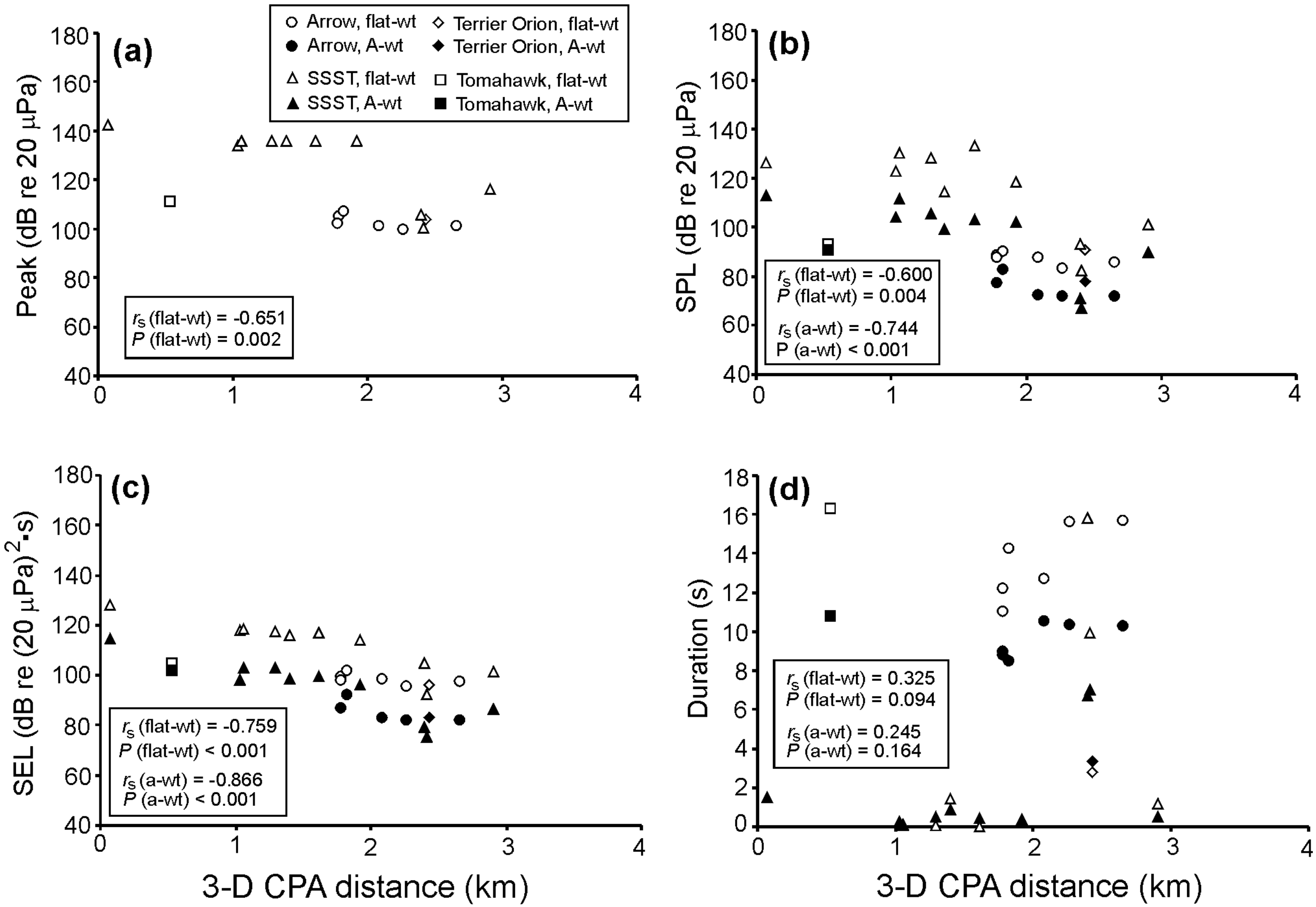

FIGURE 2.4. Sounds from other large vehicle (Terrier Orion, Tomahawk, Arrow, SSST) launches relative to the 3-D CPA distance: **(a)** Peak sound pressure, **(b)** SPL, **(c)** SEL, and **(d)** Duration. Plotted as in Figure 2.3.

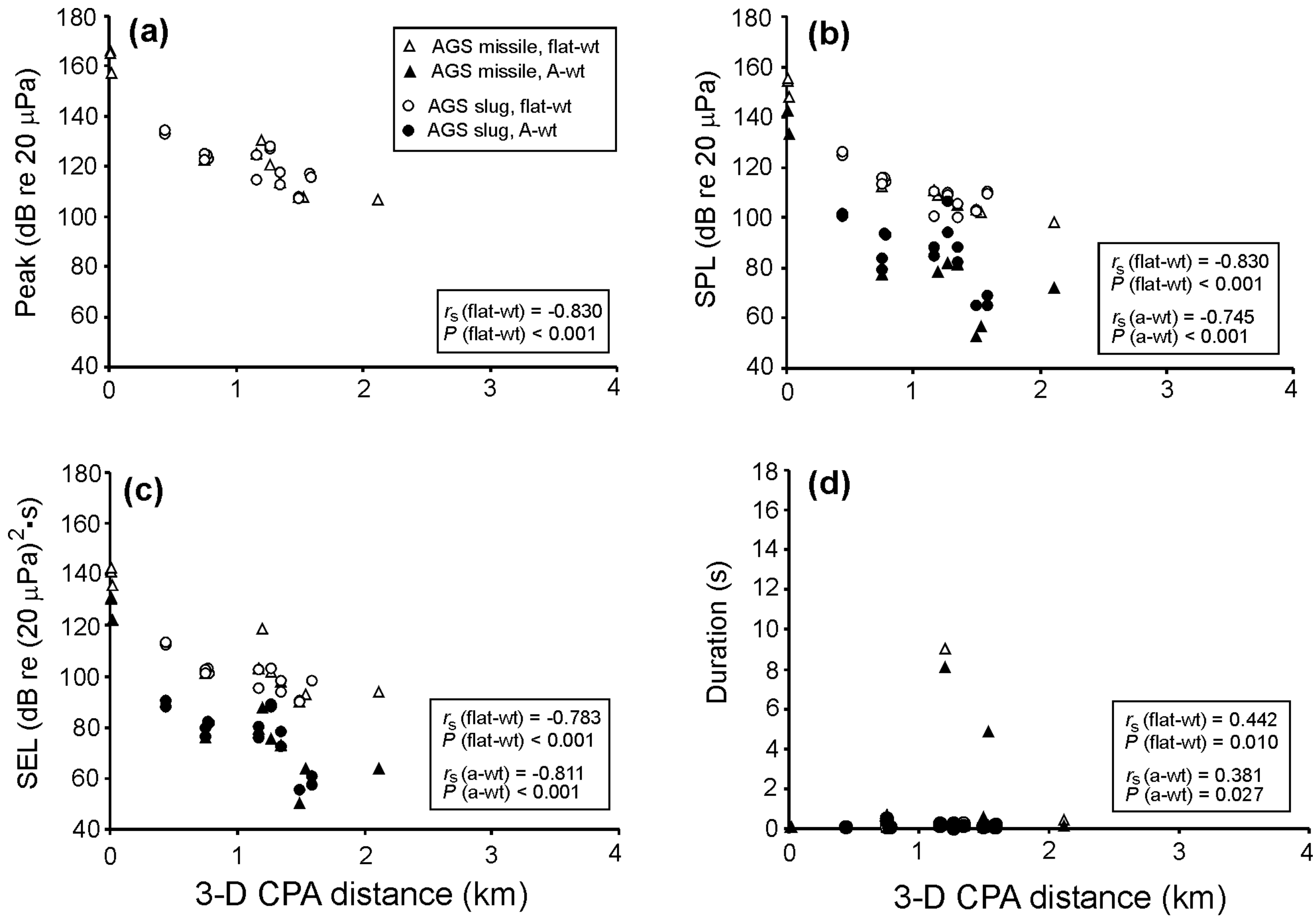

FIGURE 2.5. Sounds from launches of AGS vehicles relative to the 3-D CPA distance: **(a)** Peak sound pressure, **(b)** SPL, **(c)** SEL, and **(d)** Duration. Plotted as in Figure 2.3.

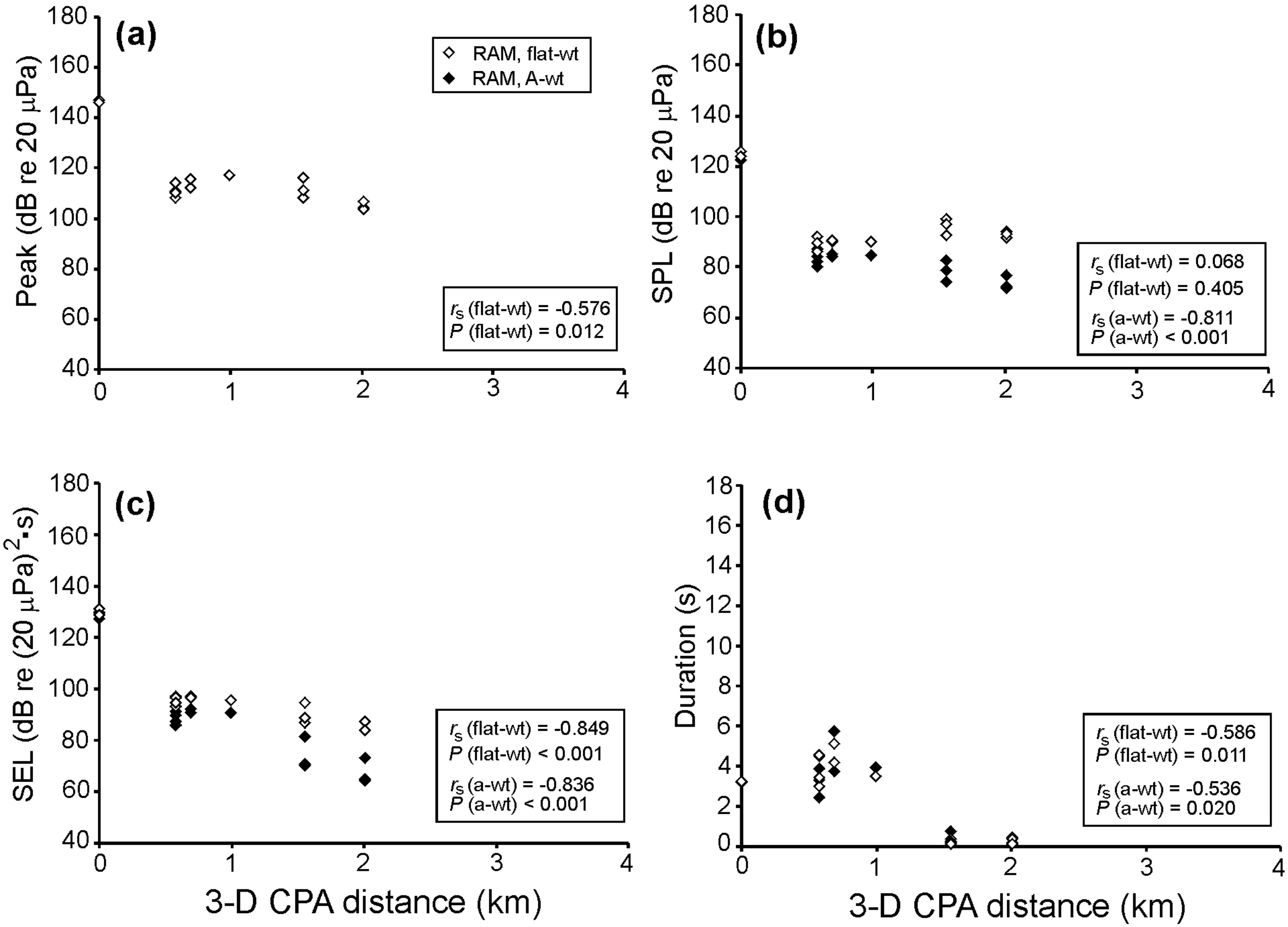

FIGURE 2.6. Sounds from launches of RAMs relative to the 3-D CPA distance: **(a)** Peak sound pressure, **(b)** SPL, **c)** SEL, and **(d)** Duration. Plotted as in Figure 2.3.

- The difference between flat- and A-weighted SPL and SEL tended to be greater for AGS vehicles than for Vandals or RAMs. This is presumably indicative of a difference in the frequency content of the sounds from different vehicles, with a higher proportion of the AGS sound being at frequencies that are down-weighted during A-weighting.
- Peak pressures were necessarily higher than SPLs. SEL is measured on a different scale than peak pressure or SPL, so direct comparisons of SEL values with other values are of limited relevance.
- At distances of 400 m or more, all measures of sound level were higher for Vandals than for AGS vehicles and RAMs, with "other large" vehicles being quite variable, as previously noted (Table 2.6). SSST launches produced the second highest sound levels at CPA distances away from the launcher (Table 2.6).
- Although sounds from the AGS vehicles were weaker than those from Vandals and SSSTs at distances beyond 400 m, the levels recorded close to the AGS launcher were as high or higher than those from the Vandal or SSST (Table 2.6). Until June 2004, the AGS launcher was at an inland location, not close to any pinnipeds, but subsequently it has been at the Building 807 launch site near the coast.
- Duration generally increased with increasing CPA distance for Vandal and AGS launches; but not so obviously for "other large" vehicles (Fig. 2.4). The latter may have been related at least in part to inclusion of a variety of vehicle types, probably with somewhat different sounds, in the "other large" vehicles category. In contrast, the duration increased with decreasing CPA distances for RAMs.

Vandal, SSST, Arrow, Terrier Orion, and (until June 2004) AGS vehicles were launched from a location in the interior of western SNI, about 1.2 mi (2 km) from the closest shoreline. They were at altitudes of at least 1280 ft (390 m) ASL when they crossed the beach at the western end of the island. Thus, the measurements made at the closest distance (e.g., launcher) would be expected to be higher than those that would have been received by any pinnipeds on the beaches. However, for Vandals and "other large" vehicles launched from the inland location, levels near the launcher were not much higher than those at 3-D CPA distances up to at least 0.6 mi or 1 km (Fig. 2.3, 2.4).

The Tomahawk and RAM vehicles, and the AGS launches from July 2004 onward, were launched from the Building 807 Launch Complex near a beach (Fig. 1.2), so for those vehicles, it is possible that some pinnipeds could have been close to the launcher. For the Tomahawk, we do not have received level measurements close to the launcher, but for the RAM and AGS launches, levels near the launcher were higher than those at any longer distance (Fig. 2.5, 2.6).

2.4.3 Other Factors Related to Missile Sound Levels and Durations

Multiple regression equations were fitted to the measurements to determine the simultaneous relationships between sound measures and several predictor variables. The coefficients are given for the best-fit models (Table 2.7) and for models where all variables were forced into the regression (Table 2.8).

Sound Level.—For all five of the sound level measures, the coefficients for all three vehicle types were negative, indicating that all three vehicle types tend to be quieter than Vandals (Table 2.7, 2.8). However, some of these vehicle-type coefficients were not statistically significant. In particular, differences between sound levels from Vandals vs. "other large" vehicles were relatively small. In contrast, sounds from the small RAM and AGS vehicles were substantially weaker than Vandal sounds by all five measures.

TABLE 2.6. The highest sound levels recorded near the launcher and at nearshore locations for all vehicle types launched at SNI from August 2001 through January 2005. Units for Peak, SPL-A, and SPL-f are in dB re 20 µPa; SEL-A and SEL-f have units of dB re (20 µPa)^2•s.

	CPA (m)	Peak (dB)	SPL-A (dB)	SPL-f (dB)	SEL-A (dB)	SEL-f (dB)
Launcher						
AGS Slug	22	158	137	150	125	137
AGS Missile	12-13	166	143	156	131	143
RAM	2-4	147	130	130	130	131
Terrier Orion	N/A	N/A	N/A	N/A	N/A	N/A
Tomahawk	N/A	N/A	N/A	N/A	N/A	N/A
Vandal	27	156	119	137	118	136
SSST	72	142	113	126	115	128
Arrow	N/A	N/A	N/A	N/A	N/A	N/A
Nearshore						
AGS Slug	442-1268	135	107	126	90	114
AGS Missile	753-1196	131	87	112	88	119
RAM	580-1555	117	87	99	92	97
Terrier Orion	2433	104	78	91	83	96
Tomahawk	539	111	91	93	102	105
Vandal	399-421	150	131	142	118	129
SSST	1062-1614	136	106	133	103	119
Arrow	1821	107	83	90	92	102

Note: N/A means no launch sounds were recorded near the launcher.

The *logarithm of CPA distance* was strongly related (nominal $P \leq 0.001$) to all five measures of sound level, and *linear CPA distance* was strongly related to 4 of the 5 ($P \leq 0.05$ for the 5th). The strong relationship to logCPADist is consistent with the "flattening out" of the level vs. range data at longer distances, as evident in Figure 2.3. The coefficient for logCPADist ranged from –13.2 to –16.1, slightly less than the –20 expected with simple spherical spreading. The coefficients for CPADist are the dB losses per km and correspond to a linear loss with distance such as is expected from absorption and scattering losses.

For the *CPA angle* (unnormalized), the regression results showed that, for higher angles (increasing above the horizontal), the A-weighted received sounds were stronger, other factors being equal. For example, for SEL-A in the best-fit model (Table 2.7), the sound from a vehicle passing overhead (90°) is predicted to be about 6 dB stronger than that from a vehicle at the same distance but at an angle of only 30° above the horizon.

The *wind component* along the CPA-to-receiver axis was not a significant variable in any of the "best" models (Table 2.7). Also, when all potential predictor variables were forced into the models, wind component had a non-significant coefficient in the model for each of the five sound level variables (Table 2.8). The coefficient is in the units dB/kt. We had expected that, after other factors were taken into account in the model, received level would be positively related to this wind component. The available evidence indicates there is no such relationship.

TABLE 2.7. Coefficients and nominal significance levels (*P*-values) of the best-fit regression models of sound measures vs. predictor variables; *n* = sample size; RMSE = root mean square error (units same as for sound measure examined); AIC = Akaike's Information Criterion; R^2 = coefficient of multiple determination; Intercept = y-intercept of the regression equation.

Variable	Peak (n = 84)	SPL-f (n = 84)	SPL-A (n = 80)	SEL-f (n = 84)	SEL-A (n = 80)	logDur-f (n = 84)	logDur-A (n = 80)
Other Large	-10.859	-11.018	-5.448	-4.598	-0.868	0.658	0.425
P-value	***	**	ns	*	ns	**	*
AGS	-10.856	-7.217	-16.970	-12.721	-22.067	-0.572	-0.549
P-value	***	*	***	***	***	**	**
RAM	-22.137	-27.138	-19.220	-22.068	-16.081	0.396	0.320
P-value	***	***	***	***	***	(*)	ns
CPADist	-6.661	-7.424	-13.453	-3.255	-9.206	0.435	0.294
P-value	***	***	***	*	***	**	**
logCPADist	-14.381	-13.153	-13.642	-15.757	-16.097	-0.312	-
P-value	***	***	***	***	***	(*)	
CPA_Angle	-	-	0.113	0.044	0.106	-	-
P-value			*	ns	**		
Wind	-	-	-	-	-	-0.019	-
P-value						ns	
R^2	0.723	0.662	0.752	0.807	0.845	0.452	0.401
RMSE	8.694	10.670	10.867	6.230	7.536	0.668	0.638
Intercept	139.983	126.990	113.945	117.160	107.008	-0.909	-0.499
AIC	369.097	403.509	388.385	314.017	329.834	-61.162	-67.012

Note: Vandals were used as a reference level for vehicle type. Wind component was considered as a potential predictor variable, but did not enter any of the regression equations as significant. *** for $P \leq 0.001$, ** for $0.001 < P \leq 0.01$, * for $0.01 < P \leq 0.05$, (*) for $0.05 < P \leq 0.1$, and ns (not-significant) for $P > 0.1$.

Sound Duration.—Sound duration, whether based on flat- or A-weighted data, was more strongly related to linear CPA distance than to logCPADist (Tables 2.7, 2.8). Duration increased as CPA distance increased. Vehicle type was also a predictor of duration. From longest to shortest duration, the order of the vehicles was "other large" vehicles (Terrier, Tomahawk, Arrow, SSST), RAMs, Vandals, and AGS vehicles. The positive coefficients for "other large" and RAM show that, after allowance for the distance effect, their sounds tended to persist longer than those for the Vandal. The negative coefficients for AGS vehicles show that AGS sounds were shorter-lasting than those of the Vandal. The wind component along the CPA-to-receiver axis was not a significant predictor of sound duration.

2.4.4 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 missile 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 are tabulated in Table 2.3 for the October 2003 to January 2005 launches, and in Tables 2.4 and 2.5 for August 2001 to August 2003.

The considerable effect of A-weighting as compared to flat weighting is evident by inspecting the Tables. A-weighted levels of ambient sound averaged 18 dB less (range 0–42 dB less) than flat-weighted levels. The measured A-weighted values, which averaged 46 ± s.d. 10 dB, were generally quite low, with the average being comparable to sound levels expected in quiet residential areas. Much of the

TABLE 2.8. Coefficients and nominal significance levels of regression equations that used all predictor variables to explain sound measures; *n* = sample size; RMSE = root mean square error (units same as for sound measure examined); AIC = Akaike's Information Criterion; R^2 = coefficient of multiple determination; Intercept = y-intercept of the regression equation.

Variable	**Peak (*n* = 84)**	**SPL-f (*n* = 84)**	**SPL-A (*n* = 80)**	**SEL-f (*n* = 84)**	**SEL-A (*n* = 80)**	**logDur-f (*n* = 84)**	**logDur-A (*n* = 80)**
Other Large	-11.289	-11.095	-5.444	-4.617	-0.869	0.637	0.459
P-value	***	**	ns	*	ns	**	*
AGS	-10.729	-7.104	-16.845	-12.788	-22.114	-0.572	-0.525
P-value	***	*	***	***	***	**	*
RAM	-20.982	-26.659	-18.925	-22.235	-16.192	0.435	0.271
P-value	***	***	***	***	***	(*)	ns
CPADist	-6.682	-7.531	-13.575	-3.174	-9.161	0.442	0.437
P-value	***	***	***	*	***	**	**
logCPADist	-14.002	-12.871	-13.362	-15.911	-16.202	-0.308	-0.271
P-value	***	***	***	***	***	ns	ns
CPA_Angle	0.052	0.018	0.122	0.039	0.103	0.002	-0.002
P-value	ns	ns	*	ns	**	ns	ns
Wind	0.163	0.102	0.100	-0.051	-0.037	-0.016	-0.014
P-value	ns	ns	ns	ns	ns	ns	ns
R^2	0.730	0.663	0.753	0.807	0.845	0.455	0.426
RMSE	8.706	10.791	10.925	6.263	7.585	0.670	0.638
Intercept	138.861	126.749	113.965	117.143	107.000	-0.962	-0.692
AIC	371.149	407.212	390.144	315.822	331.763	-59.565	-64.357

Note: Vandals were used as a reference level for vehicle type. *** for $P \le 0.001$, ** for $0.001 < P \le 0.01$, * for $0.01 < P \le 0.05$, (*) for $0.05 < P \le 0.1$, and ns (not-significant) for $P > 0.1$.

background sound was infrasonic energy in the 10–20 Hz band, probably mainly attributable to wind noise. When the 10–20 Hz components were excluded, broadband levels were typically 10 dB lower than those quoted in Tables 2.3 to 2.5 for the 10–20,000 Hz band.

2.5 Discussion and Summary

Seventeen vehicles of a variety of types were launched from SNI in Year 3 and early in Year 4, on dates ranging from 5 May 2004 to 27 January 2005. The sound levels received from SSST, RAM and AGS vehicles were comparable to those recorded previously (Holst and Greene 2003b). A new type of missile, the Arrow, was recorded for the first time.

Of the sounds recorded in Years 1–4, none exceeded 135 dBA re (20 µPa)^2·s SEL (Fig. 2.3–2.6), and the only cases that approached that level were close to the launcher (which, for most vehicles, was far from any pinnipeds). The 135 dBA value is the level at which pinnipeds might experience TTS, as noted by J. Francine, quoted in NMFS (2001:41837). Unpublished data indicate that the TTS threshold on an SEL basis may actually be around 129–131 dB re (20 µPa)^2·s for harbor seals, within their frequency range of good hearing (A. Bowles et al. pers. comm.; D. Kastak et al. pers. comm.; see also Kastak et al. 2004). The same two research teams have found that the TTS thresholds of California sea lions and elephant seals are higher. During launches from the Alpha Launch Complex (inland), the highest measured values on beaches were 129 dB re (20 µPa)^2·s SEL on a flat-weighted basis and 118 dBA SEL (Tables 2.3–2.5). Thus, during launches from the Alpha Complex, none of the recorded sound pressures appears to have been sufficiently strong to have induced even slight TTS. Somewhat higher levels would have occurred on beaches near the RAM launcher and (after June 2004) the AGS launcher. SEL measurements near those two launchers were as high as (respectively) 131 and 143 dB on a flat basis, and 130 and 131 dBA on an A-weighted basis (Tables 2.3–2.5). Chapter 4 discusses this topic further.

The monitoring work during the October 2003 to January 2005 period provided additional data on flight sounds from several types of missiles and targets. The data from launches during this period were combined with those from previous launches (August 2001 through August 2003) to provide the basis for a more comprehensive assessment of the flight sounds as a function of vehicle type, receiver location, and other factors.

The results showed that Vandals produced more sound than RAM and AGS vehicles, and on average tended to produce more sound than all "other large" vehicles launched from SNI. However, the levels from "other large" vehicles were variable and (on average) not much less than those from Vandals, other factors being equal. Levels from the SSST, in particular, were similar to those from Vandals. Received levels decreased significantly with increasing logCPADist and linear CPADist, as expected. Only A-weighted received sound levels increased with an increase in the angle above the horizon from recording site to the CPA. The CPA angle was included in the regression to account for possible differences in sound radiation depending on the vehicle aspect.

For the sound-level variables, the coefficient of the logCPADist term is the dB loss per tenfold increase in distance, and was calculated to be –13.2 to –16.1 in the "best" models. The coefficient would be –20 for pure spherical spreading (inverse square law spreading, as expected for unbounded space free of boundaries, absorption, or scattering). The "less-negative" coefficients for the sound level measures indicate that there were contributions to the received level from refraction, reflections, or multipath arrivals. The ground is a boundary as well as a medium for sound conduction. The sound probably travels to the microphone both in air and as a boundary wave along the earth-air interface.

Differences between the flat- and A-weighted sound measures reflect differences in the frequency distributions of the sound energy from the vehicles. For "other large" vehicles and RAMs, the difference with respect to Vandals decreased when A-weighting was applied, while for AGS vehicles, the difference increased. This means that, for the AGS vehicles, there was relatively more low- and/or high-frequency energy (sound at <1000 Hz or >6000 Hz). The one-third octave band spectra for AGS bear this out, indicating especially strong levels at frequencies <63 Hz. A-weighting strongly discounts that energy, giving large differences between flat- and A-weighted values (Fig. 2.5).

It is important to note that there is considerable variability in the measurements for situations that are supposedly similar. This is represented by rms error terms, in the regression models for sound level, between 6 and 11 dB (Tables 2.7, 2.8). The coefficients of determination, which indicate how much of the variability in the acoustic data is accounted for by the regression models, are never higher than about 0.85 (85 %). Thus, there is some unexplained variability. The conditions of every flight, especially meteorological, would need to be better documented in order to obtain better predictability. Atmospheric temperature-humidity profiles, which influence sound speed profiles, and wind speed and direction as a function of altitude, are all known to be important based on theory and other studies. Temperature inversions, in which temperature increases with increasing altitude, cause downward refraction of sound. Above a certain altitude, such inversions reverse, and at higher altitudes, sound waves are refracted upward and away from ground-based detectors. The development of temperature inversions is typically related to time of day, existing late at night and in the early morning, and then disappearing as the sun angle increases; marine fog layers are capped by temperature inversions.

In addition to the lack of data on vertical profiles of sound speed, various additional factors for which we have incomplete or no data are suspected to contribute to the variability in the measured data. For example, the available information about the vehicle trajectories is limited; we do not have specific information about the exact altitude of each vehicle at each point along its trajectory. Thus, our estimates of 3-D CPA distance and CPA angle are approximations. Also, for vehicles that employ a booster for the first brief period of flight, our analysis does not allow for the timing of booster burnout relative to the CPA time. Whether or not the booster is still operating when the missile is at its CPA location is likely to affect the received sounds.

Nonetheless, the results obtained to date provide much information about the levels and other characteristics of the sounds from the various types of missiles and targets launched from SNI, and about some of the factors that influence those sounds. This information is valuable in interpreting pinniped reactions, and as a basis for developing models of factors related to the variability in pinniped responses (see Chapter 3).

3. BEHAVIOR OF PINNIPEDS DURING MISSILE LAUNCHES

3.1 Introduction

A total of 13 launches occurred from the west end of SNI during October 2003 through October 2004 (Year 3), on 8 separate dates. One of the 13 launches was a dual launch of 2 vehicles within seconds of one another, so a total of 14 vehicles were launched. In addition, three launches took place on 27 January 2005 (Year 4). Specific information about each of those launches is given in Chapter 1. (Data from five additional launches in February–April 2005 have not yet been analyzed and are excluded from this chapter.) Chapter 2 documents the sounds measured at various sites on western SNI during each launch in the October 2003 through January 2005 period. Corresponding information concerning 12 launches during August 2002 to August 2003 (Year 1) and 19 launches during August 2001 through July 2002 (Year 1) was provided in previous reports (Lawson et al. 2002; Holst and Greene 2003a,b). The acoustic information from the earlier launches as well as the more recent 16 launches is summarized in Chapter 2. This chapter documents the behavioral reactions of pinnipeds exposed to the launch sounds, concentrating on the 16 recent launches but also considering data from the previous Year 1 and Year 2 launches.

Three species of pinnipeds are common on the beaches of SNI: California sea lion, harbor seal, and northern elephant seal. No other pinniped species were recorded during the monitoring work, either during the present monitoring period or during previous monitoring efforts since August 2001.

From May to July, vehicles flew high over haul-out sites occupied by molting harbor and elephant seals, as well as pupping/breeding California sea lions. During launches in August and September, there were relatively few pinnipeds ashore. That period does not coincide with the pupping season for any of the three pinniped species. The flight paths of the vehicles during that period were in proximity to haul-out sites occupied by non-breeding California sea lions and northern elephant seals. In January, vehicles flew over haul-out sites occupied by pupping/breeding northern elephant seals and non-breeding California sea lions. Non-breeding harbor seals were also hauled out near several of the vehicle flight paths.

No evidence of injury or mortality was observed on the day of any launch during the entire monitoring period (August 2001 through January 2005). However, on three occasions in Year 2, adult harbor seals were observed (on the videotape) to travel over pups when the adults were moving toward the water in response to a launch. These pups were momentarily startled, but then continued to move toward the water; they did not appear to be injured. On two occasions during Year 3 (October 2003 to October 2004), adult sea lions were seen moving over sea lion pups, but not in relation to the launches. No obvious injuries were noted.

In most cases, sea lion and elephant seal behavior returned to pre-launch states within minutes following the launches. In fact, most elephant seals demonstrated little or no reaction to the vehicle launches. Behavior as well as numbers of sea lions and elephant seals hauled-out several hours after the launches appeared similar to the behavior and numbers observed before launches. In contrast, harbor seals commonly left their haul-out sites to enter the water and did not return during the duration of the video-recording period. Data from monitoring during August 2001 to July 2002 showed 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 (Holst and Lawson 2002).

3.2 Field Methods

The launch monitoring program was based primarily on remote video recordings. Observations were obtained before, during, and after each vehicle launch. Remote cameras were essential because, during vehicle launches, safety rules prevent personnel from being present in many of the areas of interest. 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 how many species were hauled out within the presumed area of influence, and on the deployment of the three video systems used during each launch (Table 3.1, 3.2). During most launches, 2 or 3 species were monitored. However, only sea lions were monitored during the launches in September 2004, and only elephant seals were monitored during launches in January 2005 (Table 3.1).

For the combined pinniped and acoustic monitoring, the Navy usually attempted to obtain video and audio records from three locations at different distances from the flight path of the vehicle during each launch from SNI. Video data were generally obtained via two or three portable cameras that were set up temporarily at any site, plus a permanent ("fixed") camera that has been installed near Building 809. The latter fixed camera was not operational during the Year 2 launches but was used occasionally again from Year 3 onward. During most launches, one monitoring location was near the planned launch azimuth or the launcher itself; the other monitoring sites were some distance from the launch azimuth. Figure 3.1 and Appendix B show the monitoring locations relative to the launch azimuths for Year 3 and January 2005, and for Years 1 and 2, respectively. The monitoring locations varied from launch to launch.

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. To investigate the dose-response relationships, acoustic and pinniped response data from the present monitoring period are used along with corresponding data from previous monitoring during August 2001–August 2003 (see Lawson et al. 2002; Holst and Greene 2004a,b).

3.2.1 Fixed Camera

A permanent, fixed camera is installed in an elevated position at Building 809 at the west end of SNI (Fig. 3.1; Appendix B). This camera, designated "809 Camera", is situated on a metal tower overlooking Vizcaino Point (Fig. 3.2). The camera can be remotely zoomed, tilted, and panned by an observer stationed in a remote blockhouse (Building 127). Digital video data from this camera can be sent back to the blockhouse where they can be viewed on a large video monitor and recorded on large-format digital videotape. Video data from this camera can be recorded for any desired duration. This camera does not include a built-in microphone. The "809 Camera" was not operational during Year 2 launches, but was used again during Year 3 and onward.

3.2.2 Mobile Cameras

During the day of each launch, Navy biologists placed up to two portable Sony Hi-8 digital video cameras on tripods that overlooked haul-out sites (Fig. 3.1; Appendix B). Placement of the cameras was such that disturbance to the pinnipeds was minimal, and the cameras were set to record a focal subgroup within the haul-out aggregation for the maximum 4 hr permitted by the videotape capacity of

TABLE 3.1. Video data collected for California sea lions, northern elephant seals, and harbor seals during vehicle launches at San Nicolas Island, October 2003–January 2005 (Years 3–4). Multiple launches separated by minutes or hours are indicated by (x2) or (x3); dual launches separated by seconds are indicated by (d).

	Launch Date (m/d) 2004								Launch Date 2005
Video Recording Location	**05/05 RAM (d)**	**05/18 SSST**	**06/03 AGS (x3)**	**07/26 AGS (x2)**	**07/29 Arrow**	**08/26 Arrow**	**08/27 SSST**	**09/22 RAM (x3)**	**01/27 AGS (x3)**
California Sea Lion									
Dos Coves South	x	-	x	x	x	x	x	x	-
Near 809 Camera	-	-	x[a]	x	x	-	-	x[c]	-
Vizcaino Point	-	-	-	-	-	x	x	x[b]	-
Bachelor Beach North	-	-	-	x	x	-	-	-	-
Northern Elephant Seal									
Bachelor Beach North	x	-	-	x	x	-	-	-	x
Bachelor Beach South	x[a]	-	-	-	-	-	-	-	x
Redeye I	-	x		-	-	-	-	-	x
Dos Coves South	-	-	x	-	-	-	-	-	-
Harbor Seal									
Harbor Seal Overlook	-	x	x	-	-	-	-	-	-
Pirates Cove	-	x	-	-	-	-	-	-	-
Phoca Reef	-	-	-	-	x	x	x[b]	-	-

[a] No observations or behavioral data were obtained from the recording of northern elephant seals at Bachelor Beach South on 5 May nor from the recording of sea lions near 809 Camera at 11:31 on 3 June.
[b] No pinnipeds on beach at time of launch.
[c] The first launch was monitored at "The Y"; the following two launches were monitored near 809 Camera.

the mobile cameras. The entire haul-out aggregation at a given site was not recorded, as the wide-angle view that would have been necessary to encompass an entire beach would not have allowed detailed behavioral analyses. It was more effective to obtain a higher-magnification view of a sample of the animals at the site. 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 missile passed, but were uncalibrated and not of sufficient quality to provide launch sound information.

3.2.3 Wagoncam

A "wagoncam" (or Camera Cart) was also used on several occasions (Fig. 3.3). A wagoncam, unlike the "mobile cameras" can transmit its signal back to a centralized location where it is recorded. In this case, the signal from the wagoncam was recorded at Building 127. The wagoncam does not include a built-in microphone. During the day of each launch, Navy biologists placed up to two wagoncams at locations overlooking haul-out sites. 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 analyses.

TABLE 3.2. Video data collected for California sea lions, northern elephant seals, and harbor seals during vehicle launches at San Nicolas Island, August 2001–August 2003 (Years 1–2). Multiple launches are indicated by (x2) and dual launches are indicated by (d).

Video Recording Location	Launch Date (m/d) 2001					2002													2003						
	08/15 (x2)	09/20 (x2)	10/05	10/19	12/19	02/14	02/22 (x2)	03/06	05/01 (x2)	05/08	06/19	06/21 (d)	06/26 (x2)	07/18	08/23	11/18 (d)	12/10	12/18 (x2)	01/24	03/14	03/16	04/04 (d)	06/04	06/26	07/28
California Sea Lion																									
Dos Coves North	x	x	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-
Dos Coves South	x	x	-	-	-	-	-	-	-	-	-	x	-	-	x	x	-	-	-	-	-	-	-	-	x
At or near 809 Camera	x	x	x	x	x	-	-	x	x	x	x	-	x	-	-	-	-	-	-	-	-	-	x	x	x
The "Y"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		x	-
Bomber Cove	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-
Bachelor Beach North	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	x
Redeye Beach	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-
Sea Lion Cove	-	x	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vizcaino Point	-	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern Elephant Seal																									
Bachelor Beach North	-	x	-	-	-	x	x	-	-	-	-	x	-	-	x	x	x	-	-	-	-	-	-	-	x
Bachelor Beach South	-	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-
Dos Coves South	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	x	-	-	-	-	-	-
Pirates Cove	-	-	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redeye Beach	-	-	-	-	-	x	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redeye I	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sea Lion Cove	-	-	-	-	-	-	-	-	-	x	--	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Harbor Seal																									
At or near 809 Camera	x	x	x	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phoca Reef	-	-	x	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-
Redeye Beach	-	-	-	-	-	-	-	x	-	x	-	-	x	-		-	-	-	-	-	-	-	-	-	-
Sea Lion Cove	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corral Harbor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		x	-	-	-	-
Pirates Cove	-	-	-	-	-	-	-	x	x	x	-	-	-	-	-	-	-	-	-	x	x	-	-	-	-
Phoca Point	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-
No Name Cove	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x		-	-
Sheephead Ranch	-	-	-	-	-	-	-	-	-	--	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-

Note: Some video data were lost or could not be analyzed due to technical problems; these data are not included in the table. On 20 Sep. 2001, sea lions were observed at 809 Camera, but the video quality was inadequate to provide quantitative data. On 19 Dec. 2001, segments of the video for elephant seals at Bachelor Beach were lost. On several occasions (19 Dec. 2001, 22 Feb. 2002, 1 May 2002, and 14 March 2003), cameras were set up at harbor seal haul-out sites, but no seals were seen during the launch. Detailed data could not be extracted from the video recording of elephant seals at Bachelor Beach North on 18 Nov. 2002 due to poor video quality. Two launches occurred on 18 Dec. 2002, but all cameras failed. Two separate harbor seal sites were monitored at the same beach (Sheephead Ranch) on 4 June 2003.

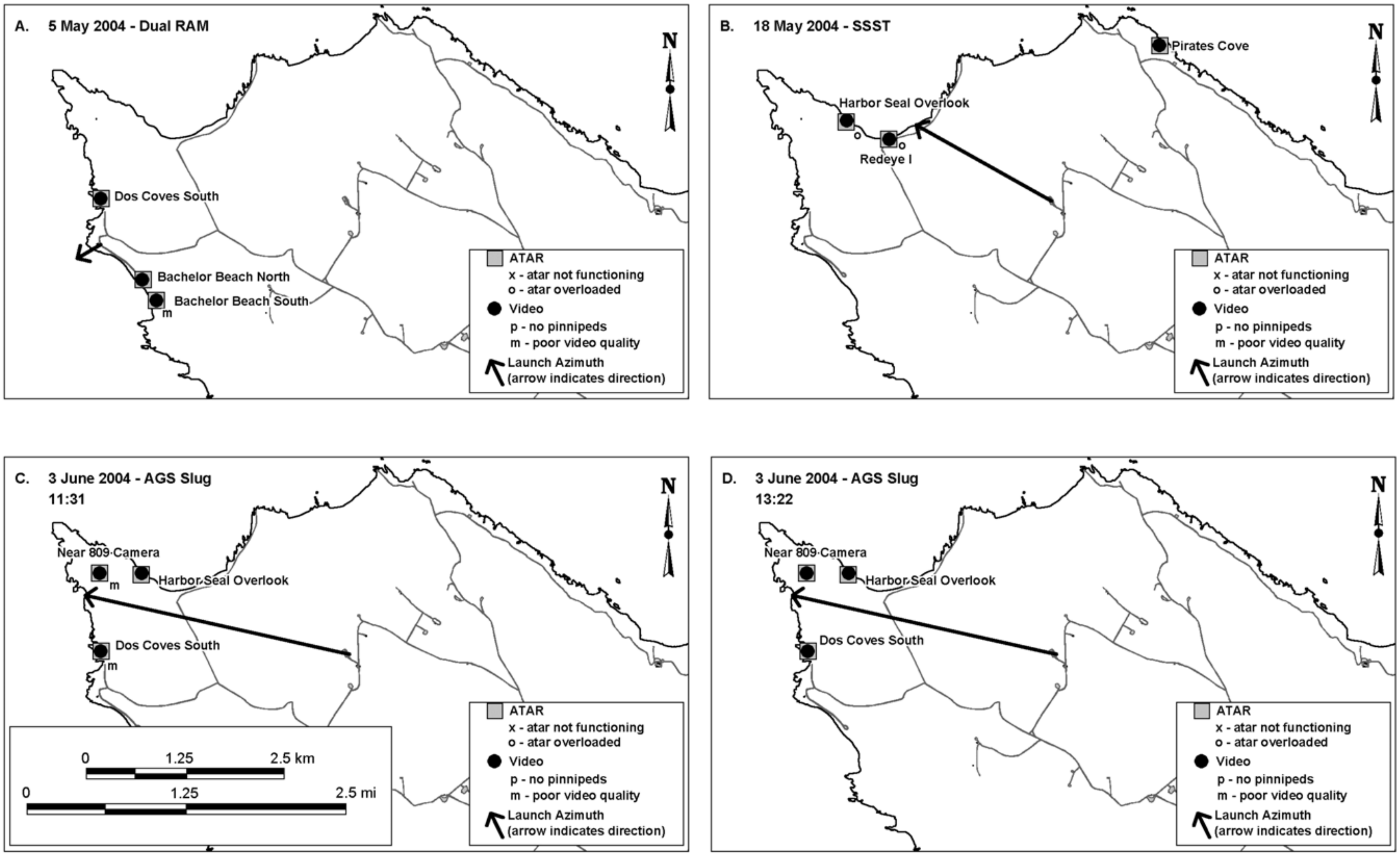

FIGURE 3.1. Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at San Nicolas Island in Year 3 (October 2003 to October 2004) and in early Year 4 (January 2005).

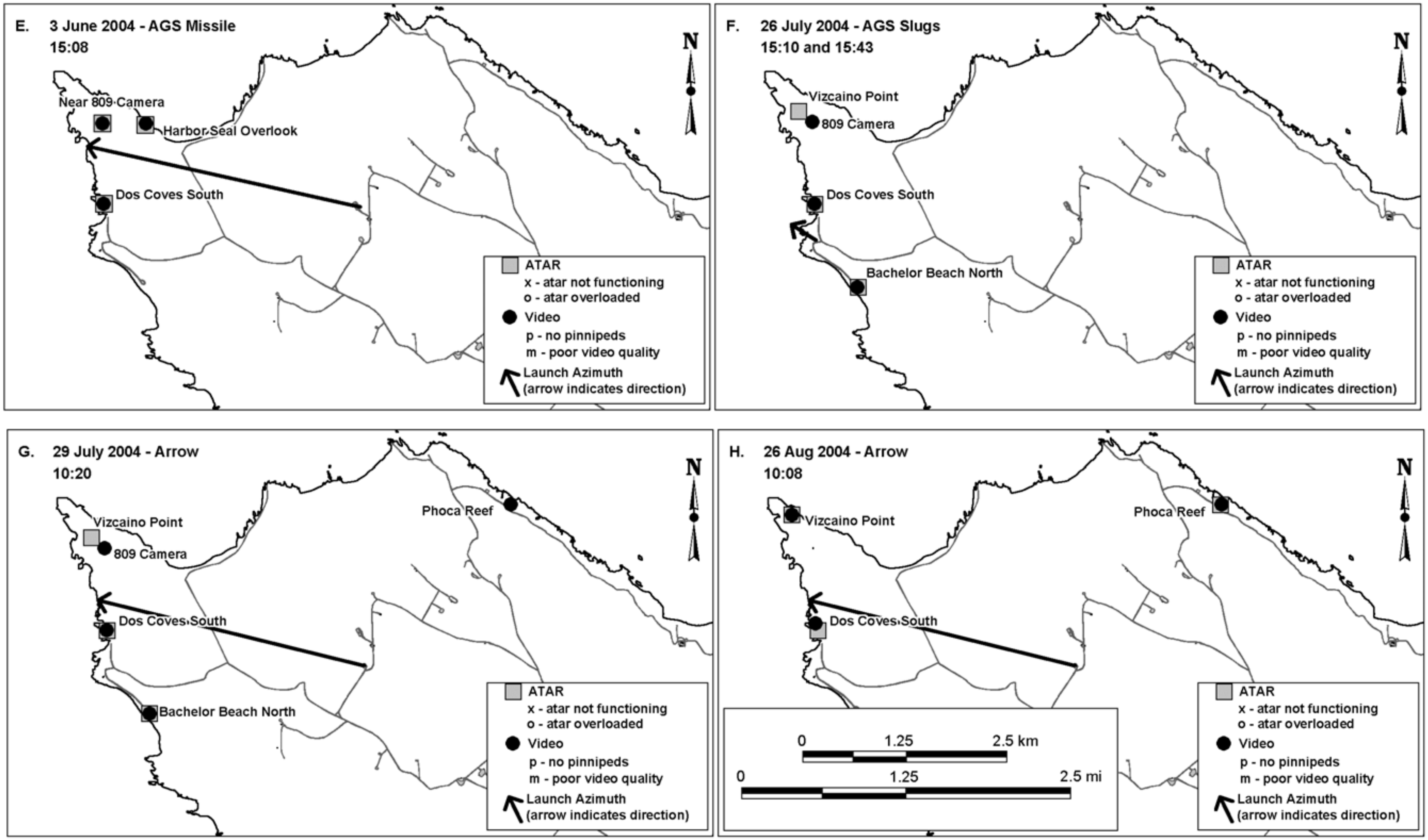

Figure 3.1. (cont'd). Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at San Nicolas Island in Year 3 (October 2003 to October 2004) and in early Year 4 (January 2005).

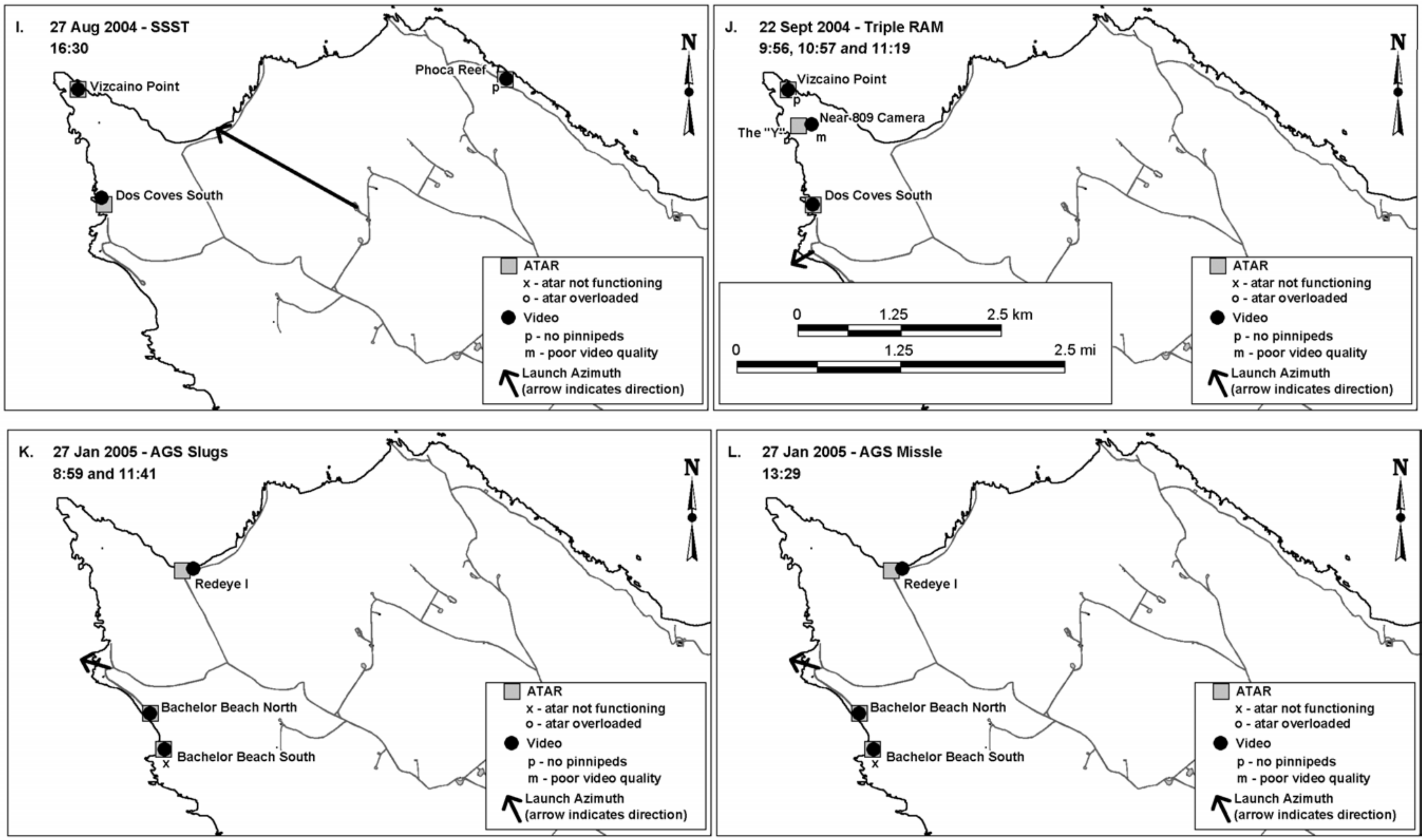

FIGURE 3.1. (cont'd). Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at San Nicolas Island in Year 3 (October 2003 to October 2004) and in early Year 4 (January 2005).

FIGURE 3.2 View of the permanent fixed video camera at Building 809. This camera can be remotely zoomed, tilted, and panned. (Photograph by U.S. Navy)

FIGURE 3.3. View of a wagoncam, which unlike other portable video cameras, can transmit its signal back to a centralized location where it is recorded. (Photograph by U.S. Navy)

3.2.4 Visual Observations

Navy biologists made direct visual observations of the pinniped groups prior to deployment of the cameras and ATARs. 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. For sites where harbor seals were monitored, the observers returned to the monitoring sites for follow-up monitoring ~2 hr after the launch or the following day to note the status of pinnipeds at the haul-out site (e.g., had the numbers of pinnipeds changed? Was there obvious evidence of recent injury or mortality?). Most video recordings of harbor seals showed that haul-out sites were usually occupied by only a few seals or void of seals for minutes or even hours following launches.

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, for analysis. Subsequent to the launch, biologists experienced in this type of analysis reviewed and coded the video data on the DVD-ROMs as they were played back to a high-resolution color monitor. The DVD player was connected to the monitor using a high-quality S-video output lead. The player had a high-resolution freeze-frame capability. A jog shuttle was used to facilitate distance estimation, launch timing, and characterization of behavior.

The videotaped data covering several hours before, during, and up to 2 hr after each launch were reviewed in order to document the types and numbers of pinnipeds present, and the nature of any overt responses to the launch.

3.3.1 Proportions of Pinnipeds Responding

The proportions of pinnipeds that moved or entered the water were determined from each video recording by observing the entire group of animals hauled out at the monitoring site during a launch. The percentage of animals that moved included all animals that traveled along the beach or entered the water, irrespective of how far or how long the movement lasted. The percentage of pinnipeds that entered the water included all individuals that left the haul-out site to enter the water during the launch.

3.3.2 Specific Behavioral Observations

Quantitative observations of pinnipeds were made based on two 1-min samples of each video recording from the day of each launch. The objective was to determine whether behavioral changes attributable to the launches persisted for more than a few minutes. (Following NMFS [2002], subtle behavioral reactions that persisted for only a few minutes were considered unlikely to have biologically significant consequences for the pinnipeds.) Data were recorded for the 1-min interval immediately preceding the launch and for a 1-min period starting 10 min after the launch (i.e., 10–11 min after the launch). A focal subgroup was chosen from the group of clearly visible animals, and individuals were observed. Only individuals that were easily seen throughout the entire sample period were chosen as focal animals. More specifically, the variables transcribed from the videotapes included

1. composition of the focal subgroup of pinnipeds (numbers by sex and age class);
2. description and timing of disruptive event (vehicle launch); this included documenting the occurrence of the launch and whether launch noise was evident on the video record's audio channel (if present);

3. movements of pinnipeds, including number and proportion moving, direction and distance moved, pace of movement (slow or vigorous);
4. interaction type: agonistic, mother/pup, play, or copulatory sequence types; and
5. interaction distance: an estimate of the minimum distance [cm] between interacting pinnipeds' bodies, based on the known size of morphological features [body or head length] or comparison with adjacent substratum features of known size.

3.3.3 Circumstances of Observations

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

1. study location;
2. local time;
3. composition of the focal subgroup of pinnipeds (numbers by sex and age class);
4. vehicle type (e.g., Vandal, AGS, RAM);
5. launch type (dual, single, double, triple);
6. season (e.g., breeding, molting, pupping);
7. 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);
8. substratum slope (0–15º, >15º, or irregular), estimated from the video records;
9. weather, including an estimate of wind strength and direction, and presence of precipitation; these data were made available by the Navy meteorological unit;
10. horizontal visibility—the average horizontal visibility (in meters) around the focal subgroup of pinnipeds, as determined by meteorological conditions and/or physical obstructions; this was estimated by determining what the farthest visible object was relative to the interacting pinnipeds, as evident from the known positions of local objects and accounting for obstructing terrain; and
11. tide state—exact time for local high tide was determined from relevant tide tables.

For each pinniped monitoring site, several parameters were calculated for each vehicle launch: the 3-D distance from the monitoring site to the CPA of the vehicle (in km), the angle above the horizon from recording site to the CPA (in degrees), and the wind component along the axis from the CPA to the monitoring site (in kt).

3.3.4 Statistical Analyses

For all analyses, data from August 2001–January 2005 were combined. The two response variables analyzed were "% that moved" and "% that entered water" (% water). Scatter plots and Spearman Rank Order Correlations were used to examine the relationships of these variables to 3-D CPA distance and the measured vehicle sound (SEL), separately by vehicle type and pinniped species. One-sided *P*-values are appropriate, since the direction of the effect was predictable.

To further investigate the effects of vehicle launches on pinniped behavior while allowing for various potentially confounding factors, we fitted logistic regression models (Ramsey and Schafer 2002) to the same two measures of behavioral response, separately for the three pinniped species. All logistic regression equations were of the form

$$\pi = \frac{\exp\left(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_k x_k\right)}{1 + \exp\left(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_k x_k\right)} \qquad [3]$$

where π was the proportion of a given pinniped species (harbor seal, sea lion, elephant seal) that moved or entered the water after a launch, $x_1, ..., x_p$ were a set of predictor variables, and $\beta_0, \ldots, \beta_p$ were parameters to be estimated. A "best" set of predictor variables to include in the logistic model was selected by fitting all possible combinations of predictor variables (without interactions) and ranking the resulting models by AIC. AIC for the logistic models was defined as

$$AIC = -2\ln\left(L_M\right) + 2K \qquad [4]$$

where K was the number of parameters in the model, and L_M was the value of the likelihood function for the fitted model. The model with minimum AIC among those fitted was chosen as our "best" model given the data and the set of models considered.

In standard logistic regression analysis, individual "successes" (here, movement or entering the water) and "failures" (here, no movement or not entering the water) are assumed to be independent of one another and follow a binomial distribution. We, however, could not assume that an individual animal's response to the launch was independent of other animals in the same field of view. For the data, it was reasonable to assume that the lack of independence in behavior displayed by individual animals manifested itself as a multiplicative increase in variance. In other words, it was reasonable to assume that the largest deleterious effect of non-independence was an increase in the underlying variance of our proportions over that predicted by the binomial distribution. This assumption was reasonable because such an increase would occur if, for example, animals reacted in clusters (McCullagh and Nelder 1989). We envision animals reacting similarly within clusters, but dissimilarly between clusters. Under this assumption, a multiplicative change in variance over and above that predicted by the binomial distribution (i.e., overdispersion) was estimated and used to adjust coefficient *P*-values. Overdispersion parameters for our logistic models were estimated by including all predictor variables except measured sound levels in the model [3], and computing the resulting Pearson χ^2 goodness-of-fit statistic. The estimated overdispersion parameter was then set equal to the square root of Pearson's χ^2 for all models involving that species. All subsequent model runs for a particular species, including model selection, included the species' estimated overdispersion parameter. *P*-values for individual parameters were calculated by dropping the variable from the model, observing the change in total model fit (i.e., deviance), dividing the change in model fit by the overdispersion parameter, and comparing the result to a χ^2 distribution (McCullagh and Nelder 1989). All calculations were carried out using SAS Proc Logistic and SAS Proc GENMOD (SAS Institute 2000).

The total number of observations available for modeling varied depending on response (% moved vs. % water) and pinniped species. Two separate analyses were completed for each combination of response variable and pinniped species, one considering sound levels (SEL-A) and one that did not consider sound levels. The sample size was smaller when SEL-A was considered, as sound measurements were not available for all times and locations where pinniped responses were observed In all, 2 (responses) x 3 (species) x 2 (variable sets) = 12 models were fitted. Predictor variables considered in the analysis were as follows: (1) vehicle type, (2) $\log_{10}$ of 3-D distance from recording site to CPA [logCPADist; km], (3) angle above horizon from recording site to CPA of vehicle [CPA_Angle; in degrees], (4) wind component along CPA-to-pinnipeds axis [Wind], (5) whether or not a previous launch had occurred the same day [Launch], (6) whether or not the launch occurred during pupping/breeding season [Season], and (7) measured A-weighted sound exposure level near the pinnipeds [SEL-A]. Season was designated by codes "1" for pupping/breeding and "0" for non-pupping/breeding. Launch was coded as either "0" for a single or dual launch, or the first launch in a multiple-launch series), or "1" for a launch preceded by another on the same day (i.e., the second or third launches in a widely-spaced series). The other predictor variables were defined as in Chapter 2 (§2.3.4). Thus, vehicle type was categorized as (a) Vandal; (b) "other large" vehicle, including Terrier, Tomahawk, Arrow, and SSST; (c) AGS, and (d) "other small" vehicle, i.e., RAMs. The 3-D CPA distance, CPA_Angle, and wind component were calculated as for the acoustic data (see §2.3.4).

Vehicle type was coded as a discrete variable with four levels: 1 = "other large" (Arrow, SSST, Tomahawk, and Terrier), 2 = AGS missile or AGS slug, 3 = "other small" (RAM), and 4 = Vandal. Level 4 (Vandal) was used as the reference level. For each species, the response variables were the proportion of animals in the video's field of view that moved, and the proportion of animals that entered the water after each launch. Without sound, a total of 63 models were fitted for each response-species combination. With sound, a total of 127 models were fitted for each response-species combination

All models that considered SEL-A in the pool of potential predictor variables suffered from low sample sizes. In addition, several models, particularly those involving elephant seals, suffered from partial incomplete separation and would not converge. Partial incomplete separation occurred when none of the animals responded to multiple vehicle flights that all occurred under similar values of the predictor variables. For example, if no harbor seals ever responded to any launches of an AGS missile or slug, the model would suffer from partial incomplete separation. Partial incomplete separation was not a result of inadequate data or modeling, but was largely caused by low sample sizes. In cases when incomplete separation prevented a model from being estimated, the models were either abandoned (e.g., elephant seal models with sound), or reduced until separation of responses was achieved and the models converged.

3.4 Descriptions of Pinniped Behavior During Recent Launches

The following subsections provide overall descriptions of pinniped responses during each launch in the October 2003 through January 2005 period, descriptions of any notable reactions, and quantitative descriptions of pinniped behavior and distribution prior to and following the launches. Corresponding descriptions for August 2001–July 2002 (Year 1) and for August 2002–August 2003 (Year 2) were provided by Lawson et al. (2002) and by Holst and Greene (2003a,b), respectively. The Year 1 and Year 2 results are summarized in Appendix D.

Video recordings of pinniped behavior during launches in the October 2003–January 2005 period were collected for California sea lions on seven dates, for northern elephant seals on six dates, and for harbor seals on five dates (Table 3.1). During that period, sea lions were monitored at four different locations (25 site–launch combinations monitored), elephant seals were observed at four different locations (17 occasions), and harbor seals were monitored at three locations (7 occasions). At some monitoring sites, no pinnipeds were hauled out at the time of the launch (see Table 3.1, 3.2; Fig. 3.1; Appendix B). The video recordings generally provided data on the responses of a sample of the total pinnipeds present on a given beach. The total number of pinnipeds hauled out at several sites could not be determined due to intervening topography, reduced horizontal visibility, or limitations of video resolution.

3.4.1 Dual RAM Launch, 5 May 2004

A dual RAM launch occurred from the Building 807 Launch Complex, with a launch azimuth of 240º and an initial elevation angle of 8º. The two vehicles were launched sequentially, ~12 s apart. California sea lions were videotaped at Dos Coves South, ~1904 ft (571 m) north of the CPA, and elephant seals were observed at Bachelor Beach North, ~2273 ft (682 m) southeast of the CPA (Table 3.1; Fig. 3.1A). Another recording of elephant seals was attempted slightly farther away (~3200 ft or 976 m), at Bachelor Beach South, but the video quality during the launch was too poor for observations. In all three cases, the CPA distance was the distance from the launcher (Fig. 3.1A). Launch sound was audible on the audio track of the video recordings at Dos Coves South and at Bachelor Beach North. There was no sound track on the video recording at Bachelor Beach South, where a wagoncam was used. Launch sounds were recorded quantitatively (via ATARs) at Dos Coves and Bachelor Beach North (Table 2.2; Fig. 3.1A).

California Sea Lions.—About 100 individuals were monitored at Dos Coves South, although more sea lions were likely present outside the field of view of the camera. Prior to the launch, there was movement on the beach, mainly by juveniles. During the first launch 80–90% of the animals looked up but only a few (three to four) animals moved, by less than 3 ft (1 m). Sea lions reacted more vigorously to the second launch. Although most animals still merely looked up, 12 animals moved 3–7 ft (1–2 m), and one sea lion entered the water. Within 1–2 min after the launch, most sea lions had settled again, although several juveniles were moving around on the beach (Table 3.3). However, this behavior was also observed prior to the launch.

Northern Elephant Seals.—Groups of juvenile elephant seals were videotaped at Bachelor Beach North. Around 76 seals were observed; 60 were lying on the sand and cobble, and 16 animals were in the water. A thousand or more elephant seals were present on the beach but outside the field of view of the camera. Just prior to the launch, there was movement by seals on the beach. During the first launch, all focal animals looked up, but none moved. During the second launch, all focal seals looked up, 5 seals moved 3–7 ft (1–2 m), and one seal that was already situated close to the water (~6 ft or 2 m away) entered the water (Table 3.4). Those remaining on the beach settled within 10 s.

3.4.2 SSST Launch, 18 May 2004

An SSST was launched from the Alpha Launch Complex, with an azimuth of 300º and an elevation angle of 18º. A video recording of northern elephant seals was made at Redeye I, 0.6 mi (1 km) from the CPA along the trajectory. Video recordings of harbor seals were obtained at Harbor Seal Overlook, 0.8 mi or 1.3 km from CPA, and at Pirates Cove, 1.4 mi (2.4 km) from the launcher (Table 3.1; Fig. 3.1B). Launch sound was audible on the audio track of the video recordings at Pirates Cove and Harbor Seal Overlook. A wagoncam, which did not have a microphone, was used at Redeye I. Launch sounds were also recorded via ATARs at all three sites (Tables 2.2 and 2.3 in Chapter 2). The signals received at Harbor Seal Overlook and at Redeye I were clipped but strong. Launch sounds received at Pirates Cove were weaker.

Northern Elephant Seals.—Eight seals were observed at Redeye I, although more seals were likely present outside of the field of view of the camera. During the launch, all seals looked up and one seal moved 1.5 ft or 0.5 m (Table 3.4). The seals settled within 10 s after the launch.

TABLE 3.3. Details of vehicle launches, SEL, and ***California sea lion*** reactions at SNI during October 2003–January 2005. A dual RAM launch occurred on 5 May 2004, a double launch occurred on 26 July 2004, and triple launches took place on 3 June 2004 and 22 September 2004. RAMs were launched from the Building 807 Launch Complex, as were AGS vehicles on 26 July 2004. All other vehicles were launched from the Alpha Launch Complex. Times are local time.

Launch Date	Launch Time	Vehicle Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	3-D CPA distance (m)	SEL [dB re $(20\ \mu\text{Pa})^2\cdot$s] flat-weighted/A-weighted	Behavioral Reaction of Animals to Launch
5 May 04	11:46	Dual RAM	240°	8° / 50 ft	Dos Coves South[n]	571	93/85-86	~100 individuals monitored; during first launch, most animals (80–90%) looked up but only ~4% moved (<1 m); during second launch ~12% moved (1-2 m) and 1 entered water; settled within minutes
3 June 04	11:31	AGS Slug	282°	50° / 4500 ft	Dos Coves South[s]	1325	98/78	35 individuals monitored; no overt reaction to launch
“	13:22	AGS Slug	282°	50° / 4500 ft	Dos Coves South[s]	1325	94/73	50 monitored; most (80–90%) looked but none moved
“	15:08	AGS Missile	282°	50° / 4500 ft	Dos Coves South[s]	1325	98/73	40 sea lions monitored; did not show any reaction
“	11:31	AGS Slug	282°	50° / 4500 ft	Near 809 Camera[n]	1248	103/89	60 animals monitored; all startled and scattered. 50% of animals moved at least 20–30 m, whereas others moved short distances of only several meters
“	13:22	AGS Slug	282°	50° / 4500 ft	Near 809 Camera[n]	1248	103/88	30 sea lions monitored; most (80–90%) were startled but none moved
“	15:08	AGS Missile	282°	50° / 4500 ft	Near 809 Camera[n]	1248	102/75	31 monitored; most (80–90%) were startled and 50% moved in response to the launch

[n] monitoring site located north of the launch azimuth.
[s] monitoring site located south of the launch azimuth.

TABLE 3.3. Continued…

Launch Date	Launch Time	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-weighted/A-weighted	Behavioral Reaction of Animals to Launch
26 July 04	15:10	AGS Slug	300°	50° / 4500 ft	Dos Coves South^n	441	112/88	100 monitored; 40% moved and 30 of those likely entered water; settled within 2 min
"	15:10	AGS Slug	300°	50° / 4500 ft	809 Camera^n	1442	98/61	60 monitored; all looked but none moved; 7 entered field of view of camera
"	15:10	AGS Slug	300°	50° / 4500 ft	Bachelor Beach North^s	772	101/82	26 monitored; all moved and 73% entered water; settled within 2 min
"	15:43	AGS Slug	300°	50° / 4500 ft	Dos Coves South^n	441	114/90	100 monitored; 60% moved and 25 of those entered water; settled within 2 min
"	15:43	AGS Slug	300°	50° / 4500 ft	809 Camera^n	1442	98/58	60 monitored; all looked and 2 moved <5 m; settled within 30 s
"	15:43	AGS Slug	300°	50° / 4500 ft	Bachelor Beach North^s	772	103/82	22 monitored; all moved and 41% entered water; settled within 2 min
29 July 2004	10:20	Arrow	385°	90°/ 7000 ft	Dos Coves South^s	1783	100/87	53 were monitored; some looked but none moved
"	10:20	Arrow	385°	90°/ 7000 ft	809 Camera^n	1963	99/83	60 monitored; most looked and 3 moved, but none entered the water
"	10:20	Arrow	385°	90°/ 7000 ft	Bachelor Beach North^s	1821	102/92	40 monitored; all moved down beach (10–15 m) and likely entered water
26 August 04	10:08	Arrow	385°	90°/ 7000 ft	Dos Coves South^s	1791	98/87	30 monitored; all moved (up to 10 m) but none entered the water; settled within 2 min
"	10:08	Arrow	385°	90°/ 7000 ft	Vizcaino Point^n	2262	96/82	40 monitored; 24 of 40 moved 2–8 m and 40% (16 of 40) entered the water; settled within 1 min

^{n} monitoring site located north of the launch azimuth.
^{s} monitoring site located south of the launch azimuth.

TABLE 3.3. Continued…

Launch Date	Launch Time	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-weighted/A-weighted	Behavioral Reaction of Animals to Launch
27 August 04	16:30	SSST	300°	18° / 3300 ft	Dos Coves South[s]	1892	114/96	12 monitored; all 12 entered the water and 48 additional animals entered the field of view of the camera
“	16:30	SSST	300°	18° / 3300 ft	Vizcaino Point[b]	1614	117/100	30 monitored; all moved and 83% entered the water; remaining sea lions settled within 1 min
22 Sept. 04	9:56	RAM	240°	10° / 50 ft	Dos Coves South[n]	582	97/91	25 monitored; 56% moved 5–10 m, others got up but did not move farther; settled within 30 s
“	10:57	RAM	240°	10° / 50 ft	Dos Coves South[n]	582	96/90	1 monitored; got up but did not move farther; settled within 1 min
“	11:19	RAM	240°	10° / 50 ft	Dos Coves South[n]	582	95/87	1 monitored; looked and settled back to resting within 30 s
“	9:56	RAM	240°	10° / 50 ft	The “Y”[n]	1568	87/73	17 monitored; all moved out of the field of view of the camera
“	10:57	RAM	240°	10° / 50 ft	Near 809 Camera[n]	1568	84/65	40 monitored; 88% entered the water and 12% (5 of 40) looked but did not move; settled within 30 s
“	11:19	RAM	240°	10° / 50 ft	Near 809 Camera[n]	1568	84/64	25 monitored; 80% moved and 15 of those entered the water; settled within 30 s

[n] monitoring site located north of the launch azimuth.
[s] monitoring site located south of the launch azimuth.
[b] monitoring site below launch azimuth.

TABLE 3.4. Details of vehicle launches, SEL, and ***northern elephant seal*** reactions at SNI during October 2003–January 2005. A dual RAM launch occurred on 5 May 2004, a double launch occurred on 26 July 2004, and triple launches took place on 3 June 2004 and 27 January 2005. RAMs were launched from the Building 807 Launch Complex. AGS slugs and missiles were launched from the Alpha Launch Complex until 3 June 2004; subsequent launches occurred from the Building 807 Complex. All other vehicles were launched from the Alpha Launch Complex. Times are local time.

Launch Date	Launch Time	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-weighted/A-weighted	Behavioral Reaction of Animals to Launch
5 May 04	11:46	Dual RAM	240°	8° / 50 ft	Bachelor Beach North[s]	682	96-97/90-91	~76 monitored; during the first launch, all looked up, but none moved; during the second launch, all seals looked up, 7% moved (1–2 m), and 1 seal entered the water; settled within 10 s
18 May 04	12:40	SSST	300°	18° / 3300 ft	Redeye I[s]	1045	>119/>103	8 were observed; all seals looked up during launch and 1 seal moved 0.5 m; seals settled within 10 s after launch
3 June 04	11:31	AGS Slug	282°	50° / 4500 ft	Dos Coves South[s]	1349	98/78	4 seals monitored; no overt reaction to launch
“	13:22	AGS Slug	282°	50° / 4500 ft	Dos Coves South[s]	1349	94/73	40 seals monitored; only a few (5–10) looked up during launch; settled within 10 s after launch; others showed no reaction
“	15:08	AGS Missile	282°	50° / 4500 ft	Dos Coves South[s]	1349	98/73	40 seals monitored; no overt reaction
26 July 04	15:10	AGS Slug	300°	50° / 4500 ft	Bachelor Beach North[s]	764	101/82	4 monitored; all looked up but did not move
“	15:43	AGS Slug	300°	50° / 4500 ft	Bachelor Beach North[s]	764	103/82	4 monitored; 3 seals looked up; one moved ~2 m; settled within 30 s
29 July 04	10:20	Arrow	385°	90°/ 7000 ft	Bachelor Beach North[s]	1821	102/92	3 monitored; 1 moved 1 m, and other 2 looked; settled within 30 s

[s] monitoring site was located south of the launch azimuth

TABLE 3.4. Continued…

Launch Date	Launch Time	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-weighted/A-weighted	Behavioral Reaction of Animals to Launch
27 Jan. 05	08:59	AGS Slug	287°	50° / 4500 ft	Redeye I[n]	1597	91/57	15 monitored; no reaction
"	11:41	AGS Slug	287°	50° / 4500 ft	Redeye I[n]	1597	90*	30 monitored; no reaction
"	13:29	AGS Missile	287°	50° / 4500 ft	Redeye I[n]	1597	90/50	30 monitored; no reaction
"	08:59	AGS Slug	287°	50° / 4500 ft	Bachelor Beach North[s]	746	103/80	50 monitored; all startled and looked; 4% (2 males) may have moved 1–2 m in response to the launch; settled within 30 s
"	11:41	AGS Slug	287°	50° / 4500 ft	Bachelor Beach North[s]	746	101/77	40 monitored; all looked but none moved
"	13:29	AGS Missile	287°	50° / 4500 ft	Bachelor Beach North[s]	746	101/76	50 monitored; 10 or so looked, others showed no reaction
"	08:59	AGS Slug	287°	50° / 4500 ft	Bachelor Beach South[s]	1206	Launch sounds audible on video recording	100 monitored; all looked and 3 moved ~1 m, but did not enter water
"	11:41	AGS Slug	287°	50° / 4500 ft	Bachelor Beach South[s]	1204	Launch sounds audible on video recording	90 monitored; most looked and 3% moved by 1–2 m
"	13:29	AGS Missile	287°	50° / 4500 ft	Bachelor Beach South[s]	1204	Launch sounds audible on video recording	90 monitored; most looked and 1 moved by ~1 m

[s] monitoring site was located south of the launch azimuth
* A-weighted SEL not available.

Harbor Seals.—At Pirates Cove, five seals were observed during the launch. During the launch, all seals moved into the water, which was 3–9 ft (1–3 m) from the seals' original locations (Table 3.5). There were no seals on the beach for the remainder of the video recording period (1 hr after the launch). Observations of 21 harbor seals were made at Harbor Seal Overlook. All seals entered the water during the launch. Harbor seals started hauling out again at the same site ~25 min after launch. The following day, harbor seals were also hauled out at Harbor Seal Overlook.

3.4.3 Triple AGS Launch, 3 June 2004

Two AGS slugs and one AGS missile were launched from the Alpha Launch Complex, with an azimuth of 282º and a 50º elevation angle. The two slugs were launched sequentially, 1 hr 51 min apart, followed by the AGS missile 1 hr 46 min later. During all three launches, a video recording of harbor seals was obtained at Harbor Seal Overlook (0.7 mi or 1.1 km north of CPA), and California sea lions were monitored at Dos Coves South and near 809 Camera, both located ~0.8 mi (1.3 km) south and north, respectively, from the CPA. Elephant seals were monitored during all three launches at Dos Coves South. At Dos Coves South, the video quality was poor (lens foggy) for the recording of sea lions and elephant seals during the first AGS launch at 11:31; video quality for the subsequent launches at 13:22 and 15:08 was fair. Near 809 Camera, some observations of sea lions could be made during the launch of the first AGS slug at 11:31, but no detailed behavioral data could be obtained, due to poor video quality. The video quality for the subsequent launches at 13:22 and 15:08 was good.

For all three AGS launches on this date, launch sounds were recorded quantitatively via ATARs at the same three sites as the video cameras (Table 2.2 in Chapter 2; Fig. 3.1C,D,E). Launch sounds from all three launches were also audible on the audio channel of the video recordings at Harbor Seal Overlook. Launch sounds were not audible on the audio channel of the video recording at Dos Coves South. A wagoncam was used at 809 Camera, so no sounds were on the video recorded there.

California Sea Lions.—During all three AGS launches, sea lions at Dos Coves (0.8 mi or 1.3 km from CPA) showed very little reaction. From 35 to 50 sea lions were monitored at that site during each AGS launch. Before the first AGS slug was launched at 11:31, there was movement by pups and juveniles along the beach. There was no overt reaction by the sea lions to the first launch. During the second AGS slug launch at 13:22, most sea lions (80–90%) looked around, but none moved. During the launch of the AGS missile at 15:08, there was no overt reaction.

Near 809 Camera, also ~0.8 mi (1.3 km) from CPA, there was some video interference during the first AGS launch, and detailed behavioral data could not be collected before the launch. During the launch, all 60 animals startled and scattered, and most (80–90%) moved vigorously along the beach. About 50% of the animals moved out of the field of view of the camera (at least 66–98 ft [20–30 m]) during the launch. Sea lions reacted less to the second AGS launch at 13:23. Most (80–90%) of the 30 animals were startled by the launch, but none moved in immediate response to the launch. Most animals settled within 1 or 2 min. During the launch of the AGS missile at 15:08, most (80–90%) of the 31 sea lions were startled, and ~50% moved along the beach. Received sound levels during the three launches were higher near 809 Camera than at Dos Coves (Table 3.3).

TABLE 3.5. Details of vehicle launches, SEL, and ***harbor seal*** reactions at SNI during October 2003–January 2005. A triple launch of AGS vehicles took place on 3 June 2004. All launches were from the Alpha Launch Complex. Times are local time.

Launch Date	Launch Time	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-weighted/A-weighted	Behavioral Reaction of Animals to Launch
18 May 04	12:40	SSST	300°	18° / 3300 ft	Pirates Cove[ne]	2358	>117/103	5 seals observed; all seals rushed into the water (1–3 m away)
"	12:40	SSST	300°	18° / 3300 ft	Harbor Seal Overlook[s]	1271	105/79	21 seals observed; all entered water immediately; seals hauled out again ~25 min after launch
3 June 04	11:31	AGS Slug	282°	50° / 4500 ft	Harbor Seal Overlook[n]	1145	103/80	15 seals observed; all startled and moved quickly (1–4 m); 4 entered the water
"	13:22	AGS Slug	282°	50° / 4500 ft	Harbor Seal Overlook[n]	1145	95/76	19 seals observed; all startled and moved quickly (1–5 m); 1 seal seen entering water and 10 others likely also entered water
"	15:08	AGS Missile	282°	50° / 4500 ft	Harbor Seal Overlook[n]	1145	103/79	11 seals observed; all startled and all moved at least 1–5 m; 9 left the area and probably entered water
29 July 04	10:20	Arrow	385°	90°/ 7000 ft	Phoca Reef[ne]	2667	Launch sounds audible on video recording	80 monitored; 60% moved in response to launch and most of those (40 of 48) entered the water; settled within 30 s
26 August 04	10:08	Arrow	385°	90°/ 7000 ft	Phoca Reef[ne]	2666	98/82	30 seals monitored; 3 moved and 2 of those entered the water; all looked during launch; settled within 30 s

[n] monitoring site located north of the launch azimuth
[ne] monitoring site located northeast of (in opposite direction to) the launch azimuth
[s] monitoring site located south of the launch azimuth

Northern Elephant Seals.—Four elephant seals were monitored at Dos Coves South (~0.8 mi or 1.3 km from CPA) during the first launch of an AGS slug at 11:31, but no overt reactions were observed. During the second launch at 13:23, elephant seals still showed very little reaction to the launch; 10 of 40 seals looked up, but they returned to resting positions within 10 s (Table 3.4). During the last launch at 15:08, the elephant seals showed no overt reaction.

Harbor Seals.—Fifteen seals were monitored at Harbor Seal Overlook (0.7 mi or 1.1 km from CPA) during the launch of the first AGS slug at 11:31. In response to the launch, all 15 seals startled and moved quickly ~3–13 ft (1–4 m), likely towards the water (not in field of view of camera), and another 7 seals entered the field of view of the camera (probably moving towards the water). In total, two animals entered the water within 30 s after the launch, and two more seals entered the water >30 s after the launch (Table 3.5).

During the second launch at 13:22, 19 seals were observed and all startled and moved quickly at least 3–16 ft (1–5 m) in response to the launch, likely towards the water (Table 3.5). Ten of those seals moved out of the field of view of the camera and likely entered the water. One seal was actually seen to enter the water 30 s after the launch. During the AGS missile launch at 15:08, 11 seals were monitored. All seals startled in response to the launch and moved quickly at least several meters 3–16 ft (1–5 m), probably towards the water. Nine of the seals left the area immediately and likely entered the water (Table 3.5). The other two seals remained in the area for another minute and then left the field of view of the camera. No seals were hauled out at Harbor Seal Overlook during the remainder of the video recording (1.5 hr), but one was hauled out during follow-up monitoring 2 hr after the launch.

3.4.4 Double AGS Slug Launch, 26 July 2004

Two AGS slugs were launched from the Building 807 Complex, with an azimuth of 300º and a 50º elevation angle. The two slugs were launched sequentially ~33 min apart. During both launches, video recordings of sea lions were obtained at three sites: Dos Coves South (1447 ft or 441 m north of the launcher and CPA); at 809 Camera located farther (4729 ft or 1.4 km) northeast of the CPA; and at Bachelor Beach North, 2532 ft or 772 m from the CPA, and generally behind the launcher. Elephant seals were also monitored at Bachelor Beach North during both launches.

For both AGS launches on this date, launch sounds were recorded quantitatively via ATARs at Bachelor Beach North, Dos Coves South, and Vizcaino Point (Table 2.2 in Chapter 2; Fig. 3.1F). Vizcaino Point is near 809 Camera. None of the cameras used to monitor seals and sea lions had microphones, so no launch sounds were on the video recordings.

California Sea Lions.—During both AGS launches, 60 sea lions monitored with the 809 Camera showed the least reaction to the launches, compared with other sites (this location was also the farthest from the CPA). During the first launch, none of the animals monitored with the 809 Camera moved, but all looked up. Seven individuals entered the field of view of the camera during the launch. During the second launch, all animals looked up and/or got up, but only two moved up to 16 ft (5 m) along the beach. After both launches, the sea lions settled within ~30 s.

The reactions of sea lions that were monitored at Dos Coves South, closer to the launcher and trajectory, were variable. Before the launches, pups were moving around on the beach, while adult females were resting. During the first launch, 40% of the 100 animals monitored moved in response to the launch (pups were the first to respond, followed by adult females), and 30% likely entered the water.

Most sea lions settled within ~2 min, although some pups were still moving around on the beach after that time, and several adult females were still vigilant (looking or moving around). Before the second launch, several pups were again moving around on the beach. During the second launch, 60 of 100 animals moved around on the beach (most were pups but several adult females moved as well). Twenty-five animals (mostly pups) entered the water. Sea lions generally settled within ~2 min after the launches. Sound levels measured at this site were higher than those at the more distant 809 Camera location during the corresponding launches (Table 3.3).

During the first launch, 26 sea lions were monitored at Bachelor Beach North, which was almost behind the launcher by 2533 ft (772 m). All of the monitored animals moved in response to the launch, and 19 of 26 animals entered the water. During the second launch, all of the 22 monitored animals moved in response to the launch, and 9 entered the water. Sea lions generally settled within ~2 min after the launches. Sound levels measured at this site were intermediate between those at the other two locations, consistent with the intermediate distance (Table. 3.3).

Northern Elephant Seals.—Four elephant seals were monitored at Bachelor Beach North, 2507 ft (764 m) from the launcher, during the first and second launches of AGS slugs (Table 3.4). During the first launch, at 15:10, all four seals looked up, but did not move. During the second launch at 15:43, three elephant seals looked up and one animal moved ~6 ft (2 m). Seals settled back to resting positions within ~30 s.

3.4.5 Arrow Launch, 29 July 2004

An Arrow vehicle was launched from the Alpha Launch Complex, with an initial 90º elevation angle transitioning to an azimuth of 285º. During this launch, video recordings of California sea lions were obtained at Dos Coves South (1.1 mi or 1.8 km from the CPA), at 809 Camera located 6439 ft (2.0 km) from the CPA, and at Bachelor Beach North (1.1 mi or 1.8 km from the CPA). Elephant seals were also monitored at Bachelor Beach North, and harbor seals were monitored at Phoca Reef (1.7 mi or 2.7 km from the CPA).

For the Arrow, launch sounds were recorded quantitatively via ATARs at Bachelor Beach North, Dos Coves South, and Vizcaino Point (Table 2.2 in Chapter 2; Fig. 3.1G). Although ambient sounds could be heard on the audio channel of the video recording at Phoca Reef, the launch sounds were not audible there, presumably due to the windy conditions combined with the relatively long distance (1.7 mi. or 2.7 km) from the launcher. The other video recordings did not have audio channels.

California Sea Lions.— During the Arrow launch, 60 sea lions were monitored with the 809 Camera. Most of the animals merely looked up in response to the launch. Only 3 of the 60 animals moved in response to the launch, but none entered the water. Sea lions settled within ~30 s after the launch. At Dos Coves South, 53 sea lions were monitored. Some sea lions looked up in response to the launch, whereas others showed no overt reaction; none moved around. Sea lions settled within ~30 s. On two occasions, once before the launch and once after the launch, two adult females moved over sea lions pups (not in response to the launch). The sea lion pups did not appear to have been injured. Sea lions were also monitored at Bachelor Beach North. Of the 40 animals monitored, all moved down the beach and likely entered the water, which was 33–49 ft (10–15 m) away.

Northern Elephant Seals.—Three elephant seals were monitored at Bachelor Beach North during the Arrow launch. One of the elephant seals moved 3 ft (1 m), and all looked in response to the launch. Elephant seals settled back to resting positions within ~30 s after the launch.

Harbor Seals.—Harbor seals were monitored at Phoca Reef. Of 80 seals, 48 moved in response to the launch and most of those (40) entered the water. The seals that moved but did not enter the water only moved by ~6 ft (1 m). The remaining seals that were monitored only looked up during the launch. Harbor seals that remained hauled out settled back to resting positions within ~30 s after the launch.

3.4.6 Arrow Launch, 26 August 2004

An Arrow was launched from the Alpha Launch Complex, with an initial 90º elevation angle, transitioning to an azimuth of 285º. During this launch, video recordings of California sea lions were obtained at Dos Coves South (1.1 mi or 1.8 km from the CPA), and at Vizcaino Point (1.4 mi or 2.3 km from the CPA). A video recording of harbor seals was obtained at Phoca Reef (1.7 mi or 2.7 km) from the CPA.

Launch sounds were recorded quantitatively via ATARs at the same three sites (Table 2.2 in Chapter 2; Fig. 3.1H). Launch sounds were audible on the audio channel of the video recording at Phoca Reef. The other video recordings did not have sound channels.

California Sea Lions.—During the Arrow launch, 40 sea lions were monitored at Vizcaino Point. During the launch, all sea lions moved, but it could not be seen from the video whether any of them entered the water. It is possible that up to 16 sea lions entered the water, as they moved from the field of view of the camera very quickly. The other 24 animals moved distances of 6–26 ft (2–8 m). The sea lions that remained at the haul-out site settled within ~1 min after the launch. At Dos Coves South, 30 sea lions were monitored. Again, all of the animals moved, but none entered the water. The sea lions settled within ~2 min after the launch. Received sound levels were similar to those received by sea lions during the previous Arrow launch (Table 3.3).

Harbor Seals.—During the Arrow launch, 30 harbor seals were monitored. Three of those seals moved, including two that entered the water. The other seal moved 3 ft (1 m). All of the remaining harbor seals settled within 30 s after the launch.

3.4.7 SSST Launch, 27 August 2004

An SSST was launched from the Alpha Launch Complex, with an azimuth of 300º and an 18º elevation angle. During this launch, video recordings of California sea lions were obtained at Dos Coves South (1.2 mi or 1.9 km from the CPA), and at Vizcaino Point (1 mi or 1.6 km from the CPA). A video recording of harbor seals was attempted at Phoca Reef, but all harbor seals left before the launch.

For the SSST launch, launch sounds were recorded quantitatively via ATARs at all three of the video recording sites (Table 2.2 in Chapter 2; Fig. 3.1I). None of the cameras used to monitor sea lions had microphones, so no launch sounds were on the video recordings.

California Sea Lions.—During the SSST launch, 30 sea lions were monitored at Vizcaino Point. During the launch, all sea lions moved, and 25 entered the water. The sea lions remaining at the haul-out site settled within ~1 min after the launch. At Dos Coves South, 12 sea lions were monitored. During the launch, all 12 animals entered the water, and an additional 48 animals entered the field of view from other areas.

3.4.8 Triple RAM Launch, 22 September 2004

Three RAMs were launched from the 807 Building Launch Complex, with an azimuth of 240º and a 10º elevation angle. The first two RAMs were launched sequentially, ~1 hr apart, followed by a third

RAM 22 min later. For all three launches, video recordings of California sea lions were obtained at Dos Coves South (1909 ft or 582 m from the launcher and CPA), and near 809 Camera (1 mi or 1.6 km from the launcher and CPA). Other video recordings of sea lions were attempted at Vizcaino Point during all three launches, but sea lions left the haul out site before the first launch, and did not return before the second or third launch.

For the RAM launches, launch sounds were recorded quantitatively via ATARs near 809 Camera, Dos Coves South, and Vizcaino Point (Table 2.2 in Chapter 2; Fig. 3.1J). Launch sounds were audible on the audio channel of the video recording at Dos Coves South. The other cameras used to monitor sea lions did not have a microphone.

California Sea Lions.— During the first RAM launch, 25 sea lions at Dos Coves South (1909 ft or 582 m from the launcher) were monitored. Fourteen of 25 sea lions moved 16–33 ft (5–10 m); the rest were startled but did not move. Before the second launch, ~1 hr later, most of the sea lions had vacated the haul-out site. During the second launch, only one sea lion was observed. This sea lion got up in response to the launch, but did not move any further. It resumed its resting position ~1 min after the launch. During the third launch, a different sea lion was visible in the field of view of the camera. It looked up in response to the launch, but settled within 30 s after the launch.

Seventeen sea lions were monitored at “The Y” (near 809 Camera and 1 mi. or 1.6 km from launcher) during the first launch at 09:56. Animals were hauled out on the sandy beach. All moved in response to the launch and left the field of view of the camera. It could not be determined whether these animals entered the water or not. Since no sea lions were left at the haul-out site after the launch, the location of the camera was changed to a slightly different area (rocky haul out) near 809 Camera at 10:30. At this location, no detailed behavioral observations could be made, but it could be determined how many animals moved or entered the water in response to the launch. During the second launch at 10:57, pups and adult females were hauled out. Thirty-five of 40 monitored sea lions reacted to the launch by entering the water. The remaining five sea lions looked during the launch, but they did not move; they settled within 30 s. During the third launch, 22 min later, 25 sea lions were in the field of view of the camera. Twenty of the 25 animals moved in response to the launch, and 15 of those entered the water. The five animals that did not enter the water moved 16–33 ft (5–10 m). The remaining five animals that did not move looked up in response to the launch. All sea lions settled within ~30 s of the launch.

3.4.9 Triple AGS Vehicle Launch, 27 January 2005

Two AGS slugs and one AGS missile were launched from the 807 Building Launch Complex, with an azimuth of 287º and a 50º elevation angle. The two slugs were launched sequentially, 2 hr 42 min apart, followed by the AGS missile 1 hr 48 min later. During all three launches, video recordings of elephant seals were obtained at Bachelor Beach South (3950 ft or 1.2 km from CPA behind the launcher), Bachelor Beach North (2447 ft or 746 m behind the launcher), and at Redeye I located 1 mi (1.6 km) to the northeast side of the launcher.

ATARs were deployed at the same three sites, and two provided quantitative data (Table 2.2 in Chapter 2; Fig. 3.1K,L). The ATAR at Bachelor Beach South malfunctioned during all three launches. Launch sounds during all three launches were audible on the audio channel of the video recording at Bachelor Beach South. The other cameras used to monitor seals did not have a microphone.

Elephant Seals.—During the first launch of an AGS slug, 100 elephant seals at Bachelor Beach South, 0.75 mi (1.2 km) from the launcher, were monitored. In response to the launch, all elephant seals looked, but only 3 of the 100 seals moved by ~3 ft (1 m), and none entered the water. During the second launch, most of the same animals were monitored, although only 90 animals were left in the field of view of the camera. Most animals looked up during the launch, although some did not show any overt reaction. Of the 90 elephant seals monitored, 3 moved a short distance (<6 ft or 2 m) and none entered the water. During the third launch, most of the same 90 seals were observed. Again, most animals looked during the launch, but several showed no reaction. Only one seal moved a short distance (<6 ft or 2 m). After all three launches, the elephant seals settled back to their resting positions within ~30 s after the launch.

During the first launch, 50 elephant seals at Bachelor Beach North, 2460 ft (750 m) from the launcher, were observed. All seals looked in response to the launch, but only 2 of 50 seals moved a short distance (<6 ft or <2 m); none entered the water. During the second launch, most of the seals looked in response to the launch, but none moved or entered the water. During the third launch, only ~10 of 50 seals looked in response to the launch, and again, no animals moved or entered the water.

At Redeye I, 1 mi. (1.6 km) from the launcher, 15 to 30 seals were observed during the three launches. On all three occasions, all seals showed no overt reactions in response to the launches.

3.5 Summary of Pinniped Responses to Launches, August 2001–January 2005

This section provides a short summary for each pinniped species, giving the general proportion of animals that responded to launches by moving or entering the water. This summary is based on all launches monitored at SNI during the August 2001–January 2005 period.

California Sea Lions.—California sea lions were observed on a total of 59 occasions (site–launch combinations) on 24 dates from August 2001 to January 2005. Responses of California sea lions to the launches varied by individual. Some sea lions exhibited startle responses, whereas others hardly reacted to the launch. On 43 of 59 occasions, sea lions reacted more vigorously by moving along the beach (3–100%; avg. 65%). On 17 of 57 occasions, sea lions entered the water in response to the launch. Less than 50% of sea lions entered the water on 11 occasions, and 60–100% entered the water on the remaining 6 occasions. Although sea lions showed increased vigilance for a short period after each launch, all age classes settled back to pre-launch behavior patterns within 1 or 2 min after the launch time.

Elephant Seals.—Elephant seals were observed on 35 occasions on 19 dates from August 2001 to January 2005. Most elephant seals exhibited little reaction to launch sounds; they merely raised their heads for a few seconds and then returned to their previous activity pattern (e.g., sleeping, resting). During several launches (16 of 35 occasions), a small proportion (avg. 23%) of northern elephant seals on the beach repositioned or moved a small distance (<6 ft; <2 m) away from their resting site. The proportion of elephant seals that entered the water was typically zero. A single elephant seal entered the water on two occasions.

Harbor Seals.—Harbor seals were observed on a total of 30 occasions during 16 dates in the August 2001 to January 2005 period. During the majority of these launches, most harbor seals left their haul-out sites and entered the water. Individuals that left the site typically did not return during the duration of the video-recording period, which lasted for an additional 1 to 2 hr. On 26 of 30 occasions, 7–100% (avg. 78%) of seals moved in response to the launch, and on 24 of 30 occasions, 7–100% (avg. 69%) entered the water. Nonetheless, reactions of harbor seals to launch sounds appear to be variable.

3.6 Comparisons of Pinniped Behavior and Distribution Prior to and After Launches

The "units of observation" were individual pinnipeds within the focal subgroups. Individuals were chosen that were clearly visible on the video recordings for the entire 1-min sampling period of interest (either pre- or post-launch). The individuals included in the focal subgroups before and after a given launch were not necessarily the same animals, especially in the situation where pinnipeds moved or left the haul-out site in response to the launch (e.g., harbor seals). In the case of northern elephant seals, the focal animals were often the same individuals that were observed prior to the launch. Table 3.6 presents means and standard deviations for inter-individual spacing, total distance moved, and number of position changes before and after launches, separately by species. In general, all three species moved more frequently and longer distances after than before launches. Harbor seals where generally located closer to their nearest neighbor before launches compared with afterwards. Because the individuals within a focal group are likely to respond to one another, they should not be assumed to be independent. Therefore, it is not appropriate to apply simple statistical analysis approaches to these data as presently organized.

3.7 Pinniped Responses in Relation to Launch Sounds and Other Predictor Variables

Scatter plots of pinniped response relative to 3-D CPA distance and SEL for each vehicle type are shown in Figures 3.4–3.6. "Other large" vehicles (Terrier Orion, Tomahawk, Arrow, SSST) were grouped together for the scatter plots, as only limited data were available for each of those vehicle types. Most generalizations are based on responses to Vandals, as these were the most frequently launched vehicle types at SNI. A-weighted peak measures are not presented in the scatter plots, as A-weighting is not relevant for the peak sound pressure.

Results of the logistic regression analyses of pinniped responses in relation to various potential predictor variables are summarized in Tables 3.7 and 3.8. The best-fit models for regressions that included sound (SEL) may be affected adversely by strong correlation between some predictor variables (e.g., SEL and CPA Distance), or multicolinearity. In addition, there is strong likelihood of fairly severe overfitting in some of these models where sample sizes are small (as they are for harbor and elephant seals) when dealing with so many potential predictors. These models should be interpreted with caution.

California Sea Lions

The percentage of sea lions that responded to launches at different CPA distances was widely variable (Fig. 3.4a). Sea lion responses in relation to SEL, either flat- or A-weighted, were also highly variable. Nonetheless, there was a significant ($P \leq 0.05$) increase in the percentage of sea lions that moved with increasing SEL (Fig. 3.4b,c). The proportion that entered the water showed only a marginal tendency ($P \leq 0.1$) to increase with increasing SEL (Fig. 3.4b,c). However, the proportion of sea lions that entered the water was most commonly low or zero (Fig. 3.4).

The best-fit regression model relating the proportion of sea lions that moved during a launch to non-sound variables indicated that, after allowing for other factors, the proportion moving was significantly related to logCPADist ($P \leq 0.001$; Table 3.7). Vehicle type and season also entered the best-fit model, although both were only marginally significant. A marginally greater proportion of sea lions tended to move in response to "other large" vehicles compared with Vandals and the two smaller vehicle types (RAM and AGS). CPA_Angle, wind component, and launch did not enter the model. (Launch represents whether the launch was the second or third of the day.)

TABLE 3.6. Description of pinniped behavior and distribution prior to and after launches, August 2001–January 2005; *n* = number of animals; SD = standard deviation.

	Before Launch			After Launch		
Behavior Analyzed	Mean	SD	*n*	Mean	SD	*n*
Number of Position Changes						
California Sea Lions	0.27	0.74	619	0.49	0.92	510
Northern Elephant Seals	0.13	0.39	300	0.18	0.55	283
Harbor Seals	0.09	0.42	298	0.25	0.64	150
Total Distance Moved (m)						
California Sea Lions	0.50	1.99	619	1.18	3.64	510
Northern Elephant Seals	0.08	0.38	300	0.13	0.57	283
Harbor Seals	0.08	0.42	298	0.12	0.35	150
Distance to Neighbor (m)						
California Sea Lions	0.50	1.27	618	0.51	1.80	509
Northern Elephant Seals	0.22	0.55	300	0.19	0.55	283
Harbor Seals	0.82	1.18	298	1.37	2.68	148

The proportion of sea lions that entered the water was related to launch and wind; both variables were significant predictors at the conventional $P \leq 0.05$ level (Table 3.7). The positive coefficient for launch indicates that sea lions may have been slightly more likely to enter the water in response to a launch if there had already been a launch earlier in the same day. Sea lion response was also marginally related to season (Table 3.7).

For the regression models that included sound as well as non-sound variables, the sample size was lower but these models had the advantage of including a direct measurement of received sound at the location of the pinnipeds (Table 3.8). Both measures of sea lion response were strongly related to vehicle type, logCPADist, CPA_Angle, and SEL-A. For proportion of sea lions that moved, season also entered the model, indicating that a higher ($P \leq 0.05$) proportion of sea lions moved outside the breeding/pupping season (Table 3.8). After allowing for other variables, the highest proportion of sea lions moved during AGS launches, followed by intermediate proportions with "other large" vehicles and RAMs, and the lowest proportion reacted to Vandals. As expected, sea lions showed significantly more response with increasing SEL-A levels. Interestingly, these models showed that, after allowing for the effects of other variables, more animals responded with *increasing* CPA distance and *decreasing* slant angle, contrary to expectation. These unexpected results could be due to incomplete separation or multicolinearity of the data. The wind component was not significant in the models. It should be noted that the number of potential predictor variables considered for inclusion in these two models was fairly large in relation to the sample size (n = 36 site–launch combinations). As a result, some caution is appropriate in assessing the results.

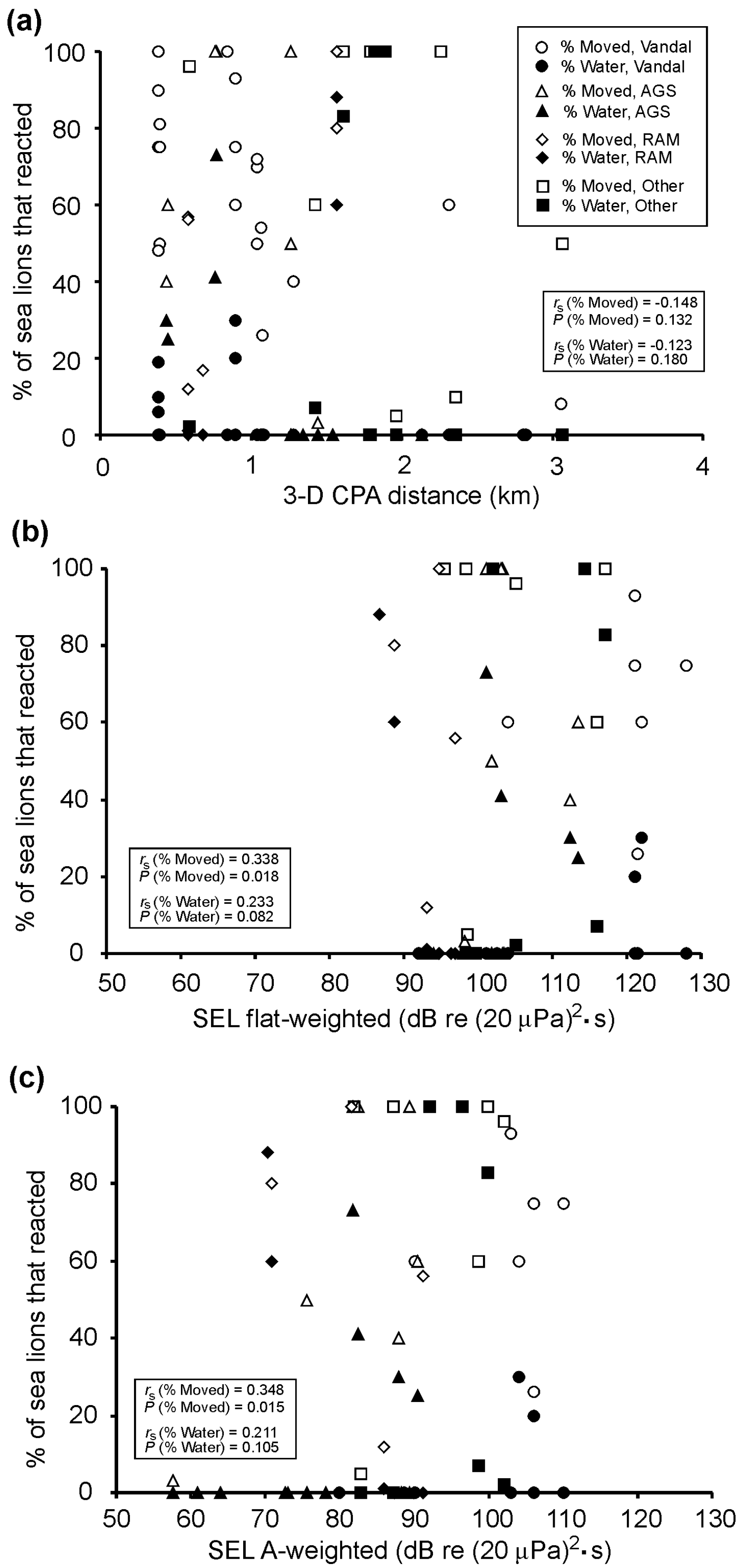

FIGURE 3.4. Percent of **sea lions** that moved (open symbols) or entered the water (solid symbols) in relation to ***(a)*** 3-D CPA distance, ***(b)*** SEL flat-weighted, and ***(c)*** SEL A-weighted for vehicles launched at SNI. Also shown are Spearman rank correlation coefficients (r_s) and their 1-sided significance levels (*P*).

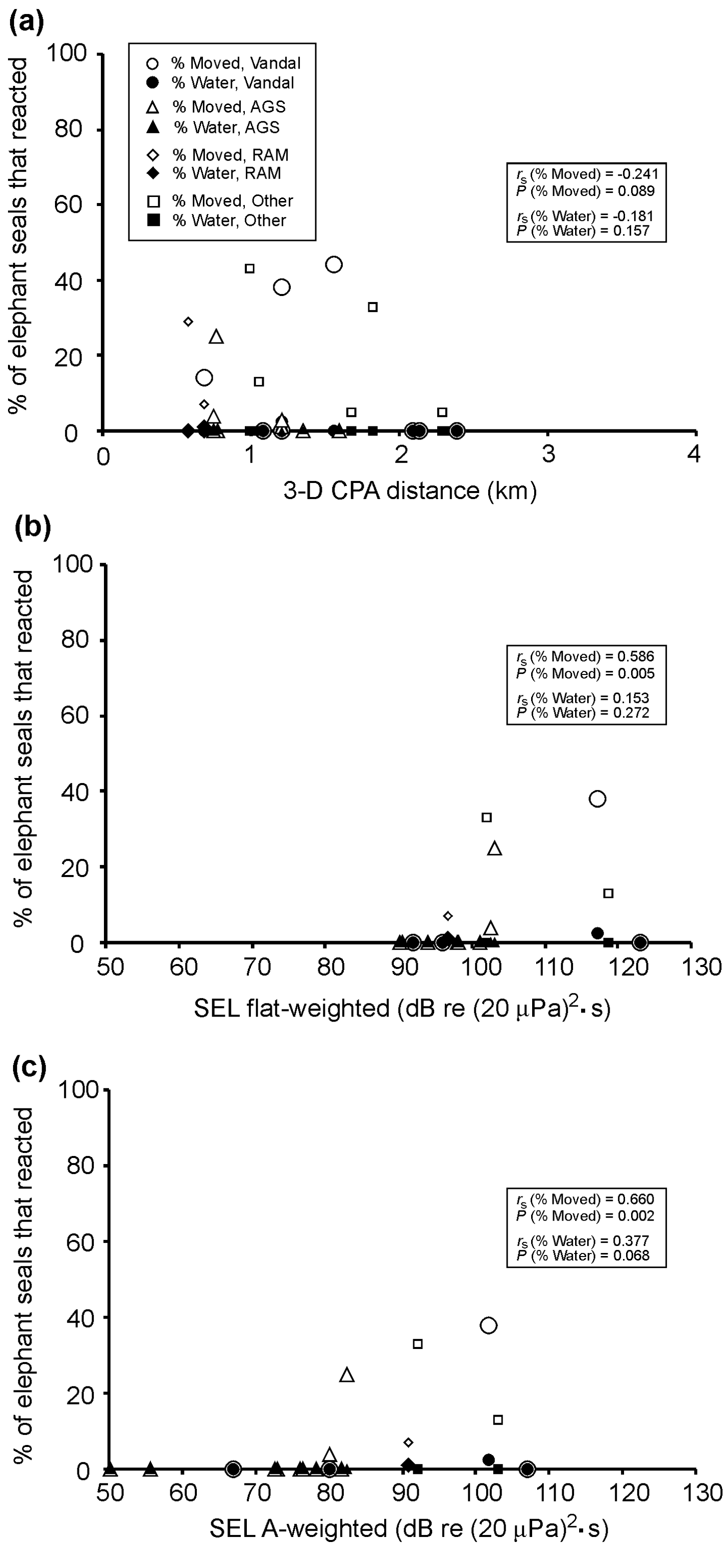

FIGURE 3.5. Percent of **northern elephant seals** that moved (open symbols) or entered the water (solid symbols) in relation to ***(a)*** 3-D CPA distance, ***(b)*** SEL flat-weighted, and ***(c)*** SEL A-weighted for vehicles launched at SNI. Also shown are Spearman rank correlation coefficients (r_s) and their 1-sided significance levels (*P*).

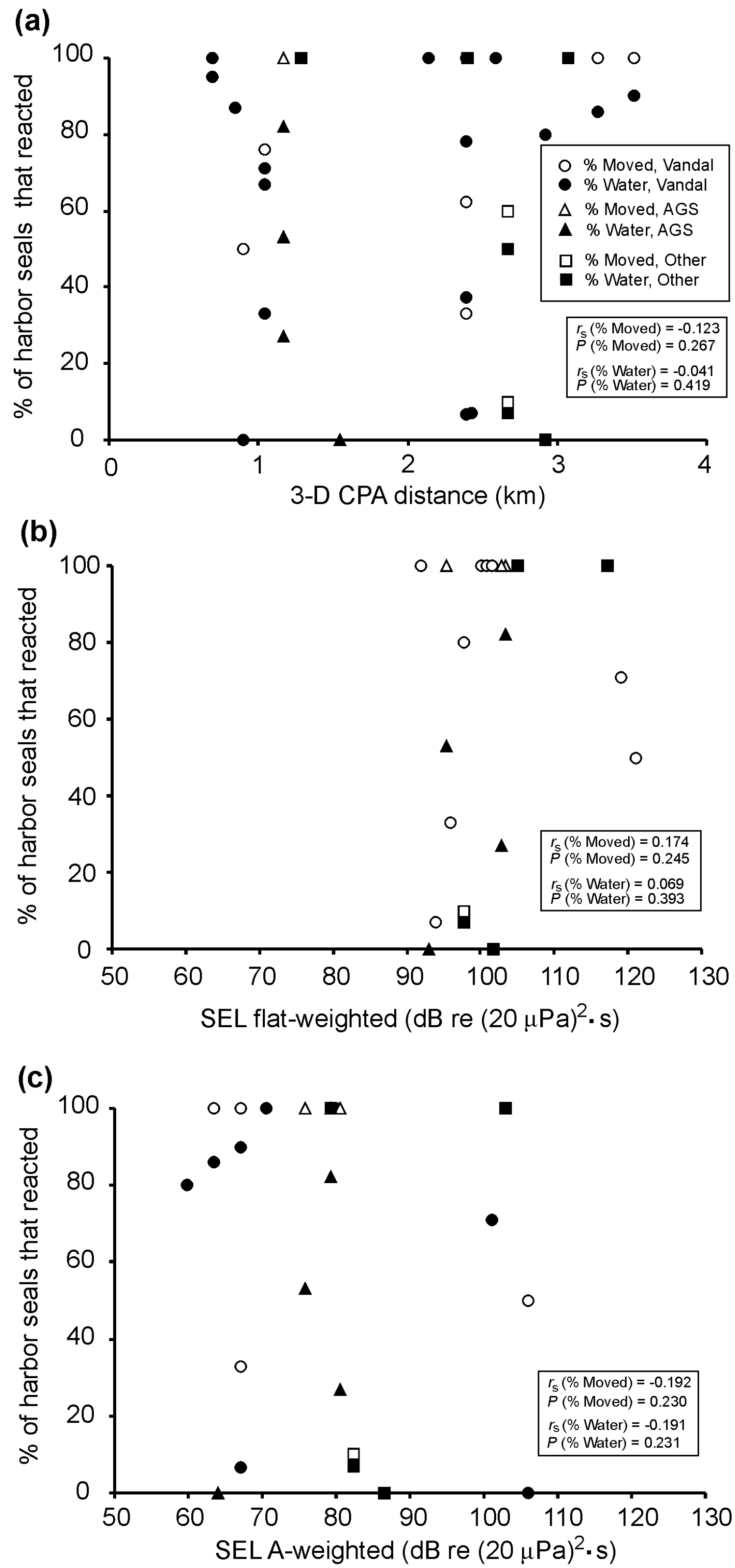

FIGURE 3.6. Percent of **harbor seals** that moved (open symbols) or entered the water (solid symbols) in relation to ***(a)*** 3-D CPA distance, ***(b)*** SEL flat-weighted, and ***(c)*** SEL A-weighted for vehicles launched at SNI. Also shown are Spearman rank correlation coefficients (r_s) and their 1-sided significance levels (*P*).

TABLE 3.7. Coefficients and nominal significance levels (*P*-values) for best-fit regression models relating pinniped response (proportion that moved, proportion that entered the water) to **non-sound predictor variables**. *n* = number of monitoring occasions (i.e., site–launch combinations); AIC = Akaike's Information Criterion; Intercept = y-intercept of the regression equation.

Variables	Harbor Seal moved (*n* = 28)	Harbor Seal water (*n* = 28)	Elephant Seal moved (*n* = 29)	Sea Lion moved (*n* = 56)	Sea Lion water (*n*=56)
Other Large	1.308	0.984	-1.522	1.383	–
P-value	ns	ns	*	(*)	
AGS	-32.029	-20.765	-3.844	-0.503	–
P-value	**	**	***	ns	
RAM	–	–	-3.595	-0.723	–
P-value			**	ns	
LogCPADist	25.810	14.988	-6.535	-3.648	–
P-value	(*)	(*)	**	***	
CPA_Angle	0.798	0.479	–	–	–
P-value	**	**			
Season	3.571	2.364	–	-0.838	1.003
P-value	**	*		(*)	(*)
Wind	–	–	–	–	0.103
P-value					*
Launch	–	–	–	–	1.304
P-value					*
Intercept	-15.744	-9.803	-0.144	0.178	-2.761
AIC	49.764	72.255	115.895	138.914	106.822

Note: The proportion of elephant seals that entered water cannot be analyzed until more animals respond; harbor seals were not monitored during RAM launches; *** for $P \leq 0.001$, ** for $0.001 < P \leq 0.01$, * for $0.01 < P \leq 0.05$, (*) for $0.05 < P \leq 0.1$, and ns (not-significant) for $P > 0.1$.

Northern Elephant Seals

The percentage of elephant seals that moved was generally low, even rather close to the launch azimuth (Fig. 3.5a). Nonetheless, elephant seals seemed to be slightly less responsive (fewer moved) at the longer CPA distances ($P < 0.1$; Fig. 3.5a). The proportion of elephant seals that moved was significantly greater with increasing SEL ($P < 0.01$; Fig. 3.5b,c).

When only non-sound variables were considered, the proportion of elephant seals that moved in response to the launch was significantly related to vehicle type as well as logCPADist (Table 3.7). A greater proportion of elephant seals moved in response to Vandals as compared with the other vehicle types. An intermediate proportion moved during launches of "other large" vehicles, and lower proportions moved during RAM and AGS launches. Wind component, launch, season, and CPA_Angle did not enter the model.

TABLE 3.8. Coefficients and nominal significance levels for best-fit regression models relating pinniped response (proportion that moved, proportion that entered the water) to **sound and non-sound variables**; *n* = number of monitoring occasions (i.e., site–launch combinations); AIC = Akaike's Information Criterion; Intercept = y-intercept of the regression equation. Results for harbor and elephant seals should be treated with considerable caution given the low number of occasions when all necessary information was available for analysis.

	Harbor Seal		**Elephant Seal**	**Sea Lion**	
	moved (*n* = 17)	**water (*n* = 17)**	**moved (*n* = 16)**	**moved (*n* = 36)**	**water (*n* = 36)**
Other Large	–	-1.831	–	5.961	6.591
P-value		ns		***	***
AGS	–	-28.696	–	8.372	11.335
P-value		**		***	**
RAM	–		–	5.009	10.657
P-value				**	***
LogCPADist	42.429	25.460	–	11.838	19.517
P-value	*	*		**	***
CPA_Angle	1.420	0.654	–	-0.096	-0.154
P-value	***	**		**	***
Season	–	–	–	-2.029	1.959
P-value				*	ns
Launch	-62.065	–	–	–	–
P-value	***				
SEL-A	-0.178	–	0.169	0.298	0.375
P-value	(*)		***	***	***
Intercept	-10.692	-13.387	-17.945	-28.534	-40.916
AIC	21.272	32.383	39.566	79.937	69.216

Note: The proportion of elephant seals that entered water cannot be analyzed until more animals respond. Wind was also included in the analysis, but did not enter the top models; harbor seals were not monitored during RAM launches; *** for $P \leq 0.001$, ** for $0.001 < P \leq 0.01$, * for $0.01 < P \leq 0.05$, (*) for $0.05 < P \leq 0.1$, and ns (not-significant) for $P > 0.1$.

When sound as well as non-sound variables were considered in the regression analysis, the best-fit model indicated that the proportion of animals that moved was strongly ($P \leq 0.001$) related to SEL-A levels; more elephant seals moved with increasing SEL-A (Table 3.8). After allowing for the SEL-A effect, the proportion of elephant seals that moved was not related significantly to any of the other potential predictors. Note that the sample size for this analysis was quite small (*n* = 16 occasions).

The percent of elephant seals that entered the water was typically zero (Fig. 3.5). Single elephant seals entered the water only on 2 of 27 monitoring occasions during the August 2001–January 2005 period. One of these occasions occurred on 5 May 2004 when elephant seals were monitored at Bachelor Beach North during a dual RAM launch. One individual that was resting near the water (~3–6 ft or 1–2 m away) entered the water during the launch. The other occasion occurred during a Vandal launch on 10

December 2002 during which seals were monitored at Bachelor Beach North. There seemed to be nothing unusual about these two launches.

Due to the very limited number of elephant seals that entered the water in response to the launches, no logistic regression analysis was possible for that variable.

Harbor Seals

Generally, moderate to high proportions of the harbor seals moved during launches, even in the case of vehicles whose 3-D CPA distance was 1.2–2.2 mi (2.0–3.5 km) away (Fig. 3.6a). Likewise, harbor seals commonly entered the water during launches with CPA distances of 1.2–2.2 mi (2.0–3.5 km) as well as during launches when the vehicle came closer to the seals (Fig. 3.6a). Harbor seal responses were highly variable in relation to both CPA distance and SEL, with no obvious trends in relation to increasing distance or SEL ($P > 0.2$; Fig. 3.6a,b,c).

When only non-sound variables were included in the regression analyses, the best-fitting models for proportion moving and proportion entering the water indicated that the responses of harbor seals were related to vehicle type, CPA_Angle, and season (Table 3.7). According to the best-fit models, the highest proportion of harbor seals responded when Vandals or "other large" vehicles were launched (e.g., Arrow, SSST, Tomahawk), with significantly lower proportions reacting during AGS launches. Harbor seals were not monitored during RAM launches. Harbor seal response increased significantly with increasing CPA_Angle ($P \leq 0.01$). Harbor seals were more responsive (more moved and entered the water in response to the launch) during the pupping/breeding season. The relationships to logCPADist were marginal (and not in the expected direction), and wind component and launch did not enter the model.

When SEL-A was included in the analysis, the sample size was low ($n = 17$ monitoring occasions). The proportion of harbor seals that moved tended to be higher with high CPA_Angle and for the first launch of the day (Table 3.8). The proportion that entered the water tended to be higher with high CPA_Angle and for Vandal and "other large" vehicles as compared with AGS launches. Various other predictor variables were included in the models with low significance levels. Given the low sample size, the reliability of those weak relationships is questionable.

3.8 Summary

Pinniped behavioral responses to launch sounds during the October 2003–January 2005 period were, with the exception of some responses by harbor seal seals, usually brief and not severe. These responses were similar to those for the 2001–2002 and 2002–2003 monitoring period (Lawson et al. 2002; Holst and Greene 2003a,b; see also Appendix C). In general, northern elephant seals usually exhibited little reaction to the launches, California sea lions showed variable responses, and harbor seals were the most responsive.

Northern elephant seals exhibited little reaction to launch sounds. Even sound exposure levels as high as 123 dB re 20 $(\mu Pa)^2 \cdot s$ (107 dBA) did not elicit a strong reaction from northern elephant seals. Most individuals merely raised their heads briefly in response to the launch and then quickly returned to their previous activity pattern (usually sleeping). However, during several launches, a small proportion of northern elephant seals on the beach moved a short distance away from their resting site. Single elephant seals were observed to enter the water on only two occasions. Elephant seals were more responsive (a greater proportion moved) when larger vehicles, such as Vandals, were launched.

Responses of California sea lions to the vehicle launches varied by individual. Some sea lions exhibited brief startle responses and increased vigilance for a short period (1–2 min) after each launch. Other sea lions, particularly pups that were previously playing in groups along the margin of the haul-out beaches, appeared to react more vigorously by moving around on the beach. Responses of sea lions to launches were related to sound levels. More sea lions moved or entered the water with increasing SELs. Movement into the water was uncommon.

During the majority of launches, most harbor seals rushed from their haul-out sites on rocky ledges to enter the water within seconds of the launch (few seals took >30 s), and did not return during the duration of the video-recording period (which sometimes extended 1 to 2 hr after the launch time). Observations during the 2001–2002 monitoring period showed that harbor seals were usually hauled out again at these sites the following day (Holst and Lawson 2002).

Reactions of harbor seals to launch sounds varied with vehicle type. Harbor seals were more responsive during launches of Vandals and "other large" vehicles as compared with AGS missiles and slugs, and tended to be more responsive during the pupping/breeding season. There was no strong relationship of response to either logCPADist or received sound level (SEL-A); if anything, harbor seals at the longer distances may have been more responsive during launches. In general, harbor seals are comparatively sensitive to vehicle launches, and harbor seals hauled out on beaches far from the launch azimuth may react to the launches by moving or entering the water.

No evidence of injury or mortality was observed during or immediately succeeding the launches. However, on three occasions, harbor seal pups were knocked over by adult seals as the adults and pups moved toward the water in response to the launch. Seal pups were momentarily startled, but did not appear to be injured, and continued to move towards the water. On two other occasions, adult sea lions moving around on the beach moved over sea lion pups; this movement was not in response to any launches. No injuries could be detected.

4. ESTIMATED NUMBERS OF PINNIPEDS AFFECTED BY MISSILE LAUNCHES, OCTOBER 2003–JANUARY 2005

This chapter provides estimates of the numbers of pinnipeds affected by the Navy's missile launches on SNI from October 2003 through January 2005, based mainly on information provided in previous chapters of this report. An additional five launches that occurred from February through April 2005 are not considered.

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, 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 were not expected to be a direct function of received sound level. However, some correlation between pinniped responses and received sound level (or distance as a surrogate for sound level) was considered likely. Results from correlation analyses performed on 2001–2003 data provided the first direct evidence for such relationships at SNI, at least for California sea lions and (weakly) for elephant seals (Holst and Greene 2003b). The analyses performed on 2001–2005 data for the current report showed similar results, now based on larger sample sizes with some allowance for additional factors influencing received sound levels.

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, but pinnipeds often show considerable tolerance of noise and other forms of human-induced disturbance (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 the launches indicates that this assumption was generally correct. However, monitoring conducted during 2002–2003 showed that, on three occasions, 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. During the present monitoring period, harbor seals were seen rushing towards and into the water during launches. However, no small harbor seal pups were present during the launches, and no pups (or others) were observed being knocked over or injured during these launches.

Since no injuries or deaths were observed during the monitored launches from August 2001 to January 2005, 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 launch sounds 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 considered significantly affected (i.e., not harassed).

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 launch sounds:

1. pinnipeds that were injured or killed during launches (e.g., by stampedes);
2. pinnipeds exposed to launch sounds strong enough to cause Temporary Threshold Shift (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, 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 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 16 launches (including one dual RAM launch) during the October 2003 through January 2005 period. Disturbance reactions (if any) were short-lived for northern elephant seals and California sea lions and did not appear to extend into subsequent hours or days. Harbor seals typically left their haul-out site during a launch, but seals often started to haul out again at the same site within 1–2 hr after the launch.

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 permanent hearing impairment or Permanent Threshold Shift (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 nearby artillery shots, the difference may be smaller (Kryter 1985).

The maximum measured levels of launch sounds as received on beaches where pinnipeds might occur are summarized below:

- Results from acoustic monitoring of Vandal launches in 1997 (Burgess and Greene 1998) and 1999 (Greene 1999) showed that pinnipeds on the beaches near the launch sites were exposed to maximum received flat-weighted SELs of about 131 dB re $(20\ \mu Pa)^2 \cdot s$ (Table 1 in Greene 1999). A-weighted values were lower.
- During the August 2001–August 2003 monitoring periods, the maximum SEL values measured for launches near haul-out locations were 129 dB flat-weighted and 118 dBA re $(20\ \mu Pa)^2 \cdot s$ (Greene and Malme 2002; see also Chapter 2).
- During the October 2003–January 2005 period, the maximum SEL value measured near a pinniped haul-out site was 119+ dB flat-weighted and 103+ dBA re $(20\ \mu Pa)^2 \cdot s$ (Chapter 2).
- The sounds received from missile and target launches were sometimes impulse sounds (when there was a sonic boom or near the AGS launcher). At other times and locations they were non-impulsive.
- Peak pressure levels received near pinniped beaches close to the missile trajectory were as high as 149–150 dB re 20 μPa during some Vandal launches when a sonic boom (impulse) was

received. None of the other types of launches produced peak pressures that high on pinniped beaches.

In 2001–2005, SEL values from 130 to 143 dB (flat) and up to 131 dBA were occasionally measured near the launchers (Table 2.3–2.5). Corresponding peak pressures near the SSST, RAM, Vandal, and AGS launchers were as high as (respectively) 142, 147, 156, and 166 dB re 20 µPa (Tables 2.3–2.5). These values were recorded close to the launchers and not near pinnipeds on the beaches. The RAM launcher and (since July 2004) the AGS launcher are close to the shore at the Building 807 Launch Complex, but pinnipeds generally do not haul out close to those launchers.

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-sec transient sound with an SEL of 135 dB 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). Unpublished data indicate that the TTS threshold on an SEL basis may actually be around 129–131 dB re $(20\ \mu Pa)^2 \cdot s$ for harbor seals, within their frequency range of good hearing (A. Bowles et al. pers. comm.; D. Kastak et al. pers. comm.; see also Kastak et al. 2004). The same research teams have found that the TTS thresholds of California sea lions and elephant seals are higher. The measured SEL values near pinniped beaches during vehicle launches on SNI from October 2003–January 2005, as well as those from 2001–2003, were below the 135-dB level, and few if any pinnipeds were exposed to sound levels above 129 dB re $(20\ \mu Pa)^2 \cdot s$ SEL on a flat-weighted basis or 118 dBA SEL. Thus, few if any of the recorded sound pressures appear to have been sufficiently strong to have induced even slight TTS.

At least for the non-impulsive launch sounds, PTS would not be expected unless the received energy levels were considerably higher than the TTS threshold. The relationship between TTS and PTS onset was discussed at the NMFS-organized “Acoustic Criteria” workshop (see also Gisiner 1999). The consensus then was that received levels would have to be at least 10 dB above the TTS threshold, and probably considerably higher than that, before there would be concern about the possibility of permanent hearing impairment as a result of relatively short-term exposure. At the time of writing (June 2005), an expert panel is again evaluating (for NMFS) the likely relationship between sound levels associated with onset of PTS vs. TTS in marine mammals. Their final conclusions are not yet available. However, for harbor seals and other pinnipeds in air exposed to non-impulse sound, the PTS threshold probably is well above an SEL value of 135 dB re $(20\ \mu Pa)^2 \cdot s$. For impulse sounds, e.g., sonic booms and artillery shots, the PTS threshold may be lower, although still above 135 dB re $(20\ \mu Pa)^2 \cdot s$.

In the case of pinnipeds exposed to impulsive sound, e.g., from a sonic boom or close to an artillery shot, it is possible that there might be PTS as a result of the high peak pressure even if the received energy did not exceed the criterion for PTS onset.

Overall, the results to date indicate that there is little potential for appreciable TTS or especially PTS in pinnipeds hauled out near the vehicle 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 (i.e., AGS launches) occur at beach locations and pinnipeds are present nearby, should this ever occur. (2) When a Vandal or perhaps some “other 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 re-considered when specific noise exposure criteria become available for possible PTS in pinnipeds in air exposed to impulse sounds. Recommended criteria are expected to become available within the next year.

4.3 Conclusions Regarding Effects on Pinnipeds

Disturbance is the main concern during the Navy’s missile launch program. Responses of pinnipeds to acoustic disturbance are highly variable, with the most conspicuous changes in behavior occurring when pinnipeds are hauled out on land when exposed to strong sounds. Vehicle launch activities conducted during October 2003–January 2005, as in August 2001–August 2003, appeared to cause no more than limited, short-term, and localized disturbance of California sea lions and especially elephant seals. In the case of harbor seals, a substantial fraction moved into the water in response to launches. With the exception of most harbor seals, the majority of pinnipeds remained in the haul-out areas (see Chapter 3). There was no evidence that pinniped reactions to launches resulted in any pup mortality or injuries.

Levels of vehicle sounds recorded near pinniped haul-out locations around western SNI during launch operations in the present monitoring period were up to 119 dB re 20 $\mu Pa^2 \cdot s$ on a flat-weighted SEL basis, and up to 103 dBA on an A-weighted SEL basis. These values represent substantial levels of transient noise, and probably underestimated the maximum values occurring at certain unmonitored nearshore locations. However, they are below the levels expected to be necessary to cause PTS, and for pinnipeds at most locations, it is unlikely that TTS would occur either.

4.4 Estimated Numbers of Pinnipeds Affected by Launches

The approach to estimating the numbers of pinnipeds affected by launch sounds during October 2003 through January 2005 was based on video observations of pinnipeds, combined with estimates of the numbers of hauled out pinnipeds not videotaped but exposed to the same launch sounds. 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 only for the periods during and immediately following the 16 launches on 9 days. Disturbance reactions (if any) for northern elephant seals and California sea lions were short-lived and did not appear to extend into subsequent hours or days. Harbor seals typically left their haul-out sites during a launch; some harbor seals were observed to haul out at the same site again during follow-up monitoring (ie., within 2 hr after the launch), but others did not return during post-monitoring periods.

For pinniped groups that extended farther along the beach than encompassed by the field of view 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). An

TABLE 4.1. Minimum estimated numbers of California sea lions, northern elephant seals, and harbor seals potentially (poten.) affected by launch sounds from the Navy's missile launch program on SNI, October 2003–January 2005. Some individuals were probably affected on more than one launch day, so total numbers of different individuals affected could have been less than the totals shown.

Launch Date	Vehicle Type	Monitoring Site	Total # in Area	# of Focal Animals Poten. Affected	Total # Poten. Affected in Area
California Sea Lions					
5 May 04	RAM	Dos Coves South	>100	1 of 100	1
18 May 04	SSST	Sea lion haul-out sites*	*>100*		*50*
3 June 04	AGS	Dos Coves South	>100	0	0
3 June 04	AGS	Near 809 Camera	>60	30 of 60	30
26 July 04	AGS	Dos Coves South	>100	85 of 100	85
26 July 04	AGS	Near 809 Camera	67	0 of 60	7
26 July 04	AGS	Bachelor Beach North	>200	19 of 26	146
29 July 04	Arrow	Dos Coves South	>53	0	0
29 July 04	Arrow	Near 809 Camera	>60	0	0
29 July 04	Arrow	Bachelor Beach North	>40	40 of 40	40
26 Aug. 04	Arrow	Dos Coves South	>30	25 of 30	25
26 Aug. 04	Arrow	Vizcaino Point	>40	16 of 40	16
27 Aug. 04	SSST	Dos Coves South	>60	12 of 12	60
27 Aug. 04	SSST	Vizcaino Point	>30	30 of 30	30
22 Sep. 04	RAM	Dos Coves South	>25	0	0
22 Sep. 04	RAM	Near 809 Camera	>40	35 of 40	40
27 Jan. 05	AGS	Sea lion haul-out sites*			*80*
Total number of sea lions potentially affected					**610**
Northern Elephant Seals					
5 May 04	RAM	Bachelor Beach	>1000	1 of 76	13
18 May 04	SSST	Redeye I	>8	0	0
3 June 04	AGS	Dos Coves South	50	0	0
26 July 04	AGS	Bachelor Beach North	>100	0	0
29 July 04	Arrow	Bachelor Beach North	3	0	0
26 Aug. 04	Arrow	Seal haul-out sites*			*0*
27 Aug. 04	SSST	Seal haul-out sites*			*0*
22 Sep. 04	RAM	Seal haul-out sites*			*0*
27 Jan. 05	AGS	Bachelor Beach North	>1000	0	0
27 Jan. 05	AGS	Bachelor Beach South	>1000	0	0
27 Jan. 05	AGS	Redeye I	>700	0	0
Total number of elephant seals potentially affected					**13**
Harbor Seals					
5 May 04	RAM	Seal haul-out sites*			*0*
18 May 04	SSST	Pirates Cove	5	5 of 5	5
18 May 04	SSST	Harbor Seal Overlook	>21	21 of 21	21
3 June 04	AGS	Harbor Seal Overlook	>20	20 of 20	20
26 July 04	AGS	Seal haul-out sites*			*58*
29 July 04	Arrow	Phoca Reef	>80	40 of 80	40
26 Aug. 04	Arrow	Phoca Reef	>30	2 of 30	2
27 Aug. 04	SSST	Seal haul-out sites*			*22*
22 Sep. 04	RAM	Seal haul-out sites*			*25*
27 Jan. 05	AGS	Seal haul-out sites*			*25*
Total number of harbor seals potentially affected					**218**

* No sites were monitored during launch dates. *Note*: Numbers in italics are estimates derived from data previously collected during the 2001–2003 monitoring programs (Lawson et al. 2002; Holst and Greene 2003b), as well as the current monitoring period, for launch dates when monitoring of certain pinniped species did not occur.

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 may have been hauled out. Thus, despite this extrapolation, the estimates of the numbers of pinnipeds affected by launch sounds are likely underestimates. Even so, it is not likely that any of the pinnipeds present on western SNI were adversely impacted by such reactions, given the results from the beaches that were monitored. (One task that will be attempted during the ongoing launch monitoring in 2005 will be to develop a more effective extrapolation process, with the objective of providing more complete estimates of the total numbers of pinnipeds affected.)

For pinniped species that were not monitored on certain launch dates, the number of animals affected by launch sounds was estimated based on data from the 2001–2003 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 or Guadalupe fur seals on SNI from October 2003 through January 2005 or from August 2001 through August 2003, and none were evident in the video segments that were analyzed.

There appeared to be no increase in aggressive interactions as a result of the reactions to the launches. There was no evidence of injury or mortality during any of the launches. However, on three occasions, harbor seal pups were knocked over by adult seals as adults and pups moved toward the water in response to the launch. Seal pups were momentarily startled, but did not appear to be injured, and continued to move towards the water.

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).

4.5 Summary

No evidence of pinniped injuries or fatalities related to launch noises was evident, nor was it expected. Few if any pinnipeds were exposed to levels above 135 dB SEL re $(20\ \mu Pa)^2 \cdot s$ or above 131 dBA SEL. The specific received levels of transient airborne sound that cause the onset of TTS in pinnipeds are not well documented. However, few if any of the recorded sound pressures appear to have been sufficiently strong to have induced TTS if TTS onset occurs at about the level indicated by Bowles et al. (1999, pers. comm.) and Kastak et al. (2004). Any TTS would presumably be mild and quickly recoverable. PTS is unlikely to have occurred.

At least 610 California sea lions, 13 northern elephant seals, and 218 harbor seals are estimated to have been affected by launch sounds during the October 2003–January 2005 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. Of the California sea lions, most were young animals such as pups or juveniles. It is not likely that any of the pinnipeds on SNI were adversely impacted by such behavioral reactions.

The results suggest that any effects of these launch operations were minor, short-term, and localized, at least for California sea lions and especially elephant seals. In the case of harbor seals, a substantial fraction moved into the water in response to launches. Some harbor seals may have left their haul-out site until the following low tide; however, numbers occupying haul-out sites shortly after a launch, or the next day, were similar to pre-launch levels.

5. ACKNOWLEDGEMENTS

The acoustical and marine mammal monitoring work was funded and in part conducted by NAWCWD, Point Mugu, California. It was done under the provisions of IHAs and LOAs issued by NMFS. We thank Alex Stone, Steve Schwartz, Grace Smith, Gina Smith, Sandra Harvill, Tony Parisi, and many others at Point Mugu and SNI for their support, assistance, and very positive approach to the monitoring and mitigation effort. In particular, Grace Smith, Sandra Harvill, and Steve Schwartz of NAWCWD have been instrumental in acquiring and providing the sound and video recordings from SNI, and ancillary visual observations, weather data, and other information.

Bob Norman and Clay Rushing, consultants to Greeneridge, were largely responsible for the design of the ATARs, and continue to improve their operation. Bob Blaylock and Bob Norman of Greeneridge analyzed the recordings and prepared the figures of launch-by-launch acoustic results. Sandra Harvill, Steve Schwartz, Grace Smith, and Lisa Thomas 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, Anne Wright helped with report production. Dr. Jack Lawson, then of LGL, was principally responsible for the project design and initial project reports.

Peer Amble at TEC Inc., prime contractor for this work, assisted with management and logistical matters, and Rick Spaulding reviewed a draft of this report.

We are grateful to all concerned.

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APPENDIX A: LETTER OF AUTHORIZATION FOR 8 OCTOBER 2004 – 7 OCTOBER 2005

DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NATIONAL MARINE FISHERIES SERVICE

Letter of Authorization

The Department of the Navy, Naval Air Warfare Center Weapons Division, Point Mugu, 1 Administration Circle, China Lake, California 93555 is hereby authorized under section 101(a)(5)(A) of the Marine Mammal Protection Act (16 U.S.C. 1371(a)(5)(A)), 50 CFR 216.107, and 50 CFR 216.151 to harass small numbers of marine mammals incidental to vehicle launch operations from the western end of San Nicolas Island, California, contingent upon the following conditions:

1. This Authorization is valid from October 8, 2004, through October 7, 2005.

2. This Authorization is valid only for activities associated with a maximum of 40 Vandal (or similar sized) vehicles from Alpha Launch Complex and smaller missiles and targets from Building 807 from the western end of San Nicolas Island, California.

3. General Conditions:

(a). The taking, by incidental harassment only, is limited to the species listed under condition 3(b) below. The taking by serious injury or death of these species, 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 species authorized for incidental harassment takings are: northern elephant seals (*Mirounga angustirostris*), harbor seals (*Phoca vitulina*), and California sea lions (*Zalophus californianus*).

(c). The taking of any marine mammal in a manner prohibited under this Authorization must be reported within 48 hours of the taking to the Southwest Regional Office, National Marine Fisheries Service (NOAA Fisheries) at (562) 980-4023. If injurious or lethal take is discovered during monitoring, in coordination with NOAA Fisheries, launch procedure, mitigation measures, and monitoring methods must be reviewed and appropriate changes made prior to the next launch.

4. Cooperation:

The holder of this Authorization is required to cooperate with NOAA Fisheries and any other Federal, state or local agency monitoring the impacts of the activity on marine mammals. The holder must notify the Southwest Regional Office, NOAA Fisheries, at least 48 hours prior to launches (unless constrained by the date of issuance of this Authorization).

5. Mitigation Requirements:

To the extent practicable, the holder of this Authorization must:

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

(b). Avoid launch activities during harbor seal pupping season (February to April), when operationally practicable.

(c). Limit launch activities during other pinniped pupping seasons, when operationally practicable.

(d). Not launch Vandal target missiles from the Alpha Complex at low elevation (less than 1,000 feet) on launch azimuths that pass close to pinniped haul-out site(s).

(e). Avoid launching multiple target missiles in quick succession over haul-out sites, especially when young pups are present.

(f). Limit launch activities during nighttime hours.

(g). Ensure that aircraft and helicopter flight paths maintain a minimum altitude of 1,000 feet from pinniped haul-outs.

6. Monitoring Requirements:

(a). General.

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

(2). The NOAA Fisheries must be informed immediately of any changes or deletions to any portions of the proposed monitoring plan submitted, in accordance with condition 7(a) of this Authorization.

(b). Visual Land-Based Monitoring.

(1). Prior to each missile launch, an observer(s) will place 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 4 hours or as permitted by the videotape capacity.

(2). Systematic visual observations, by those individuals described in condition 6(a)(1) above, on pinniped presence and activity will be conducted and recorded in a field logbook a minimum of 2 hours prior to the estimated launch time and for no less than 1 hour immediately following the launch of Vandal and similar types of target missiles.

(3). Systematic visual observations, by those individuals described in condition 6(a)(1) above, on pinniped presence and activity will be conducted and recorded in a field logbook a minimum of 2 hours prior to launch, during launch, and for no less than 1 hour after the launch of the BQM-34, BQM-74, Exocet, Tomahawk, RAM target and similar types of missiles.

(4). Documentation, both via autonomous video camera and human observer, will consist of: (a) numbers and sexes of each age class in focal subgroups; (b) description and timing of launch activities or other disruptive event(s); (c) movements of pinnipeds, including number and proportion moving, direction and distance moved, and pace of movement; (d) description of reactions; (e) minimum distances between interacting and reacting pinnipeds; (f) study location; (g) local time; (h) substratum type; (i) substratum slope; (j) weather condition; (k) horizontal visibility; and (l) tide state.

(c). Acoustic Monitoring.

(1). During all launches, calibrated recordings of the levels and characteristics of the received launch sounds will be obtained from 3 different locations of varying distances from the target missile's flight path. Insofar as possible, these acoustic recording locations will correspond with the haul-out sites where video and human observer 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 dimensions.

(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 target missile.

7. Reporting:

(a). For each target 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, NOAA Fisheries (562-980-4023), providing reporting items found under condition 7(b), unless other arrangements for monitoring are agreed in writing.

(b). A draft final technical report will be submitted to the Office of Protected Resources and Southwest Regional Office, NOAA Fisheries, 120 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 launches planned during the next 1-2 months.

(c). A revised final technical report, including all monitoring results during the entire period of the Authorization will be due 90 days after the end of the Authorization's expiration.

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

8. 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.

9. 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 216.151-216.158) may result in the modification, suspension or revocation of this Authorization

10. A copy of this Authorization and the attached Subpart N of the regulations must be in the possession of each observer or group operating under the authority of this Letter of Authorization.

Laurie K. Allen
Director
Office of Protected Resources

OCT 8 2004
Date

APPENDIX B: MAPS OF LAUNCH AZIMUTHS AND MONITORING SITES FOR YEARS 1 AND 2

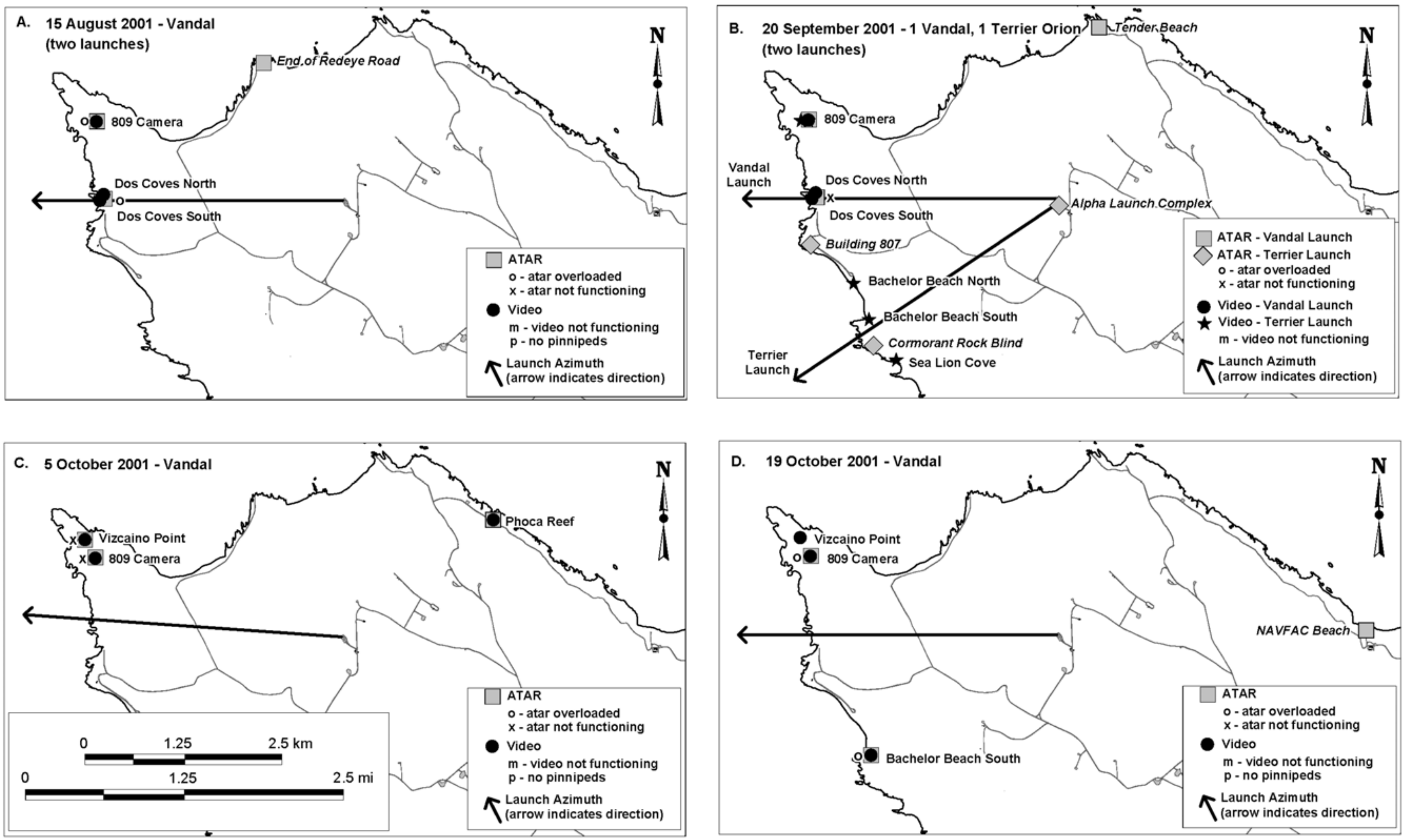


FIGURE B-1. Launch azimuths, acoustic recording sites (ATARs), and video recording sites for launches at San Nicolas Island from 15 August 2001 to 18 July 2002.

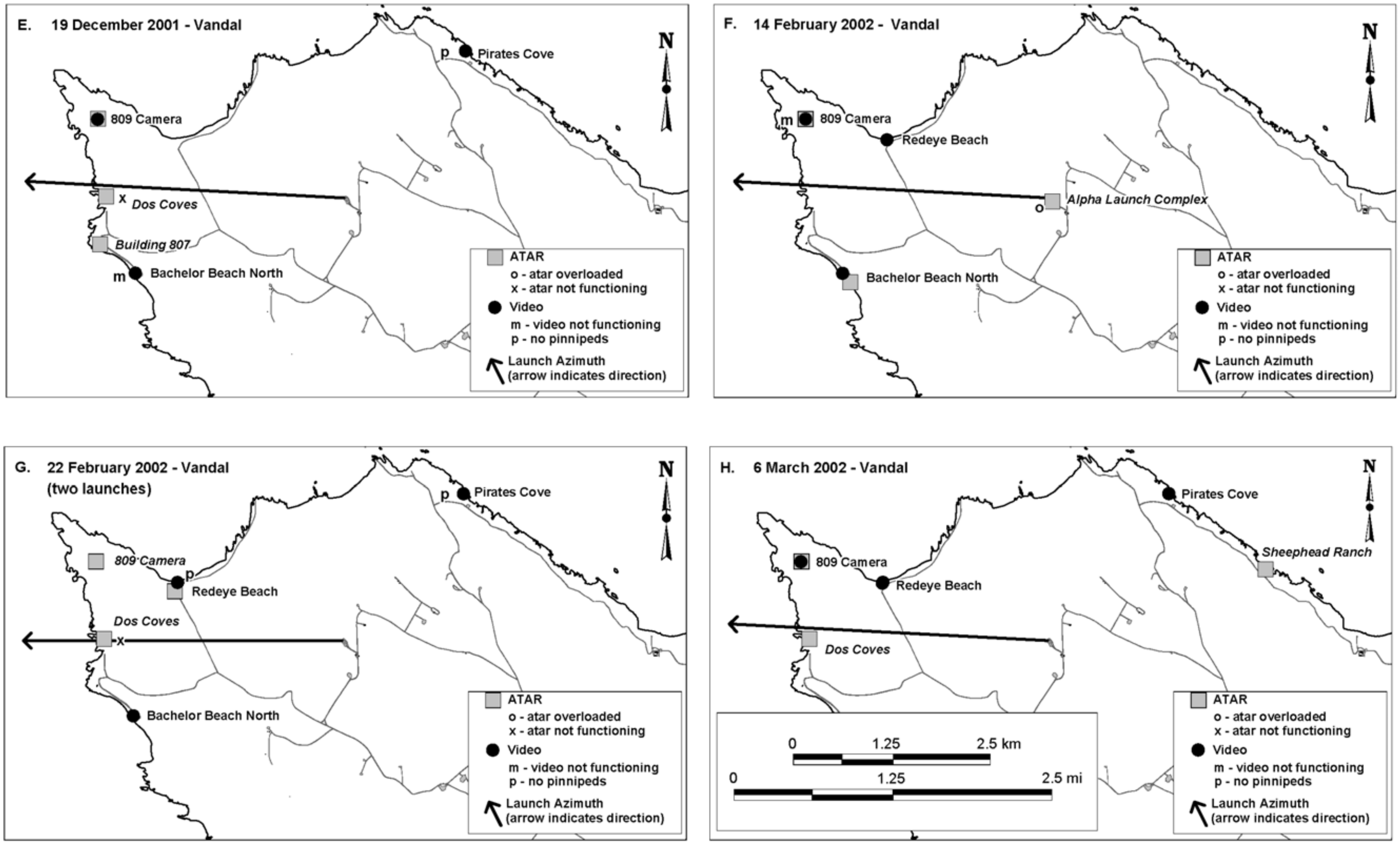


FIGURE B-1. (cont'd). Launch azimuths, acoustic recording sites (ATARs), and video recording sites for launches at San Nicolas Island from 15 August 2001 to 18 July 2002.

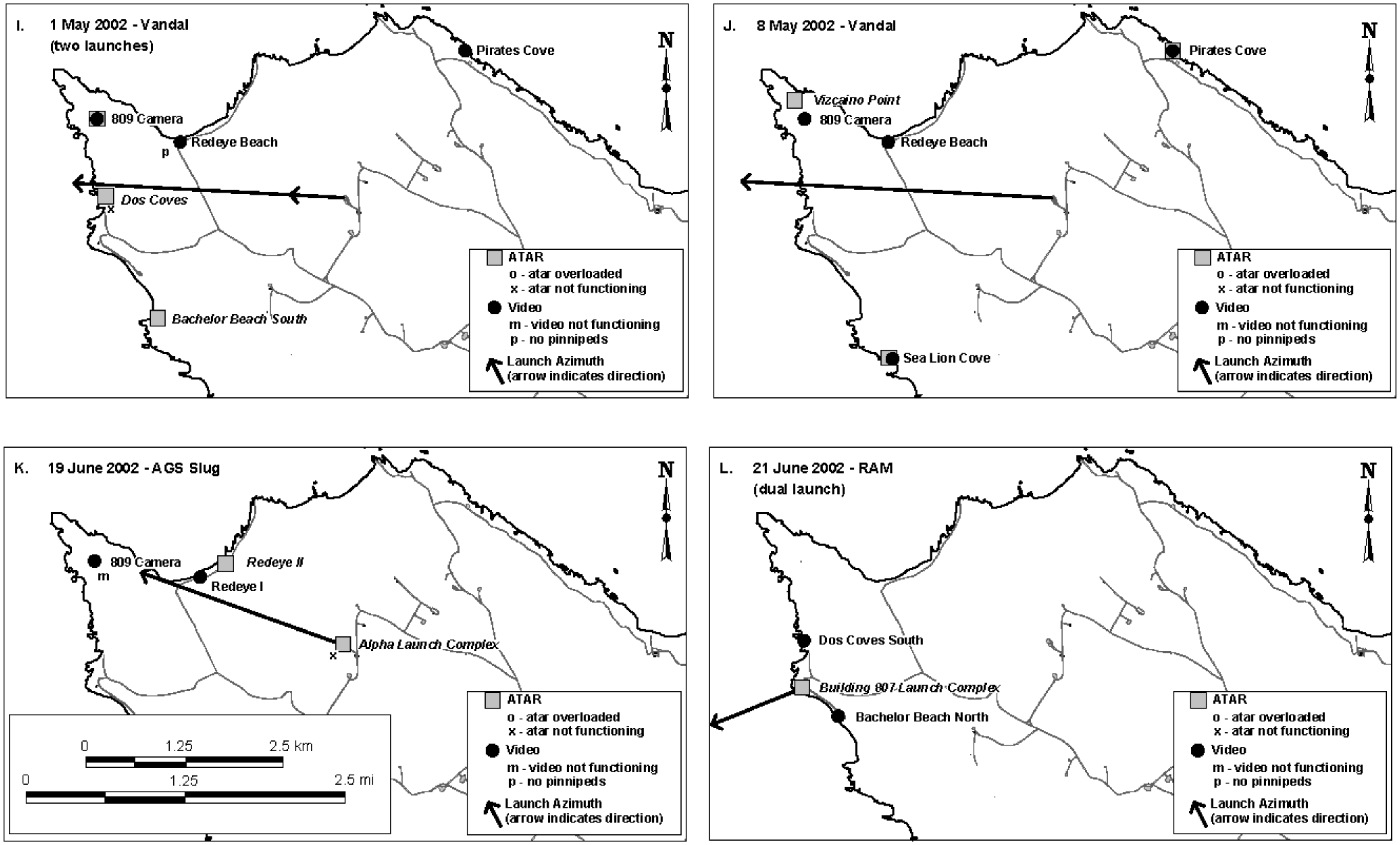


FIGURE B-1. (cont'd). Launch azimuths, acoustic recording sites (ATARs), and video recording sites for launches at San Nicolas Island from 15 August 2001 to 18 July 2002.

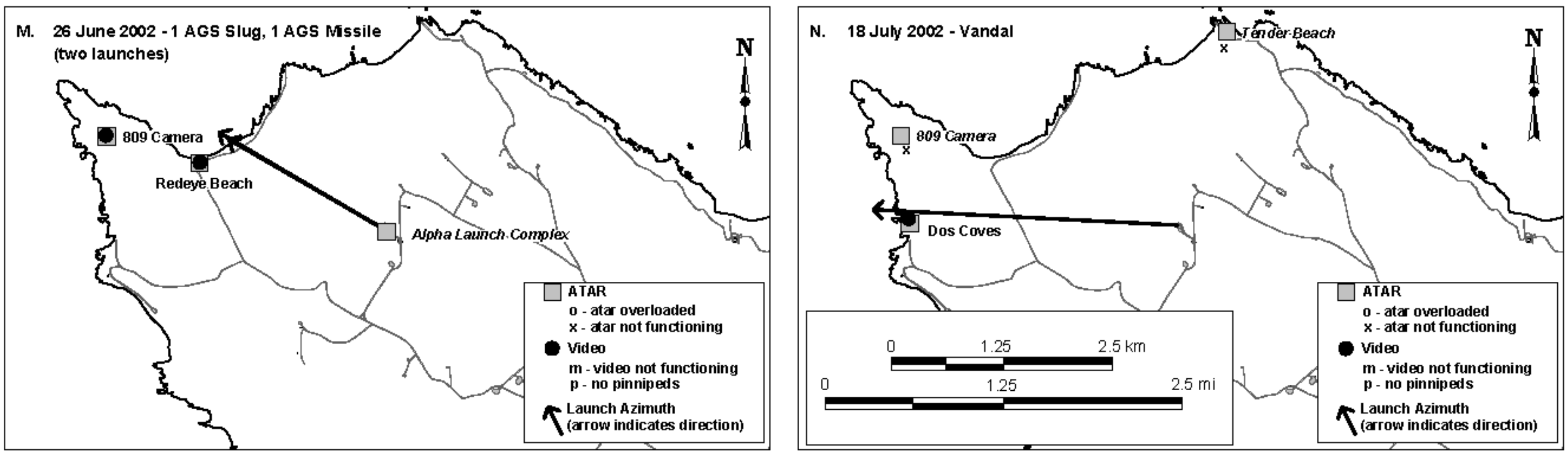


FIGURE B-1. (cont'd). Launch azimuths, acoustic recording sites (ATARs), and video recording sites for launches at San Nicolas Island from 15 August 2001 to 18 July 2002.

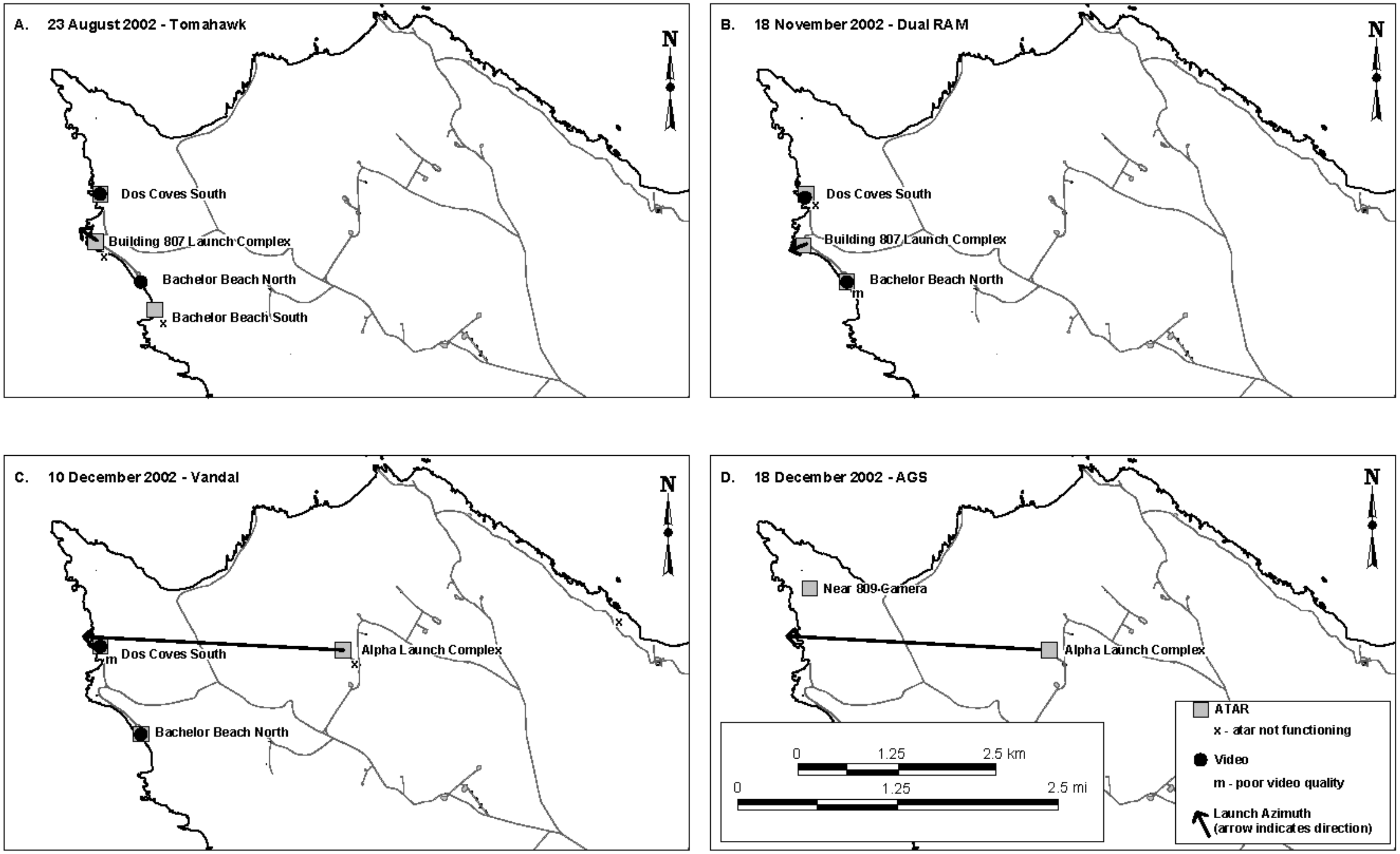


FIGURE B-2. Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at San Nicolas Island from 23 August 2002 to 28 July 2003.

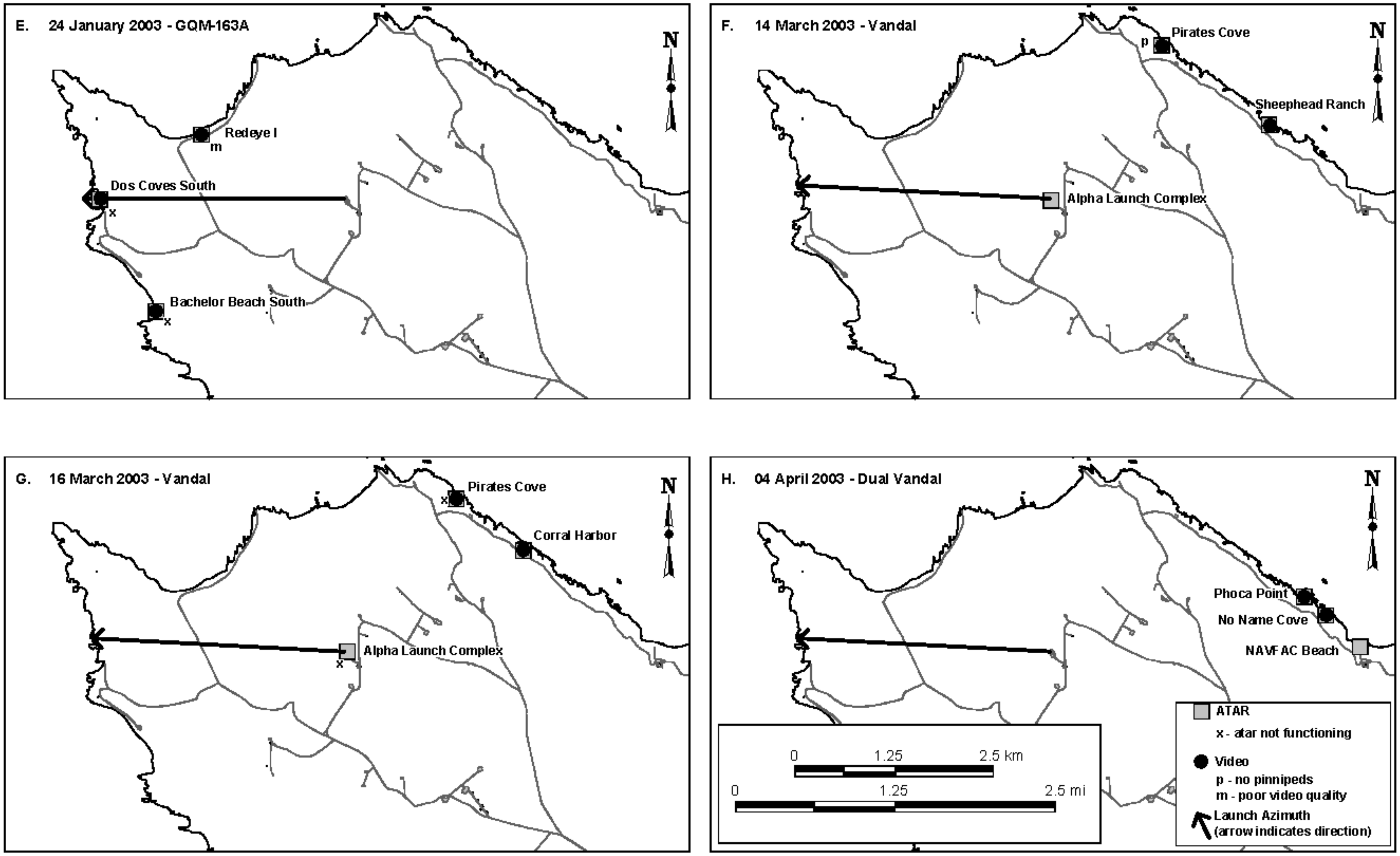


FIGURE B-2. (cont'd). Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at San Nicolas Island from 23 August 2002 to 28 July 2003. Note that GQM-163A = SSST.

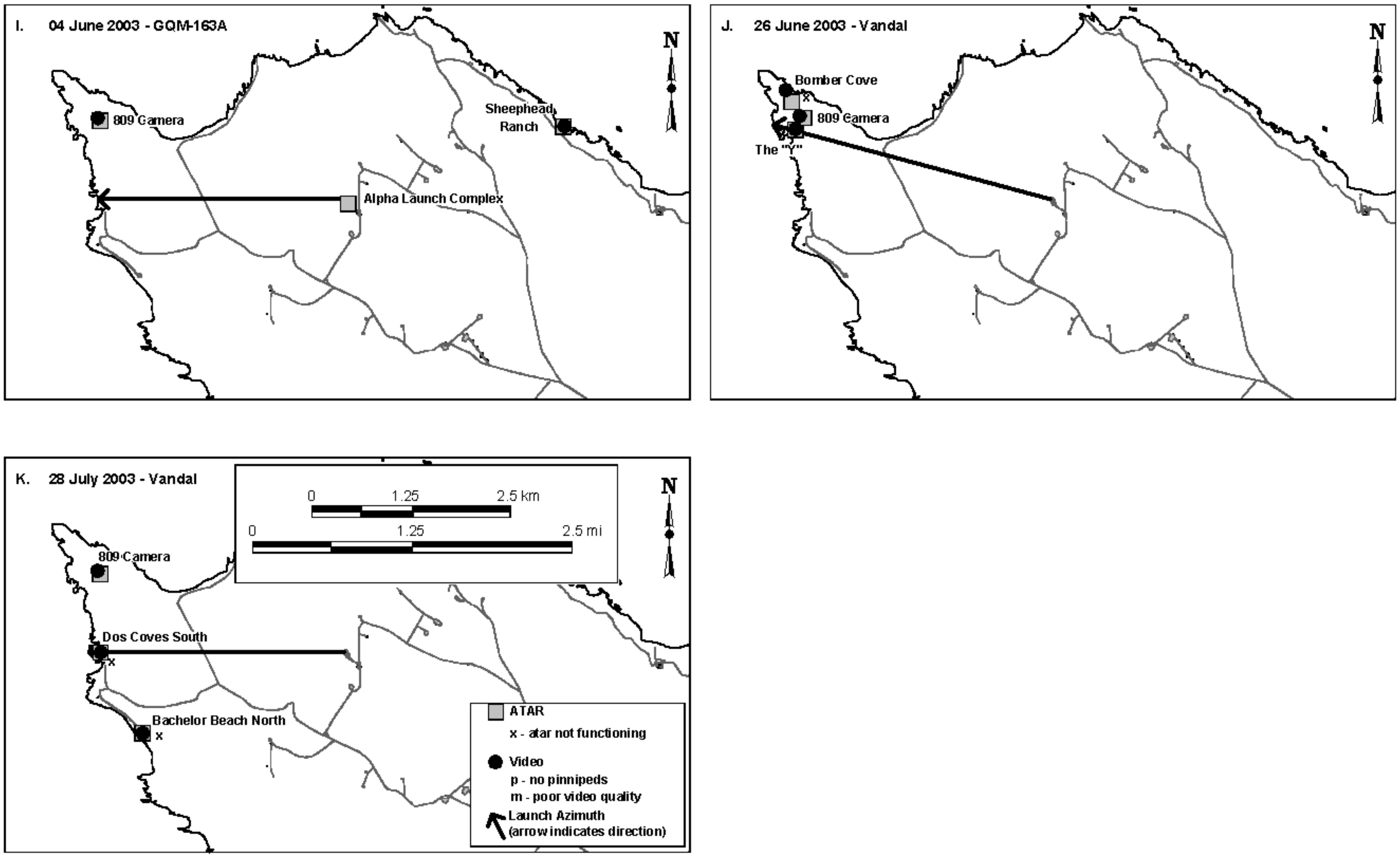


FIGURE B-2. (cont'd). Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at San Nicolas Island from 23 August 2002 to 28 July 2003. Note that GQM-163A = SSST.

APPENDIX C: ACOUSTIC DATA FROM INDIVIDUAL LAUNCHES FOR OCTOBER 2003–JANUARY 2005

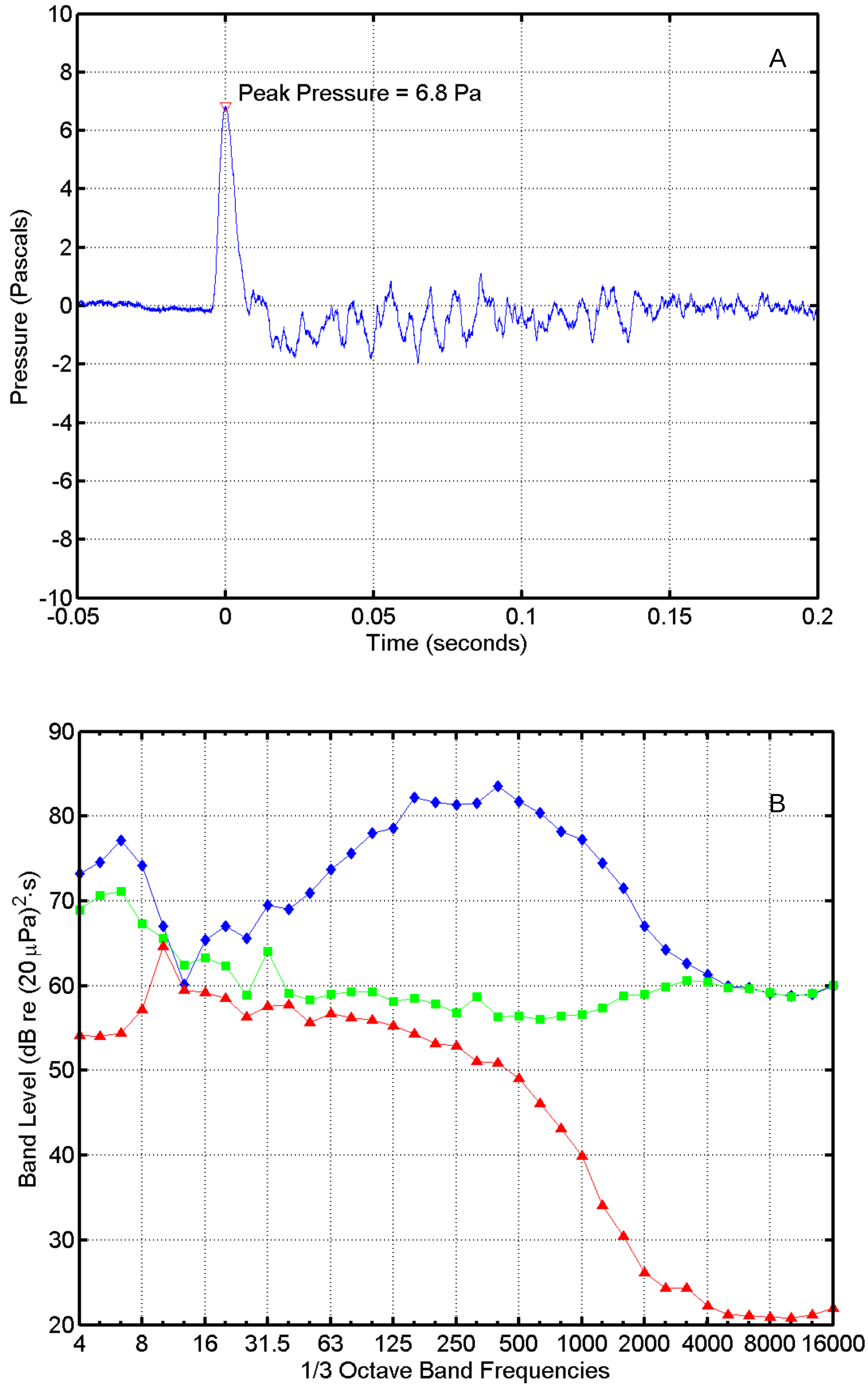


FIGURE C-1. (A) Pressure waveform and (B) one-third octave band levels for the first missile of the dual RAM launch at 11:46:00 on 5 May 2004 at "Dos Coves". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

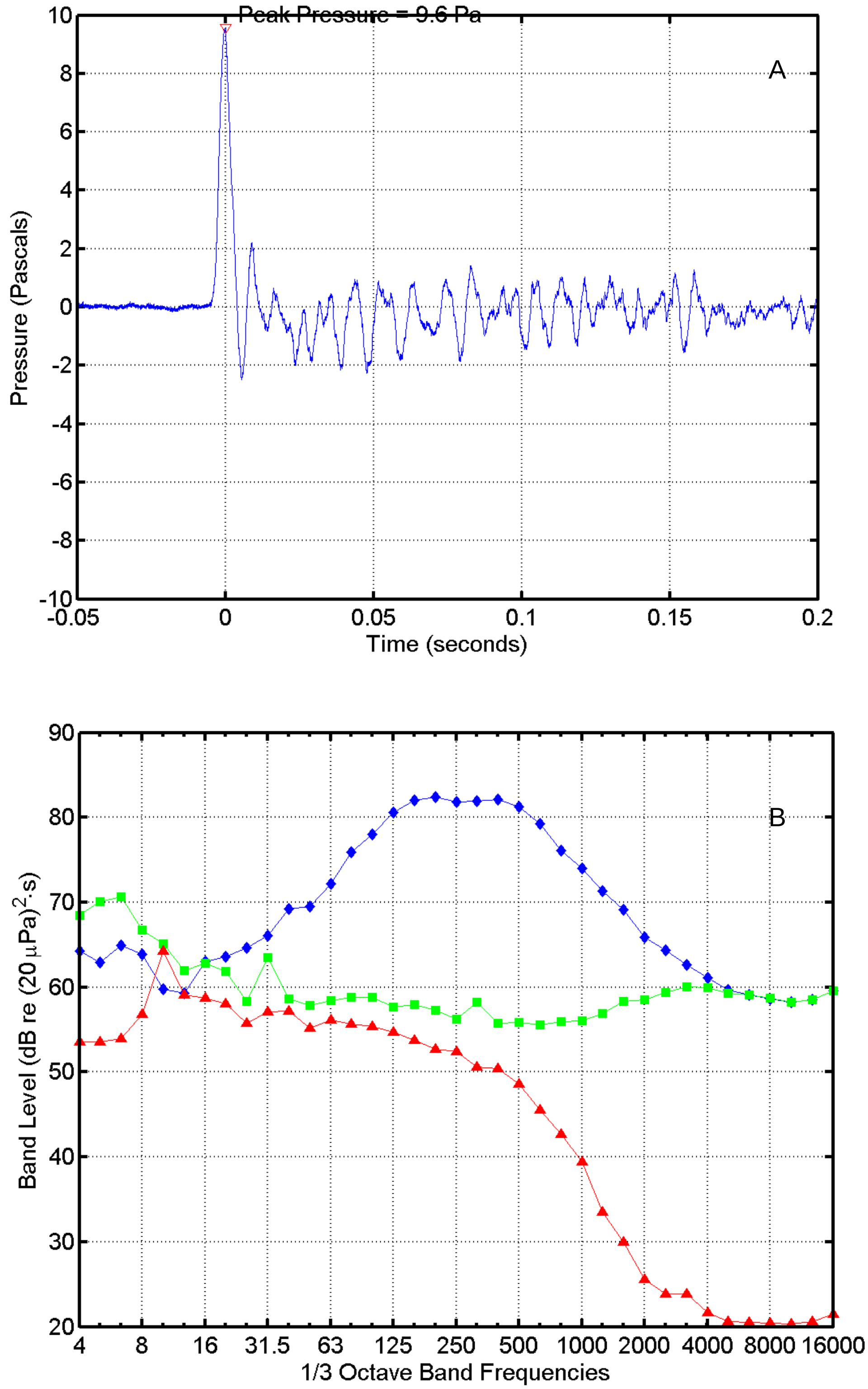


FIGURE C-2. (A) Pressure waveform and (B) one-third octave band levels for the second missile of the dual RAM launch at 11:46:12 on 5 May 2004 at "Dos Coves". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

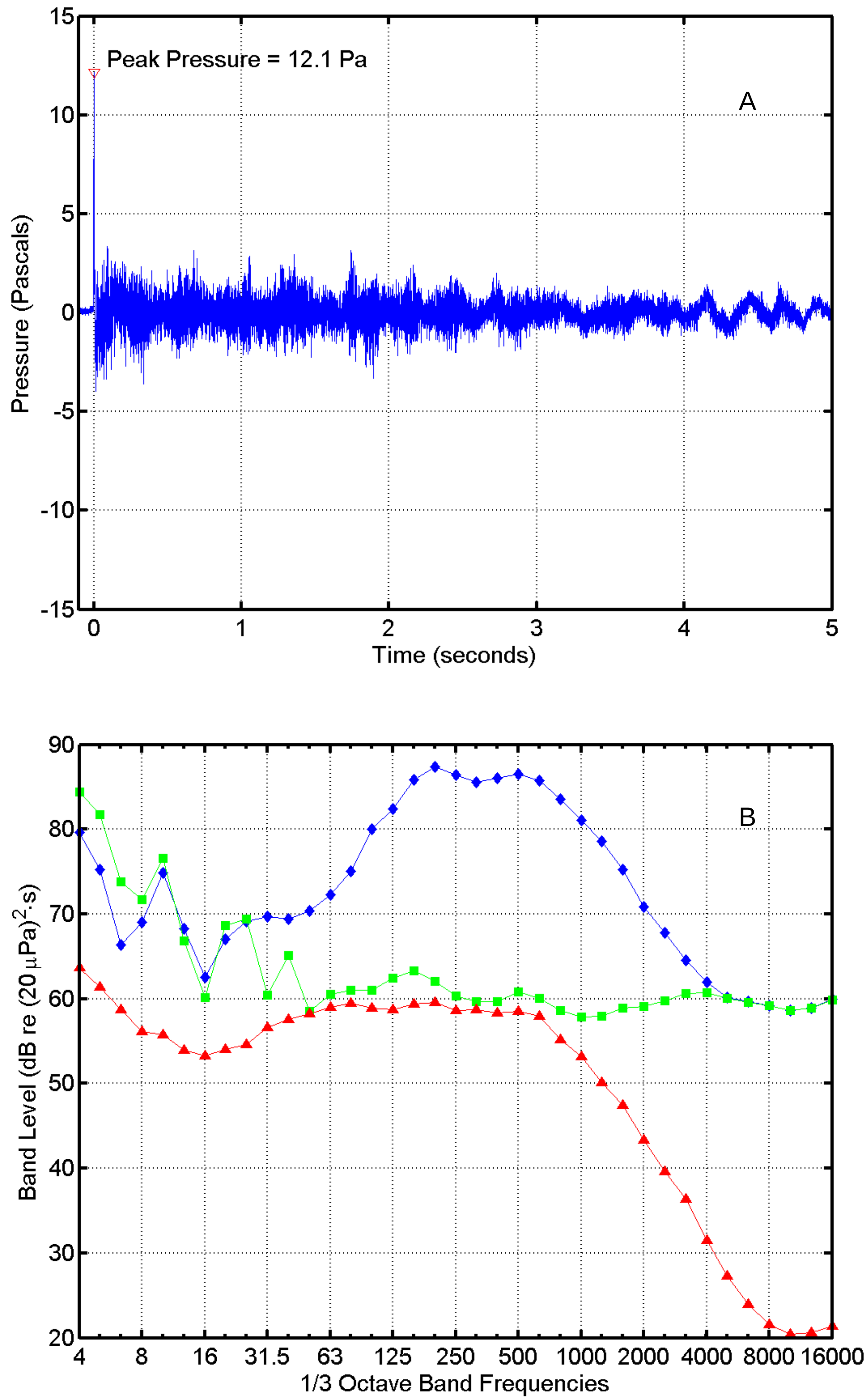


FIGURE C-3. (A) Pressure waveform and (B) one-third octave band levels for the first missile of the dual RAM launch at 11:46:00 on 5 May 2004 at "Bachelor Beach North". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

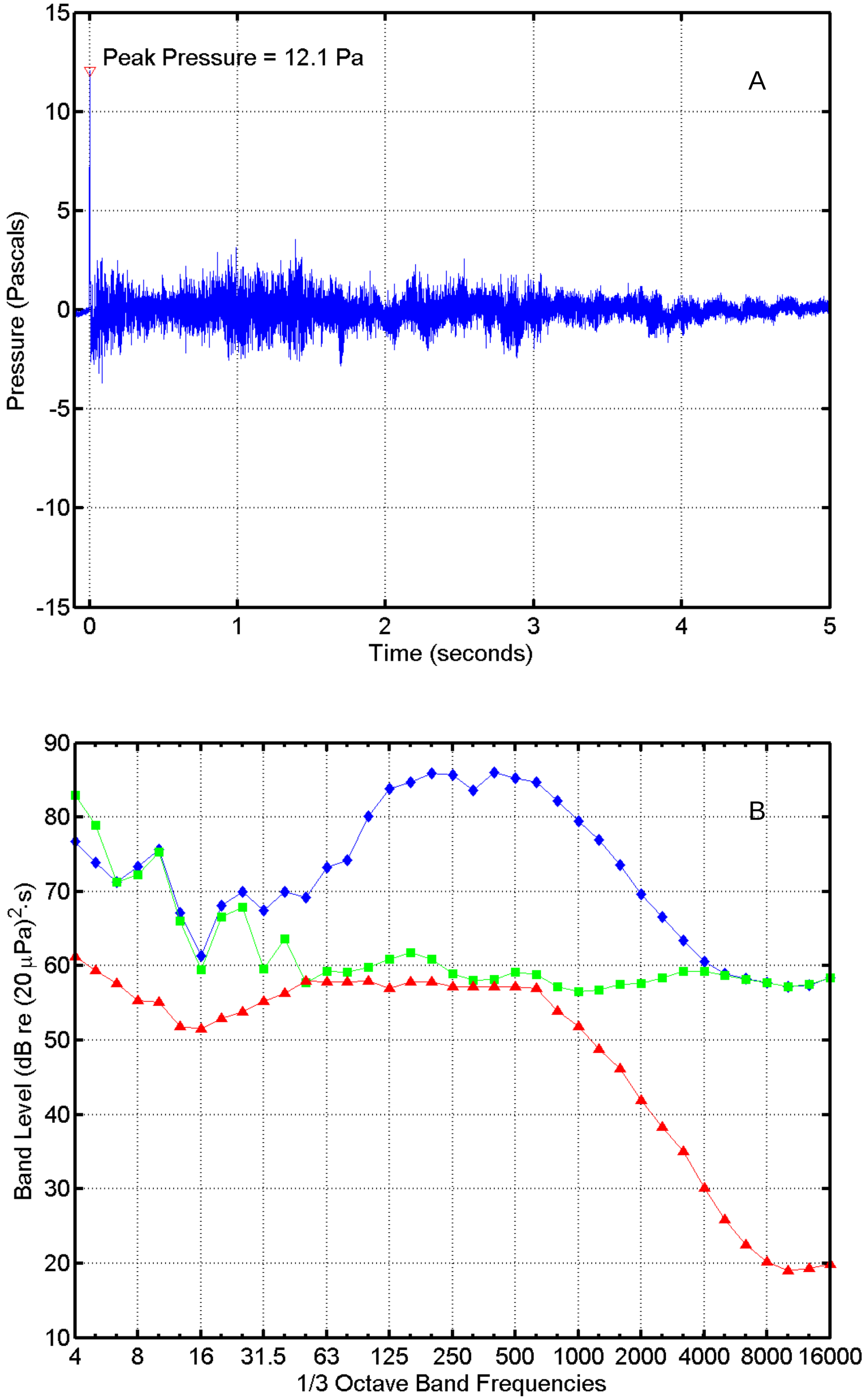


FIGURE C-4. (A) Pressure waveform and (B) one-third octave band levels for the second missile of the dual RAM launch at 11:46:12 on 5 May 2004 at "Bachelor Beach North". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

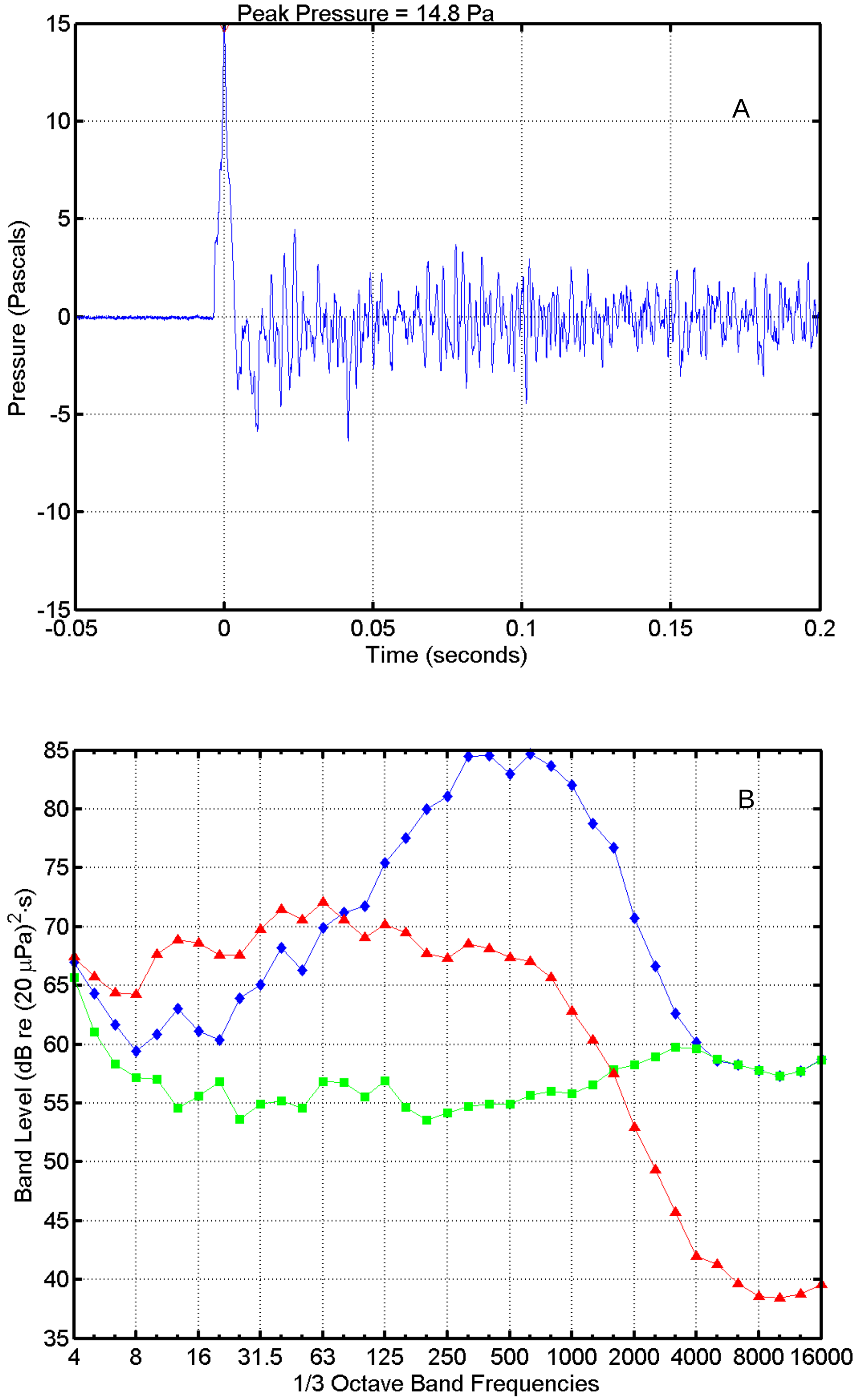


FIGURE C-5. (A) Pressure waveform and (B) one-third octave band levels for the first missile of the dual RAM launch at 11:46:00 on 5 May 2004 at "Bachelor Beach South". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

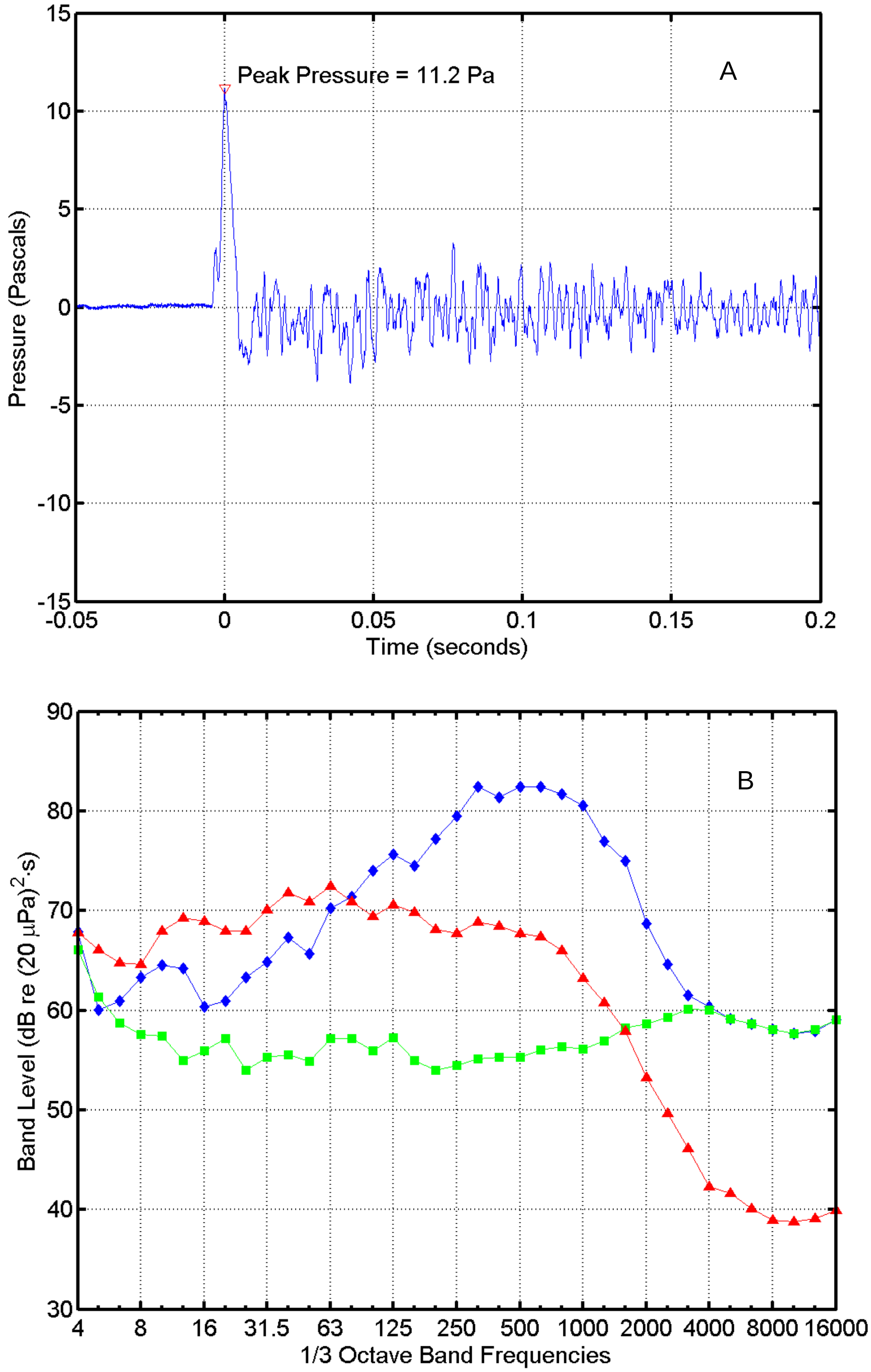
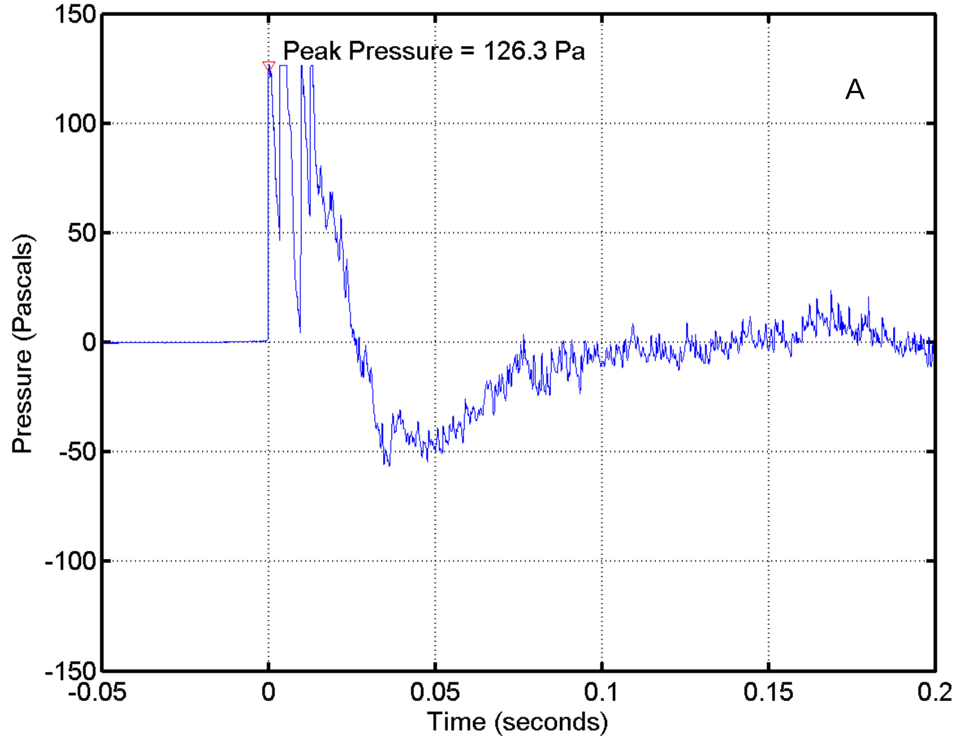


FIGURE C-6. (A) Pressure waveform and (B) one-third octave band levels for the second missile of the dual RAM launch at 11:46:12 on 5 May 2004 at "Bachelor Beach South". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).



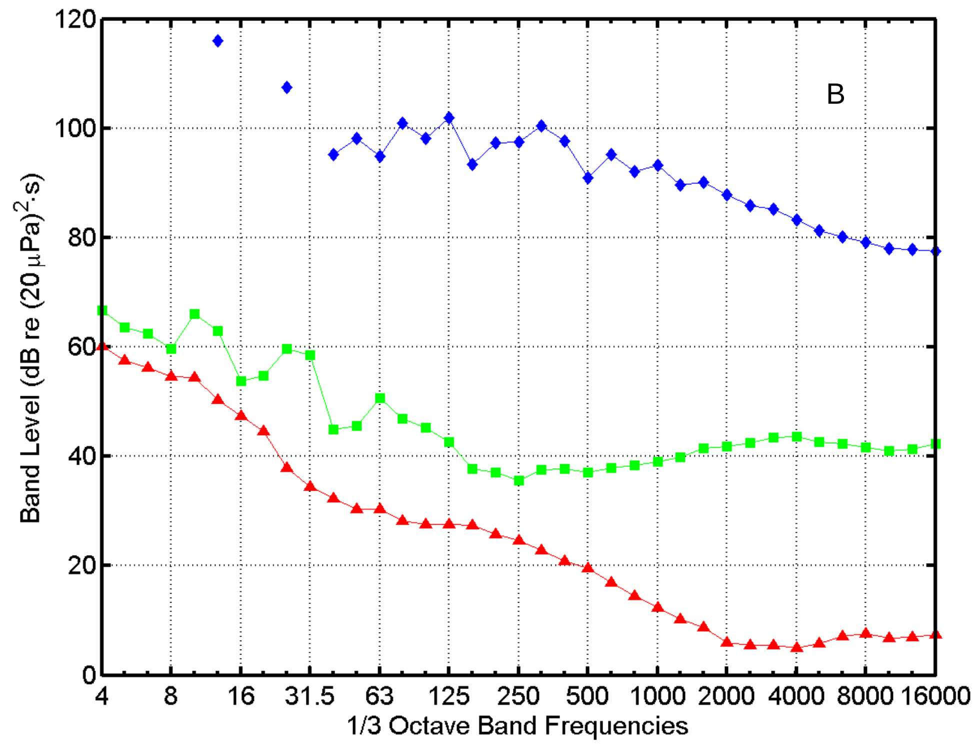


FIGURE C-7. (A) Pressure waveform and (B) one-third octave band levels for the SSST launch at 12:40 on 18 May 2004 at "Harbor Seal Overlook". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

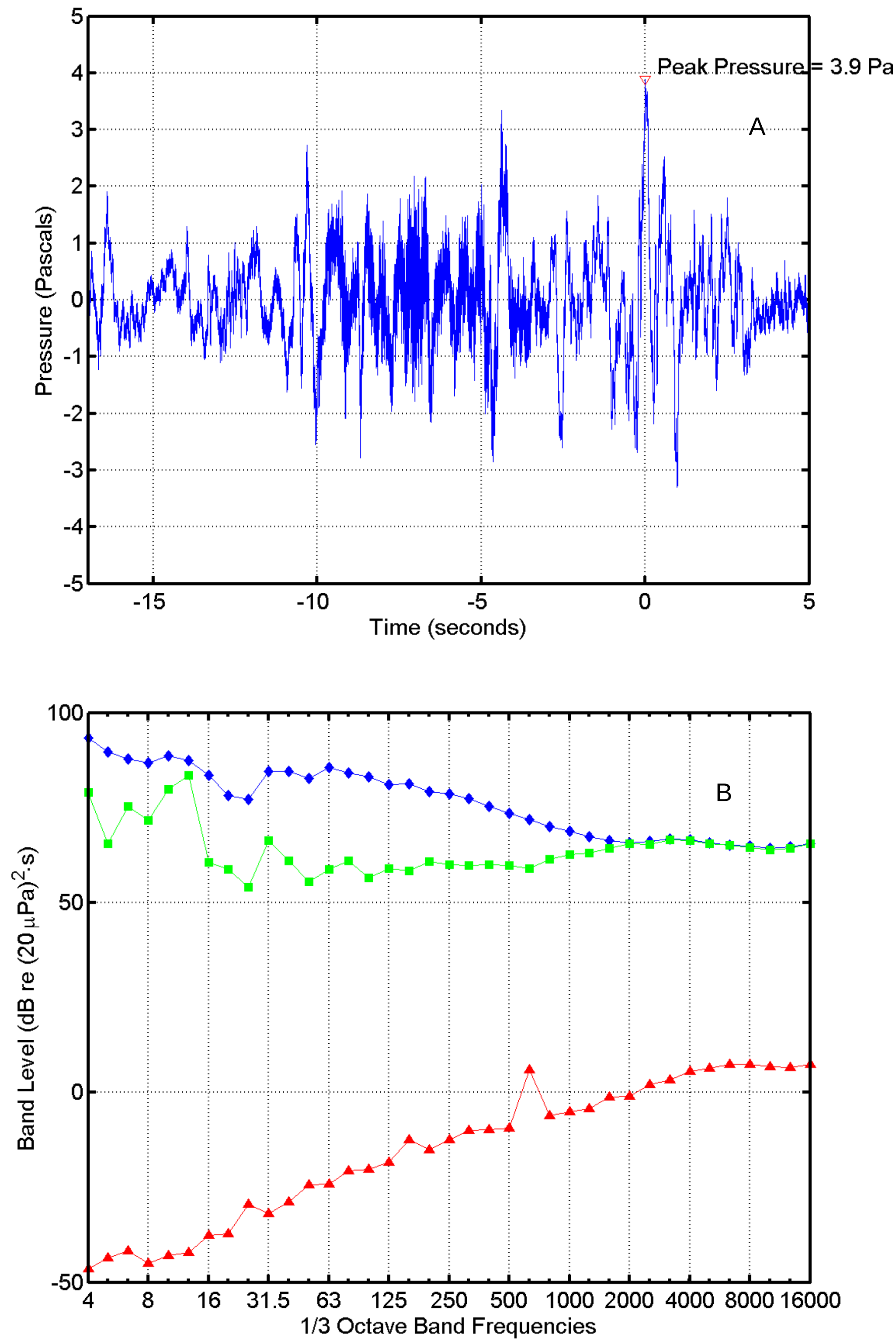
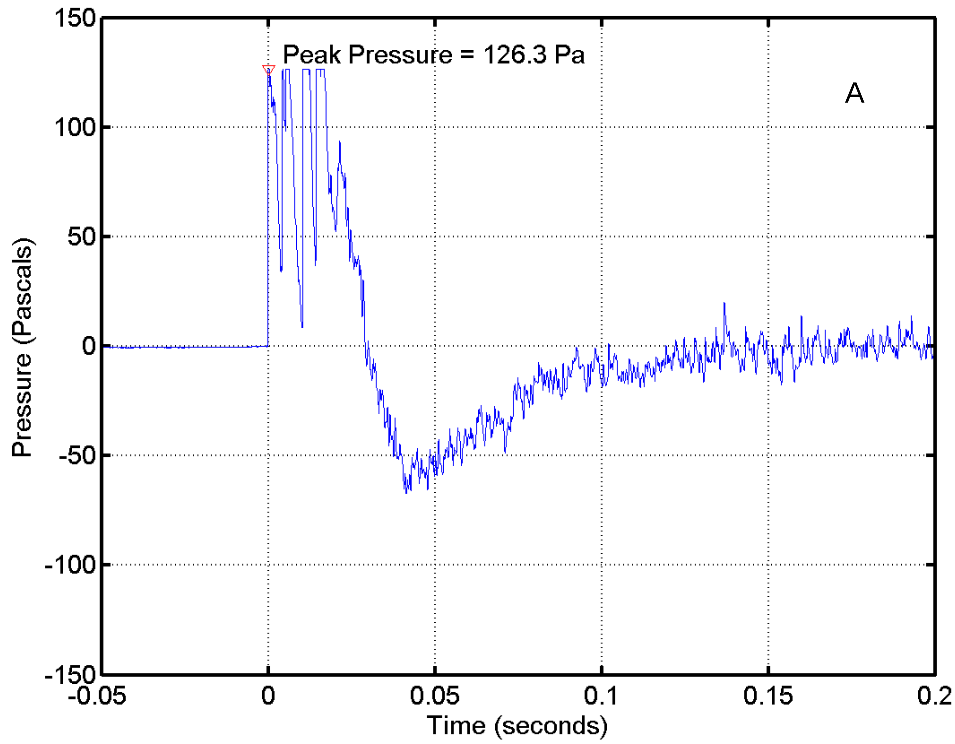


FIGURE C-8. (A) Pressure waveform and (B) one-third octave band levels for the SSST launch at 12:40 on 18 May 2004 at "Pirates Cove". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).



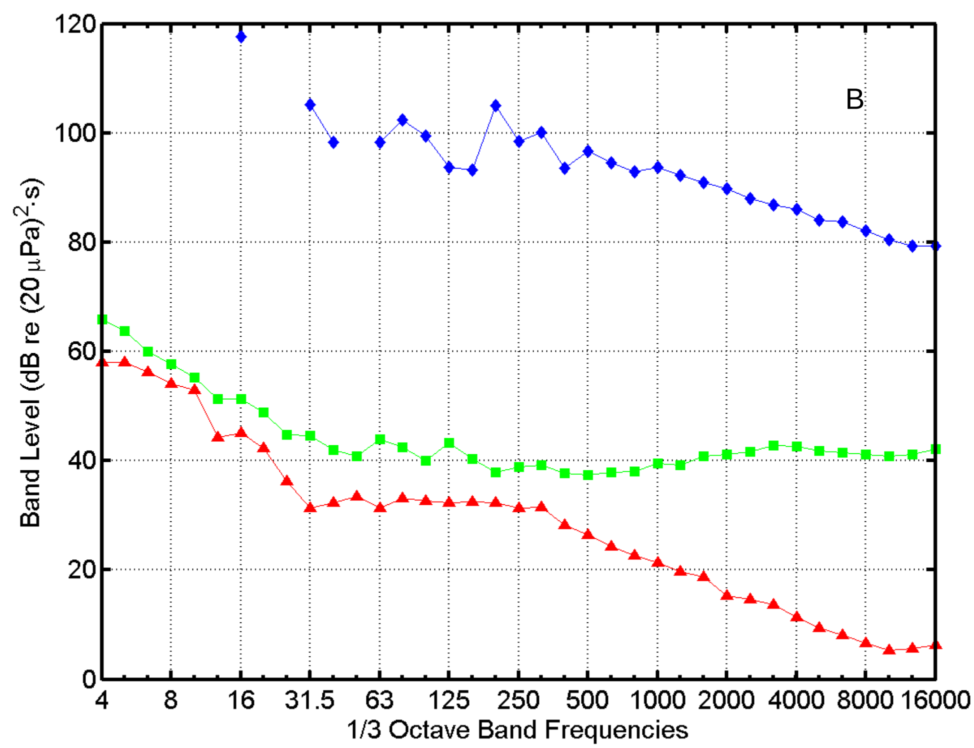


FIGURE C-9. (A) Pressure waveform and (B) one-third octave band levels for the SSST launch at 12:40 on 18 May 2004 at "Redeye I". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

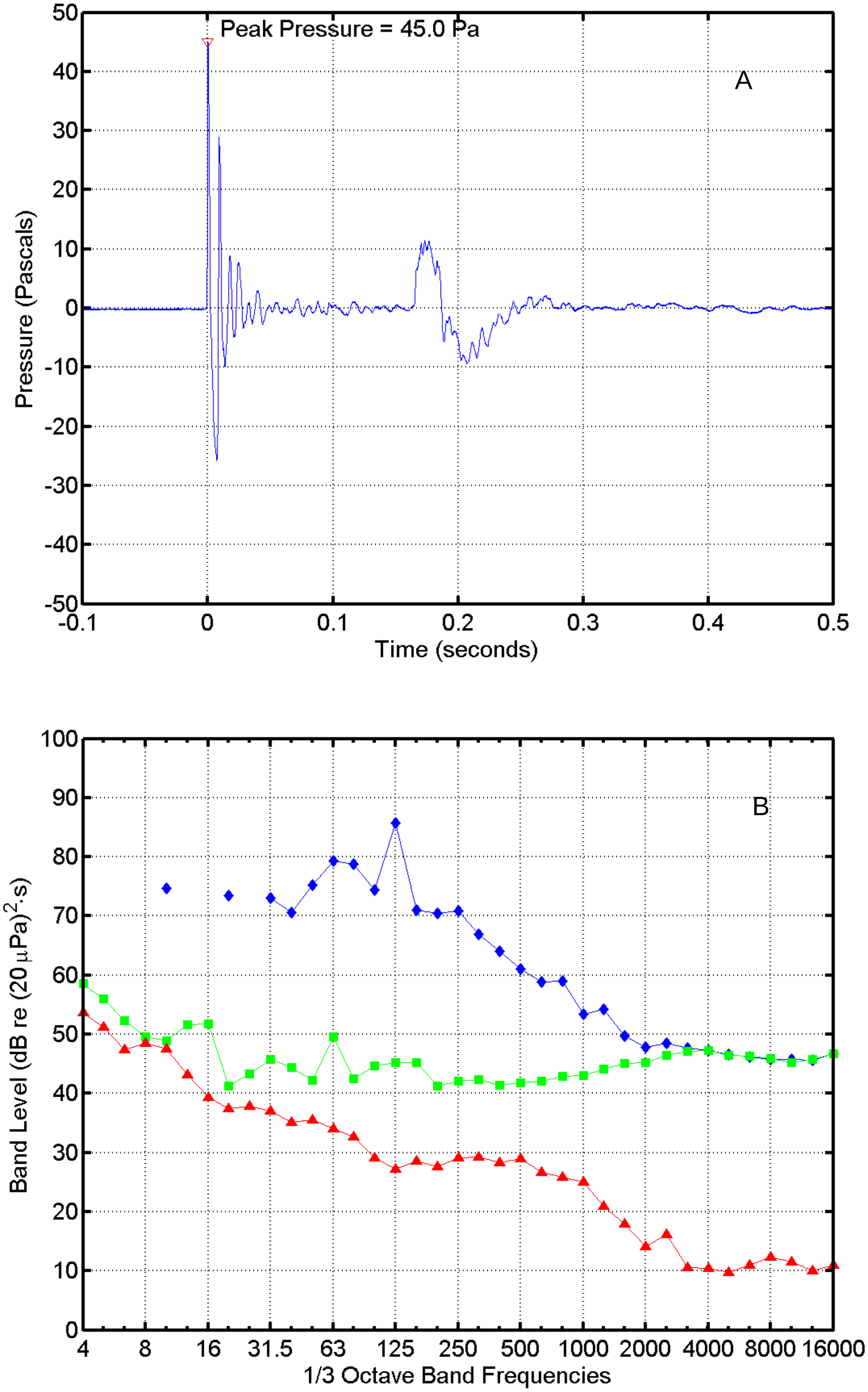


FIGURE C-10. (A) Pressure waveform and (B) one-third octave band levels for the AGS Slug launch at 11:31 on 3 June 2004 "Near 809 Camera". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

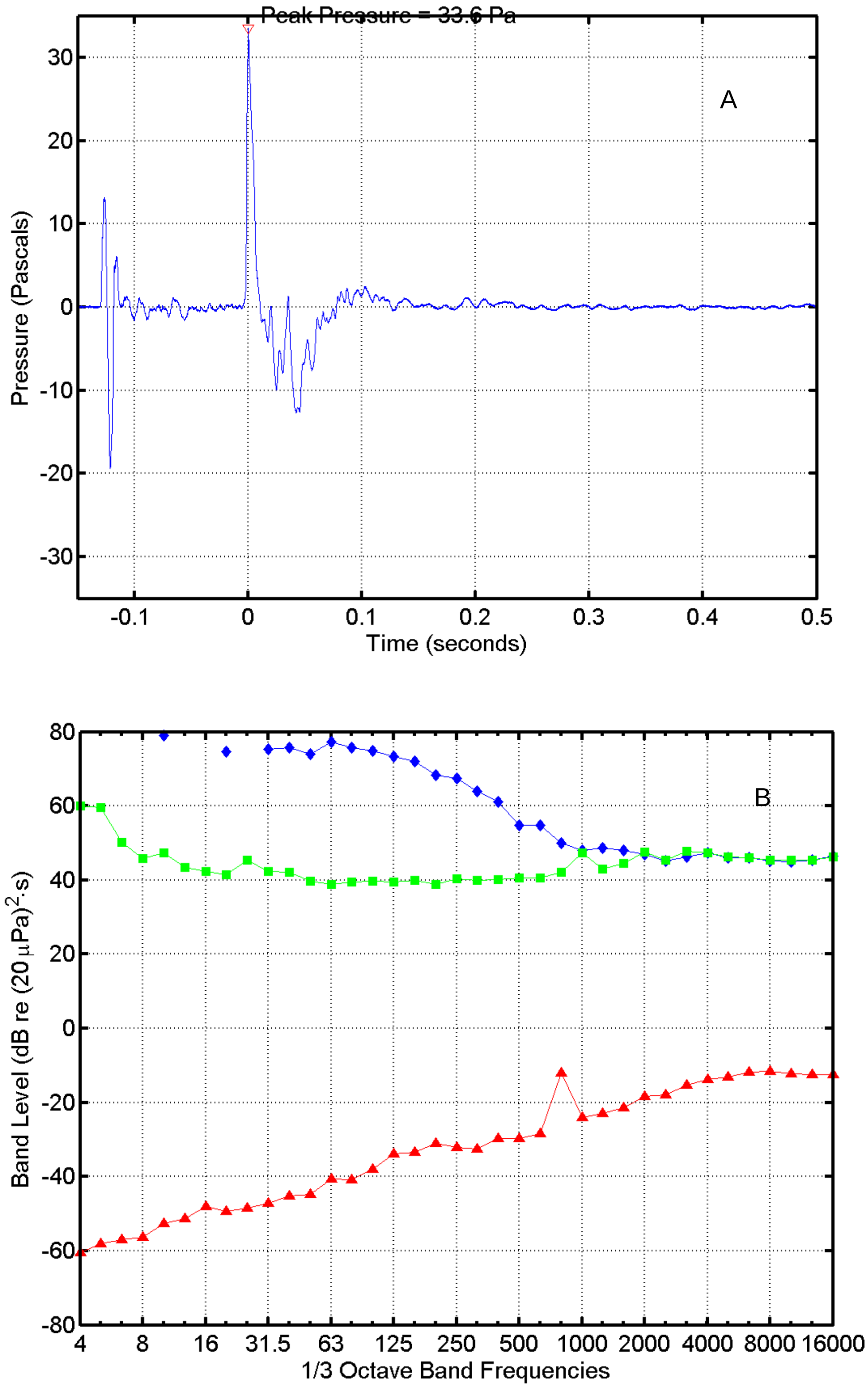


FIGURE C-11. (A) Pressure waveform and (B) one-third octave band levels for the AGS Slug launch at 11:31 on 3 June 2004 at "Harbor Seal Overlook". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

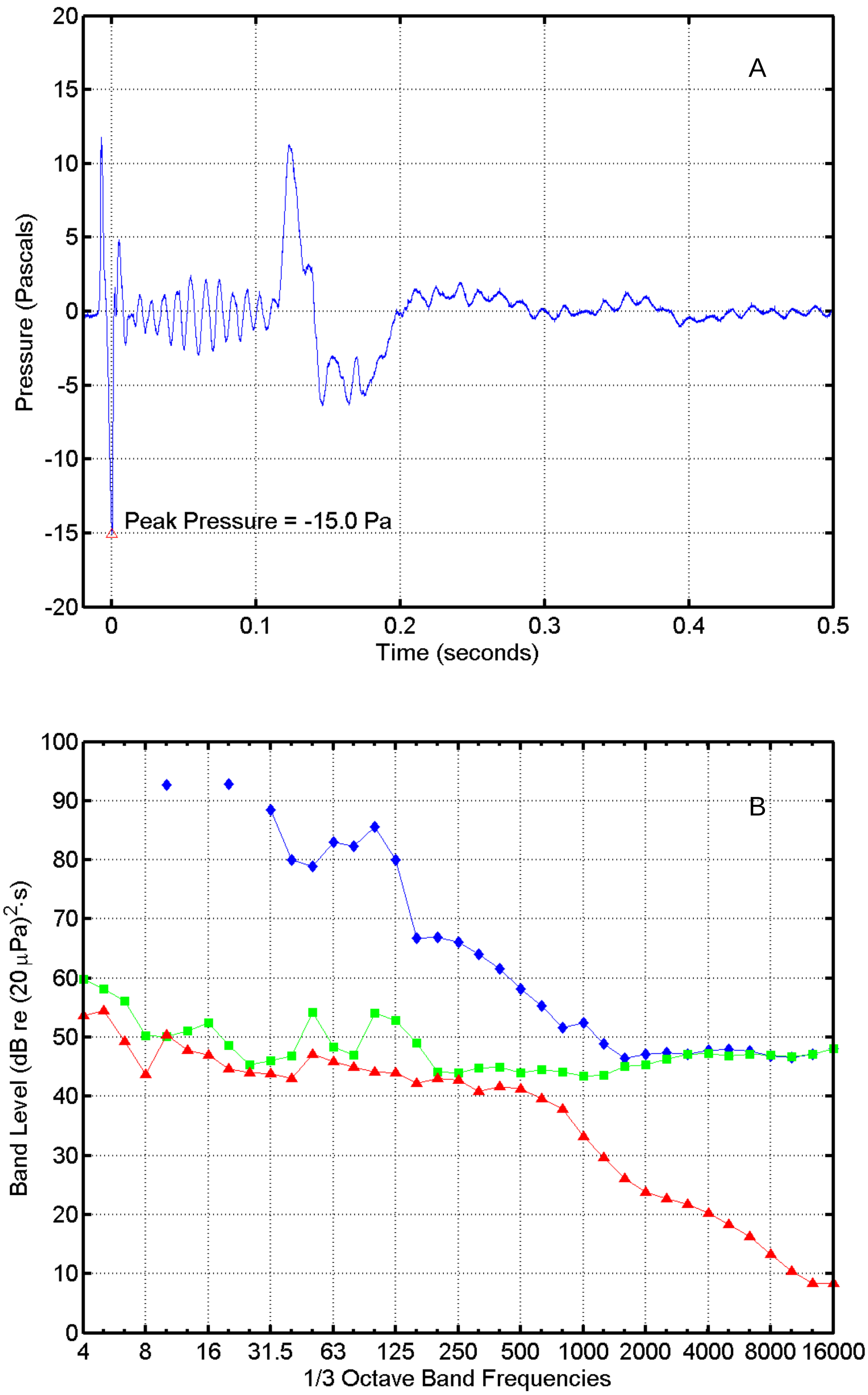


FIGURE C-12. (A) Pressure waveform and (B) one-third octave band levels for the AGS Slug launch at 11:31 on 3 June 2004 at "Dos Coves". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

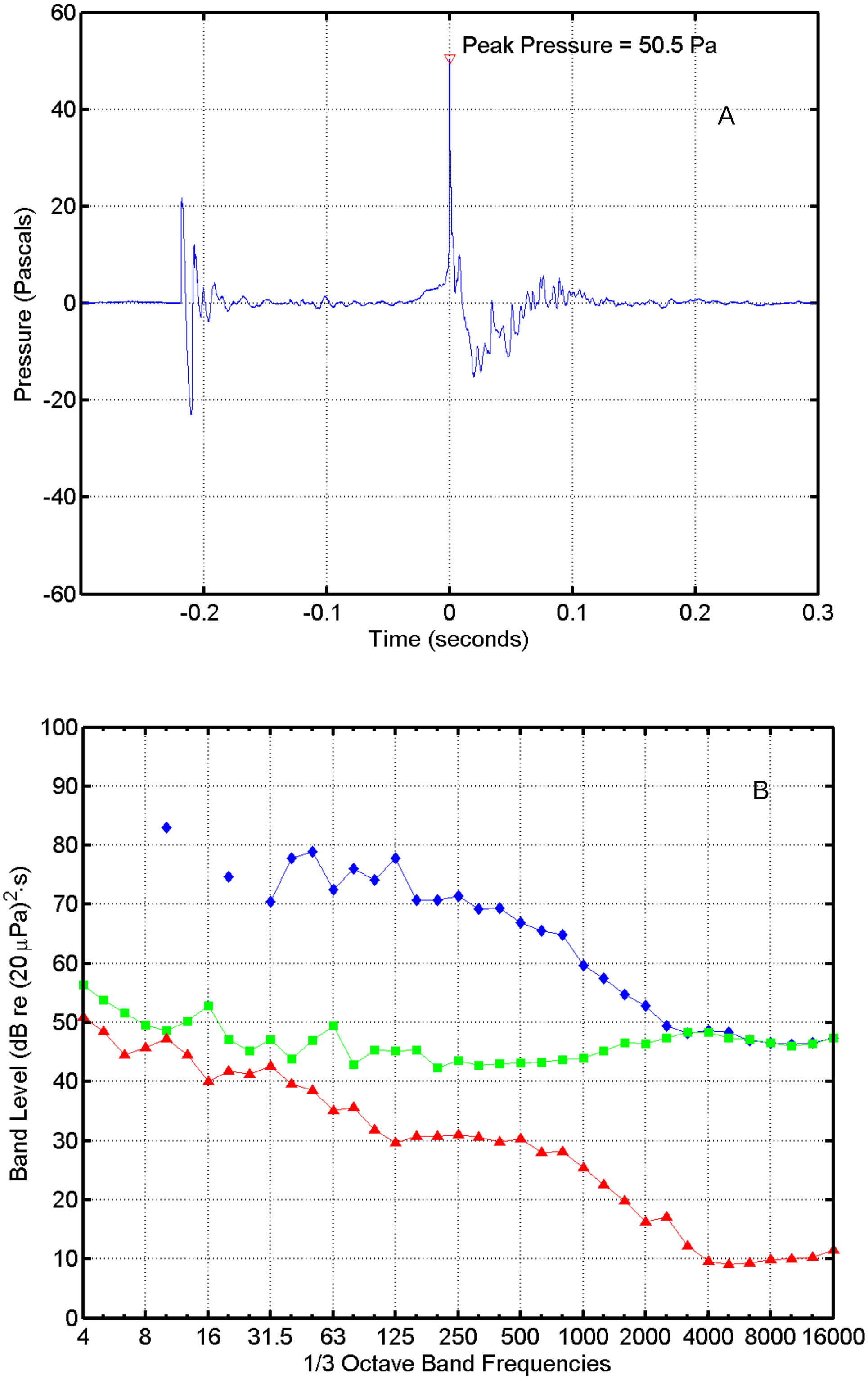


FIGURE C-13. (A) Pressure waveform and (B) one-third octave band levels for the AGS Slug launch at 13:22 on 3 June 2004 "Near 809 Camera". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

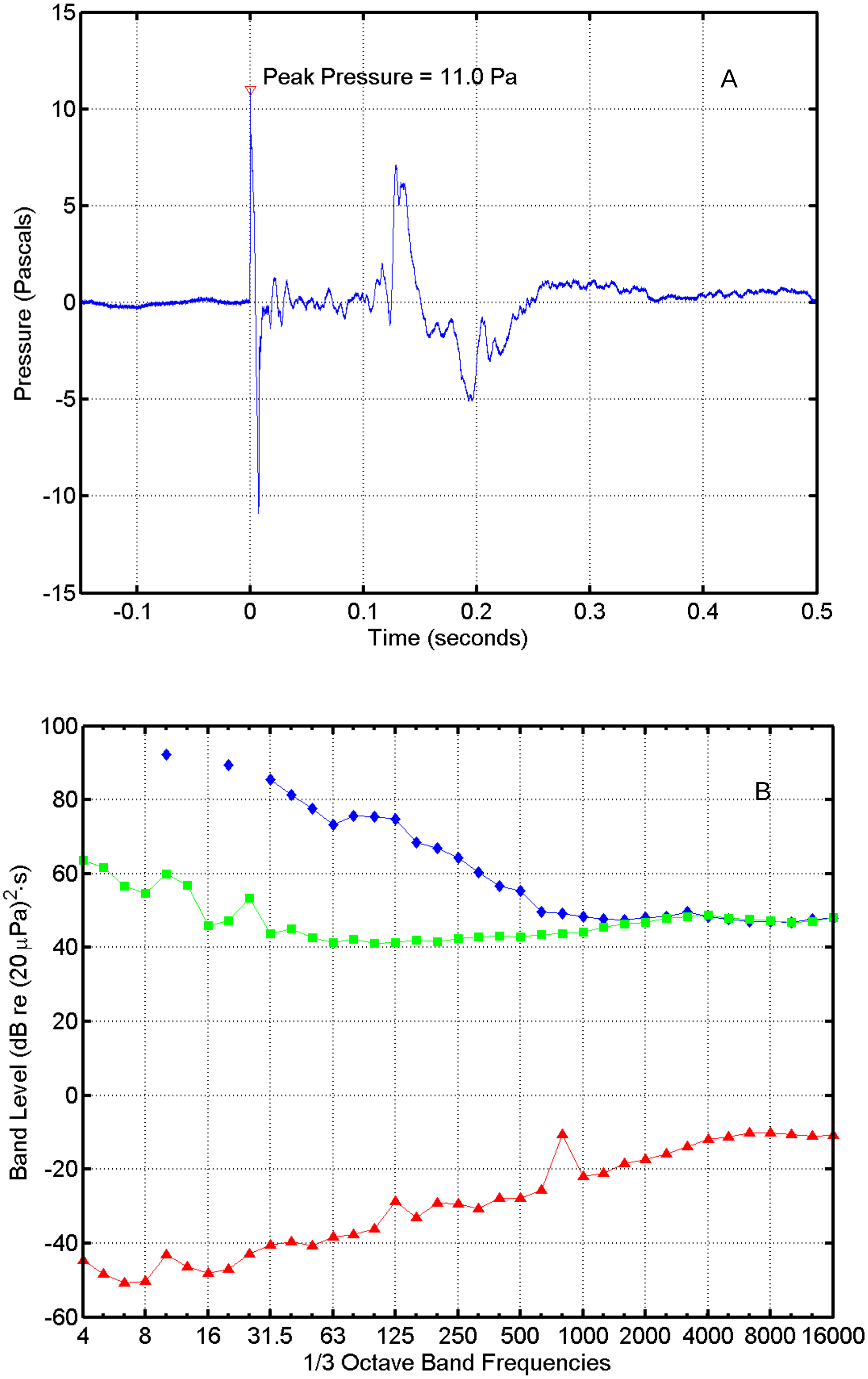


FIGURE C-14. (A) Pressure waveform and (B) one-third octave band levels for the AGS Slug launch at 13:22 on 3 June 2004 at "Harbor Seal Overlook". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

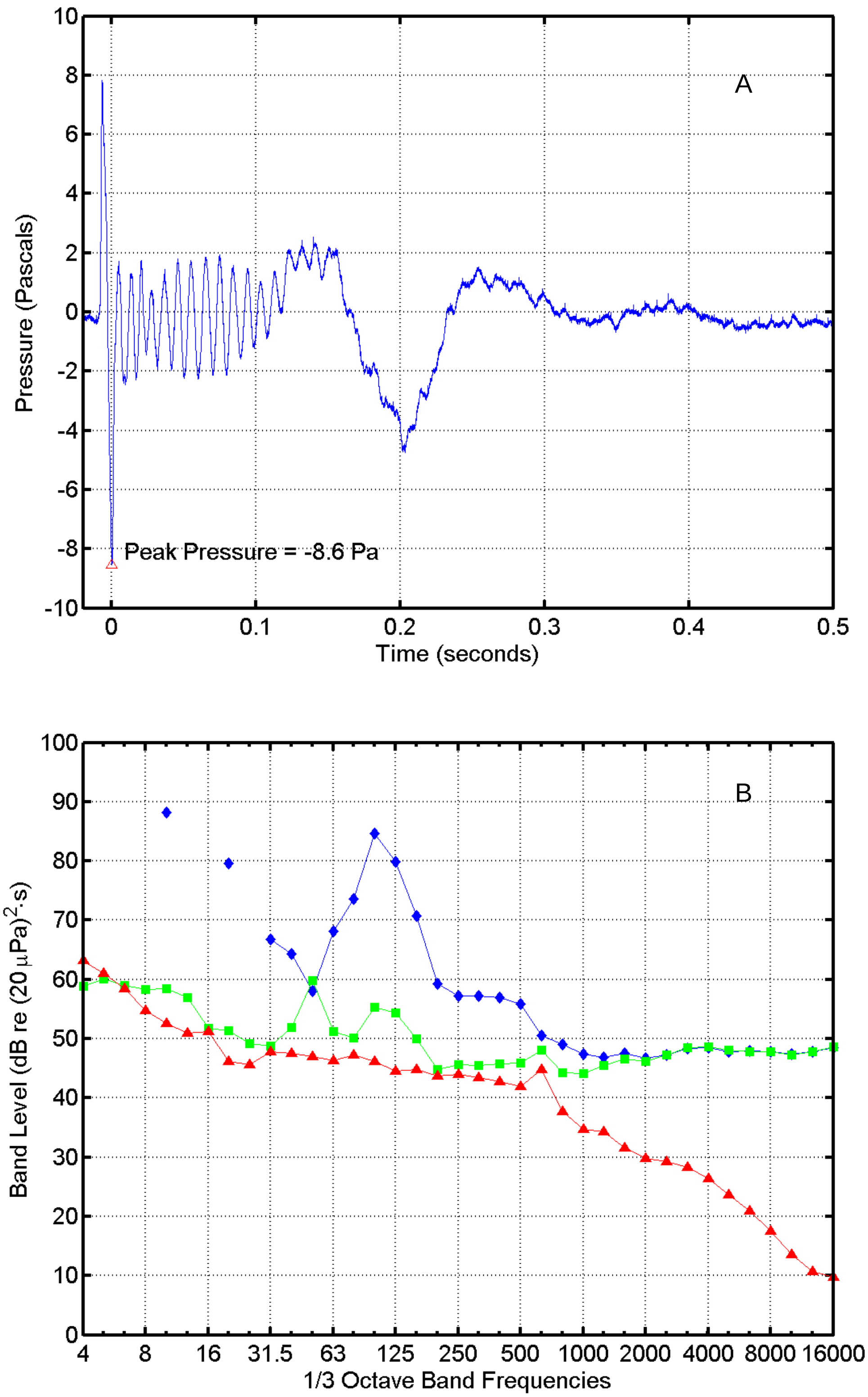
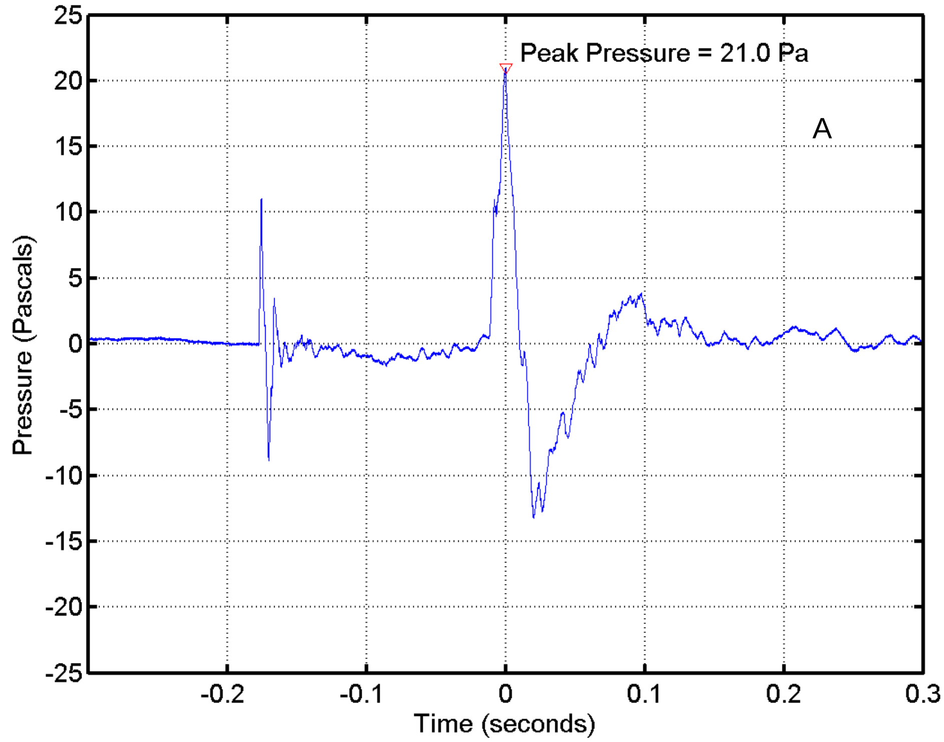


FIGURE C-15. (A) Pressure waveform and (B) one-third octave band levels for the AGS Slug launch at 13:22 on 3 June 2004 at "Dos Coves". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).



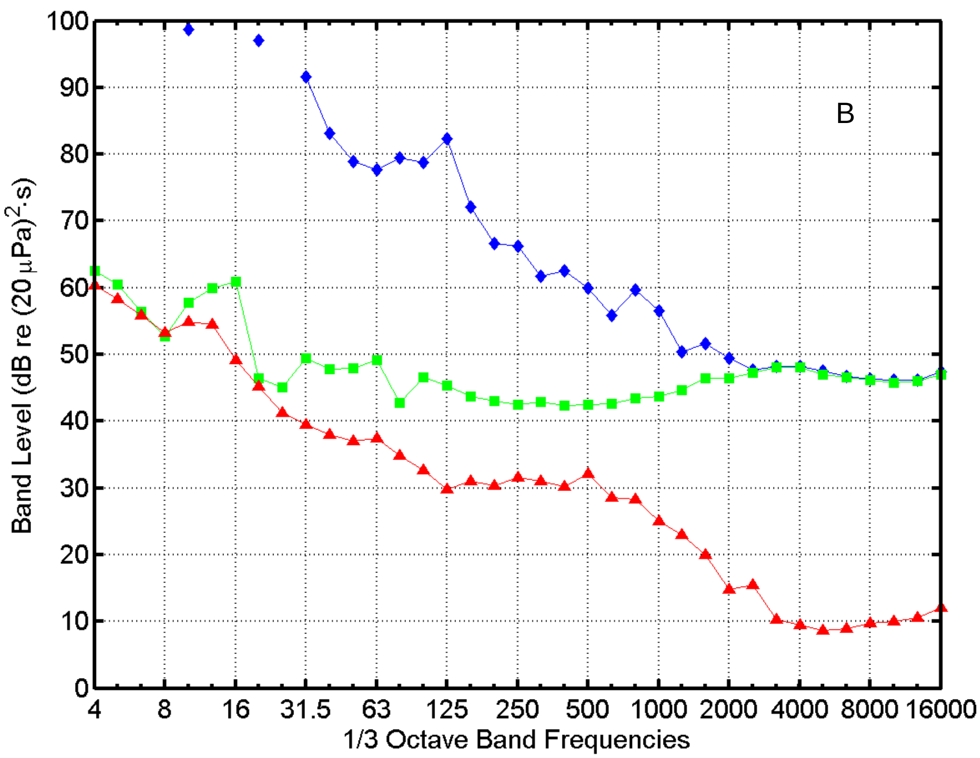


FIGURE C-16. (A) Pressure waveform and (B) one-third octave band levels for the AGS Missile launch at 15:08 on 3 June 2004 "Near 809 Camera". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

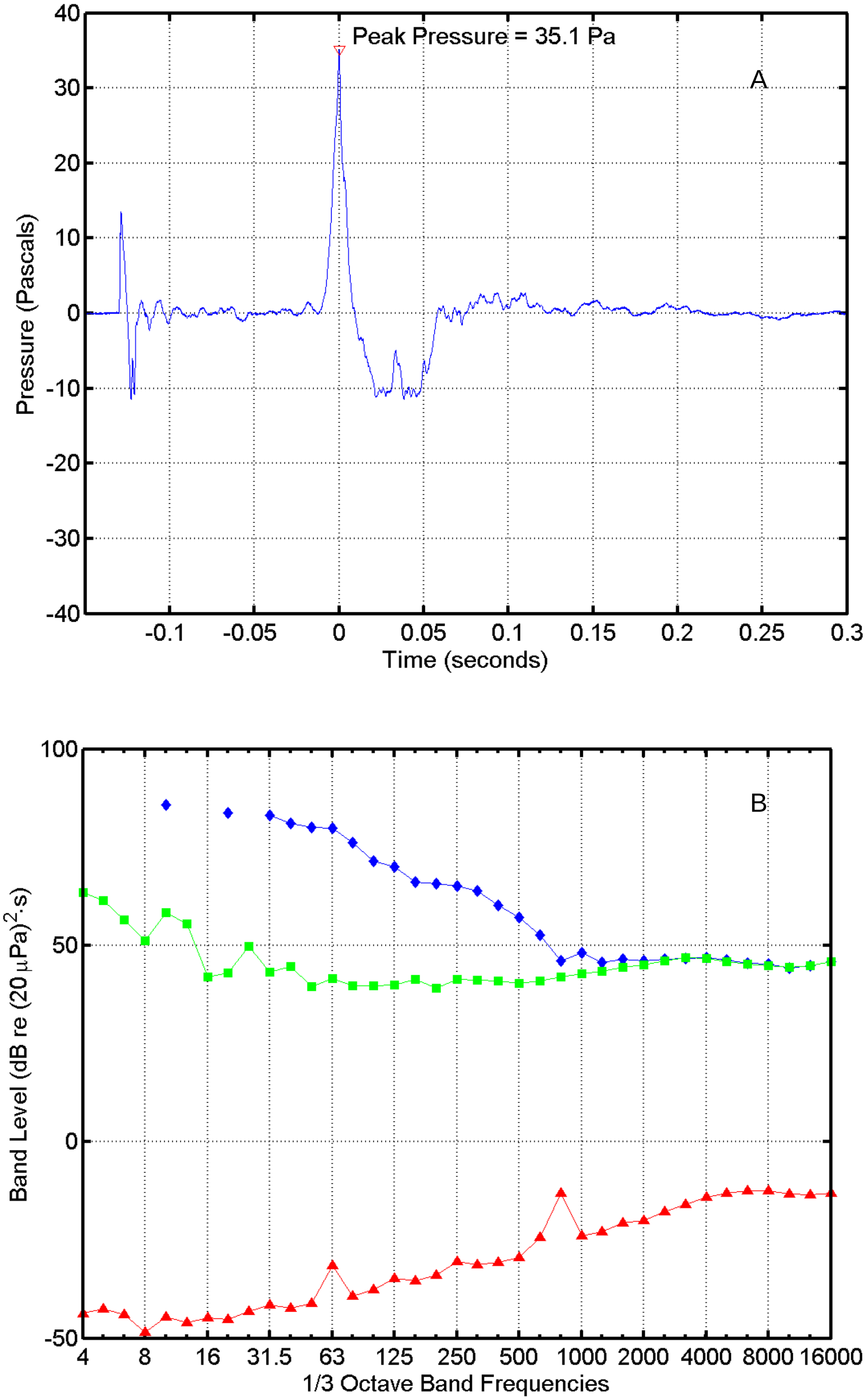


FIGURE C-17. (A) Pressure waveform and (B) one-third octave band levels for the AGS Missile launch at 15:08 on 3 June 2004 at "Harbor Seal Overlook". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

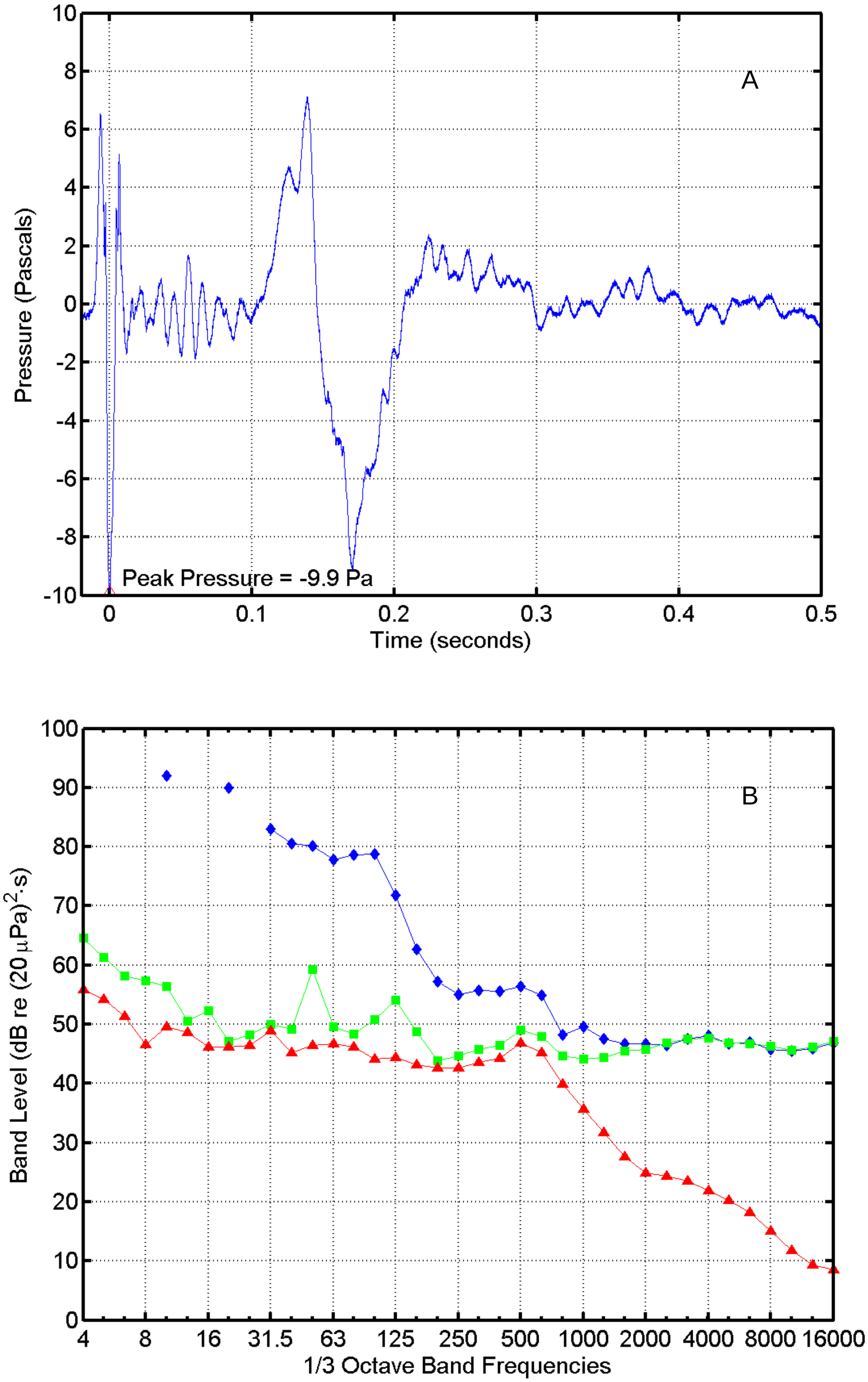


FIGURE C-18. (A) Pressure waveform and (B) one-third octave band levels for the AGS Missile launch at 15:08 on 3 June 2004 at "Dos Coves". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

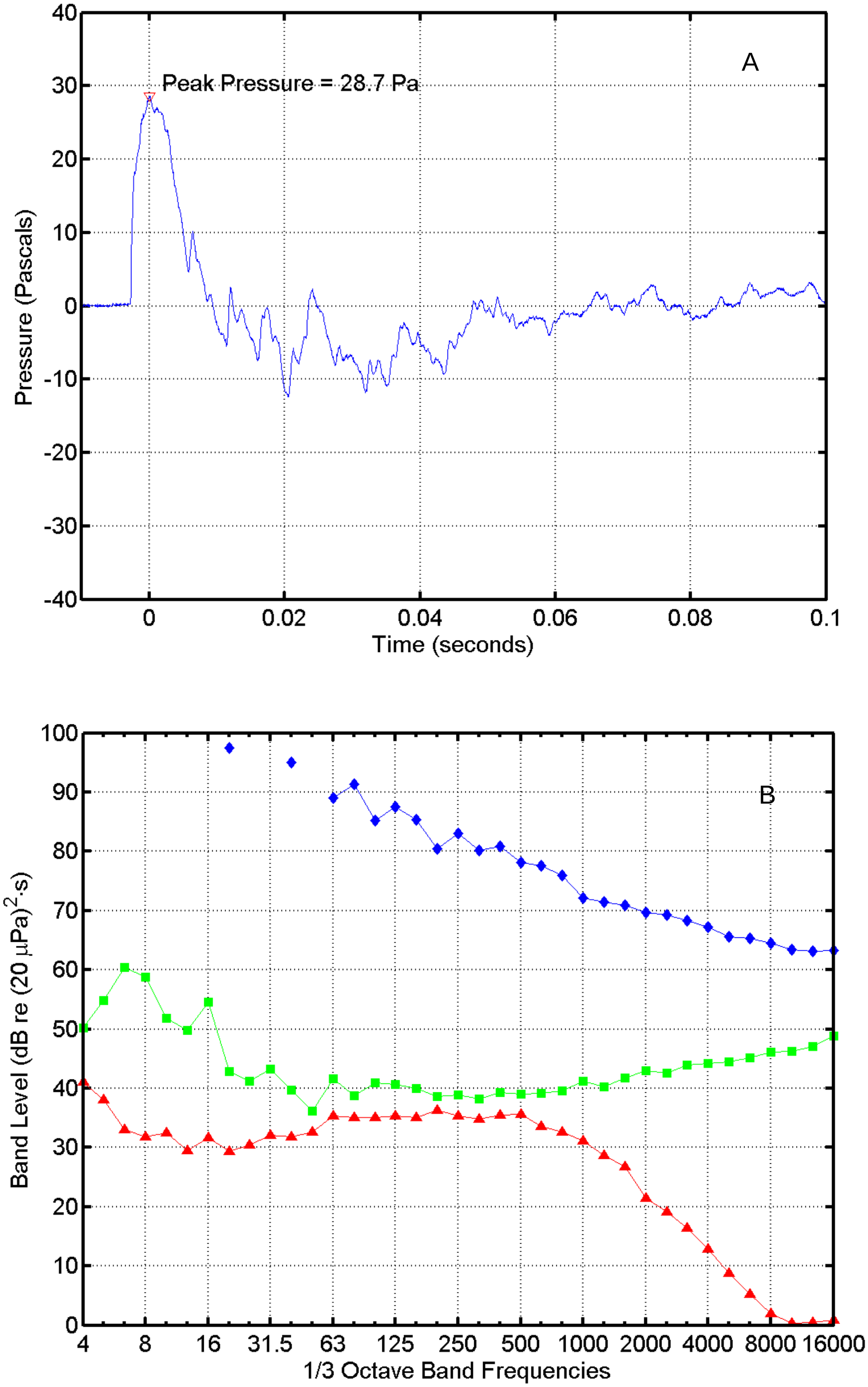


FIGURE C-19. (A) Pressure waveform and (B) one-third octave band levels for the AGS Slug launch at 15:10 on 26 July 2004 at "Bachelor Beach North". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

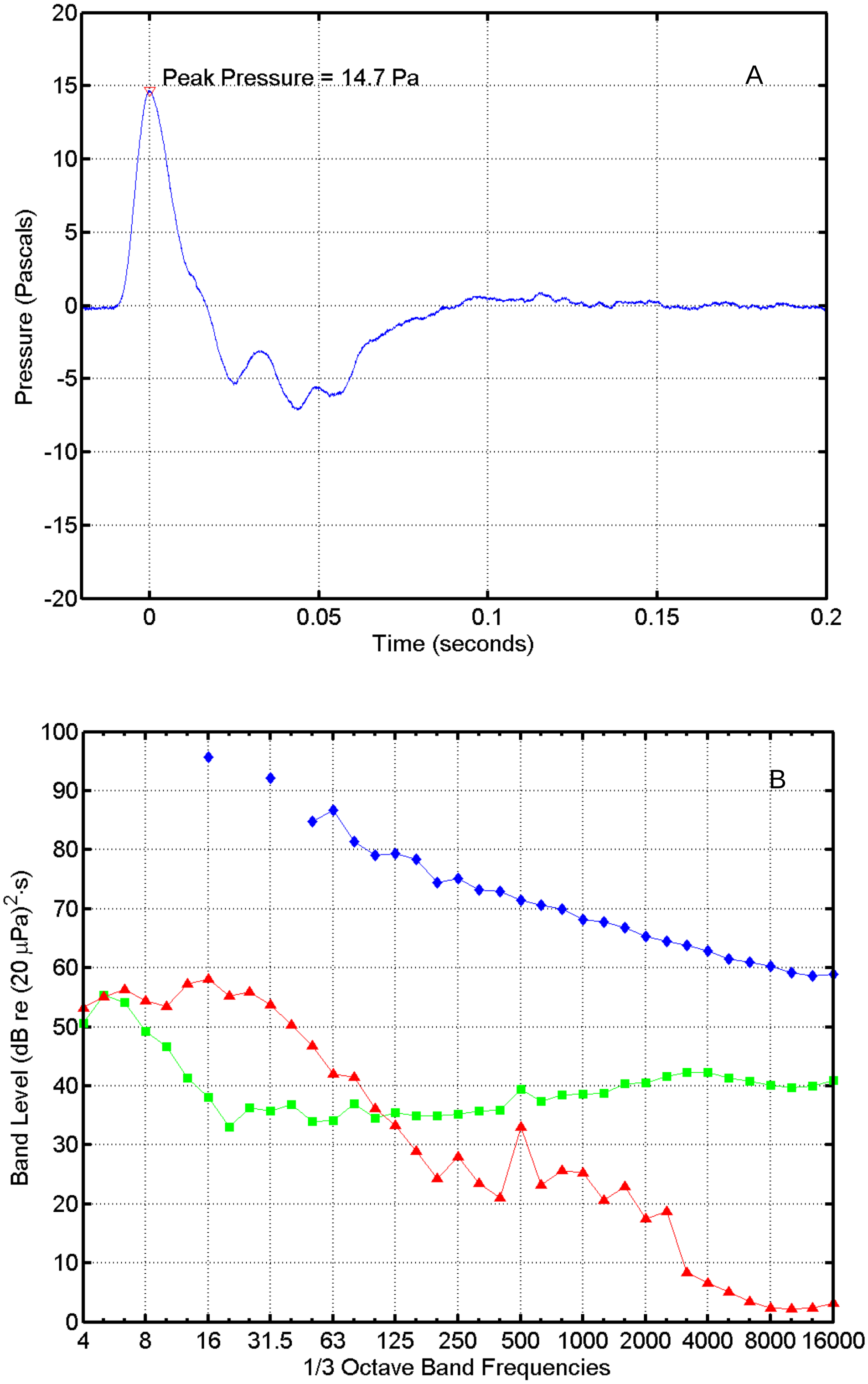


FIGURE C-20. (A) Pressure waveform and (B) one-third octave band levels for the AGS Slug launch at 15:10 on 26 July 2004 at "Vizcaino Point". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

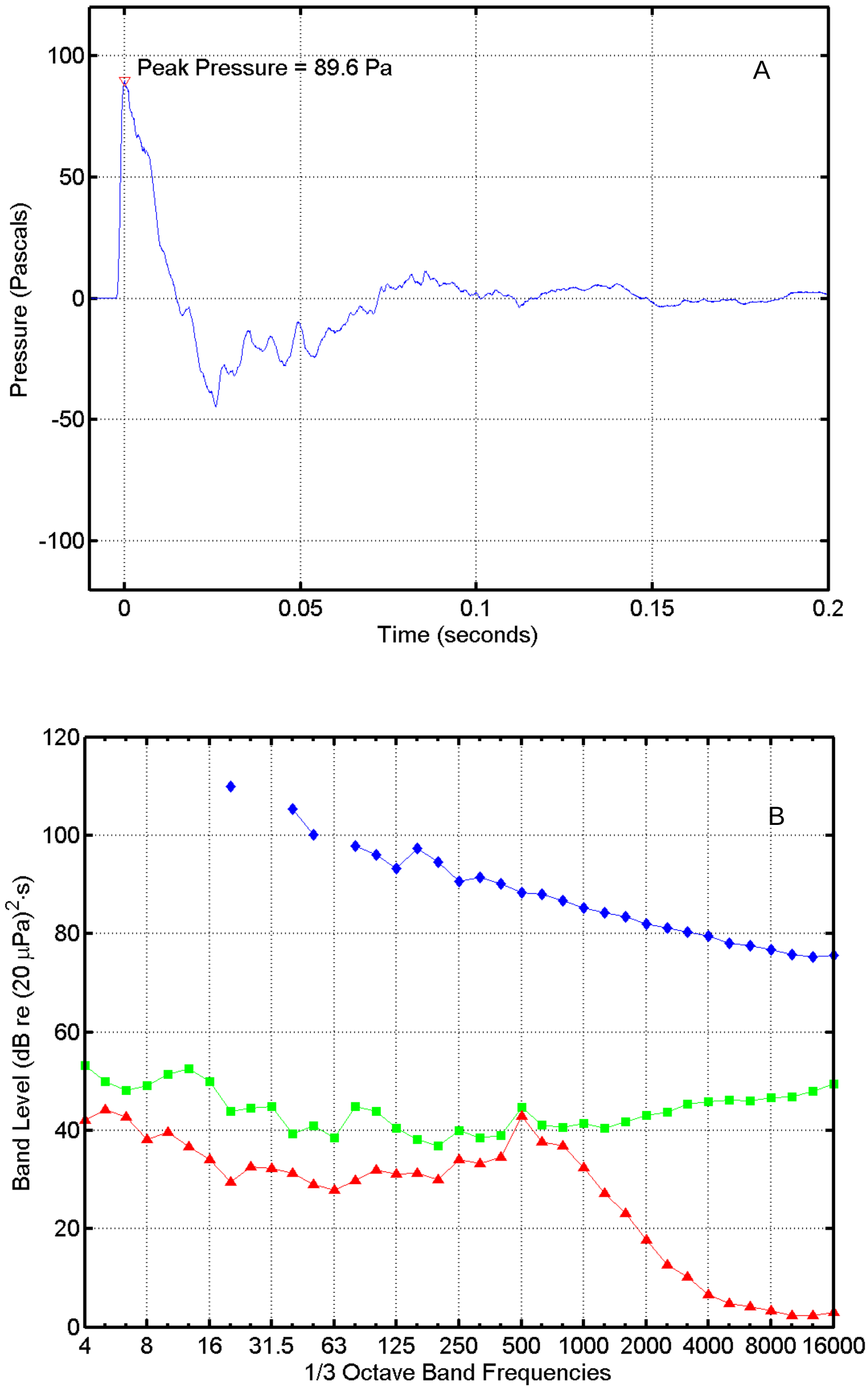


FIGURE C-21. (A) Pressure waveform and (B) one-third octave band levels for the AGS Slug launch at 15:10 on 26 July 2004 at "Dos Coves South". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

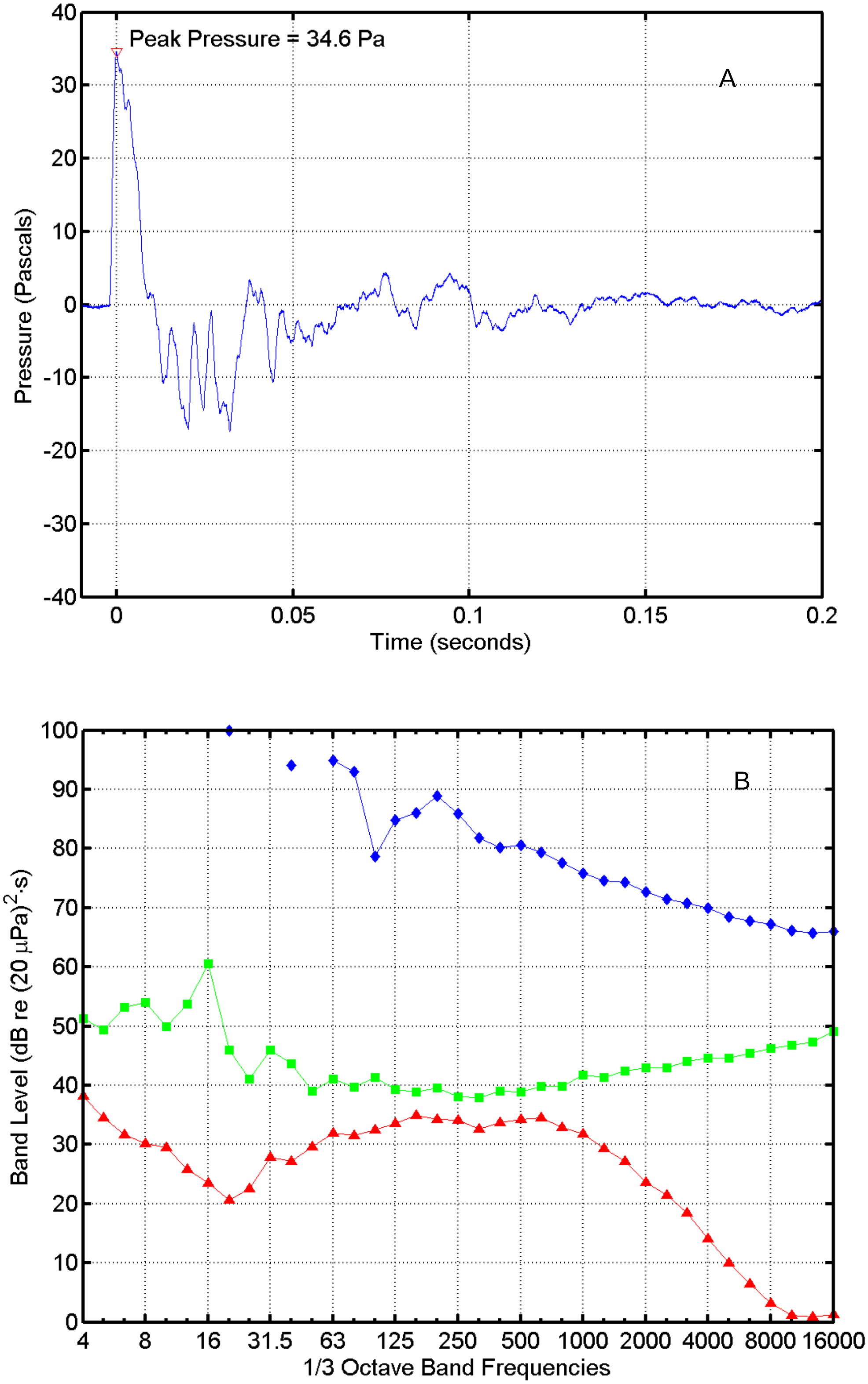


FIGURE C-22. (A) Pressure waveform and (B) one-third octave band levels for the AGS Slug launch at 15:43 on 26 July 2004 at "Bachelor Beach North". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

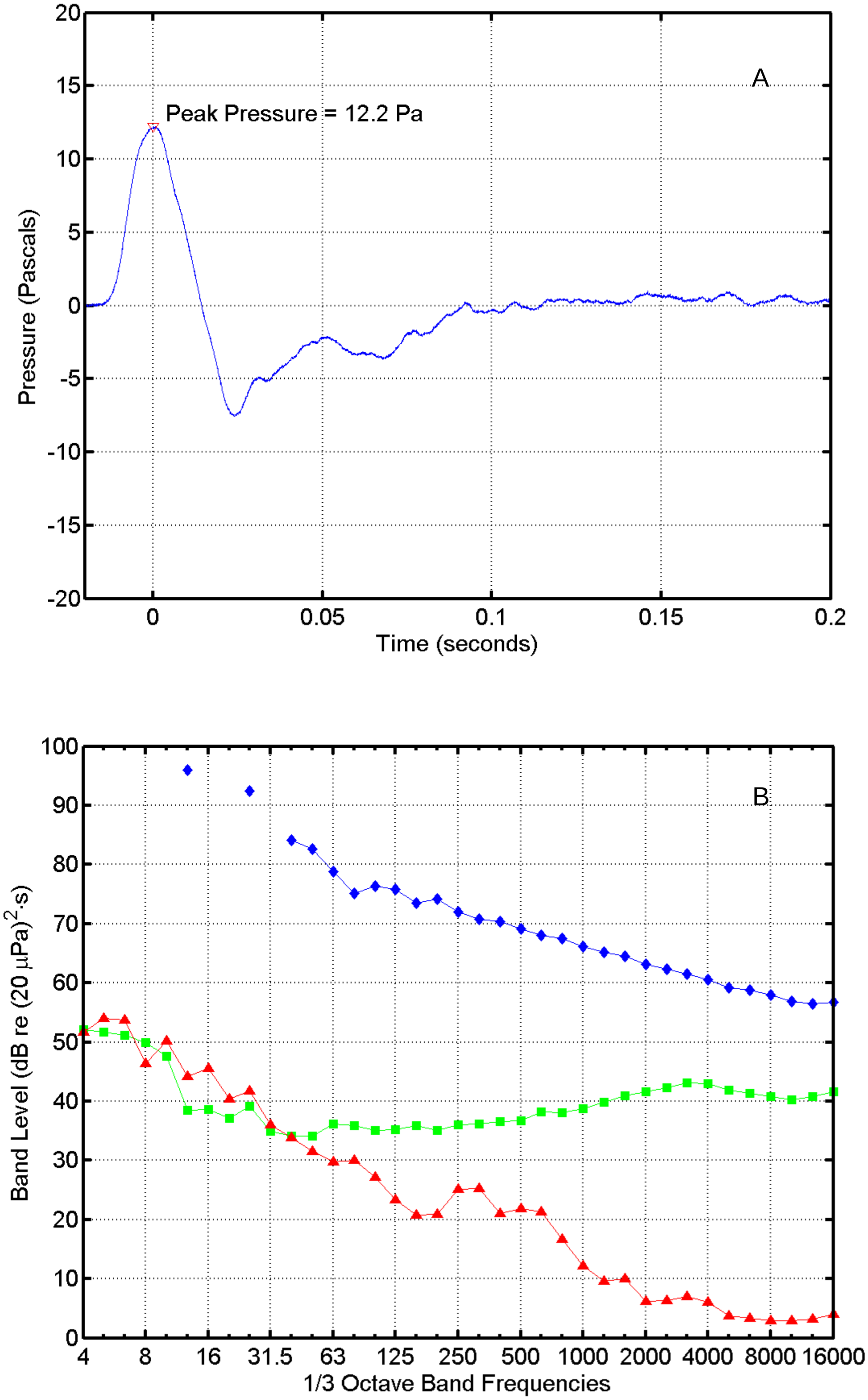


FIGURE C-23. (A) Pressure waveform and (B) one-third octave band levels for the AGS Slug launch at 15:43 on 26 July 2004 at "Vizcaino Point". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

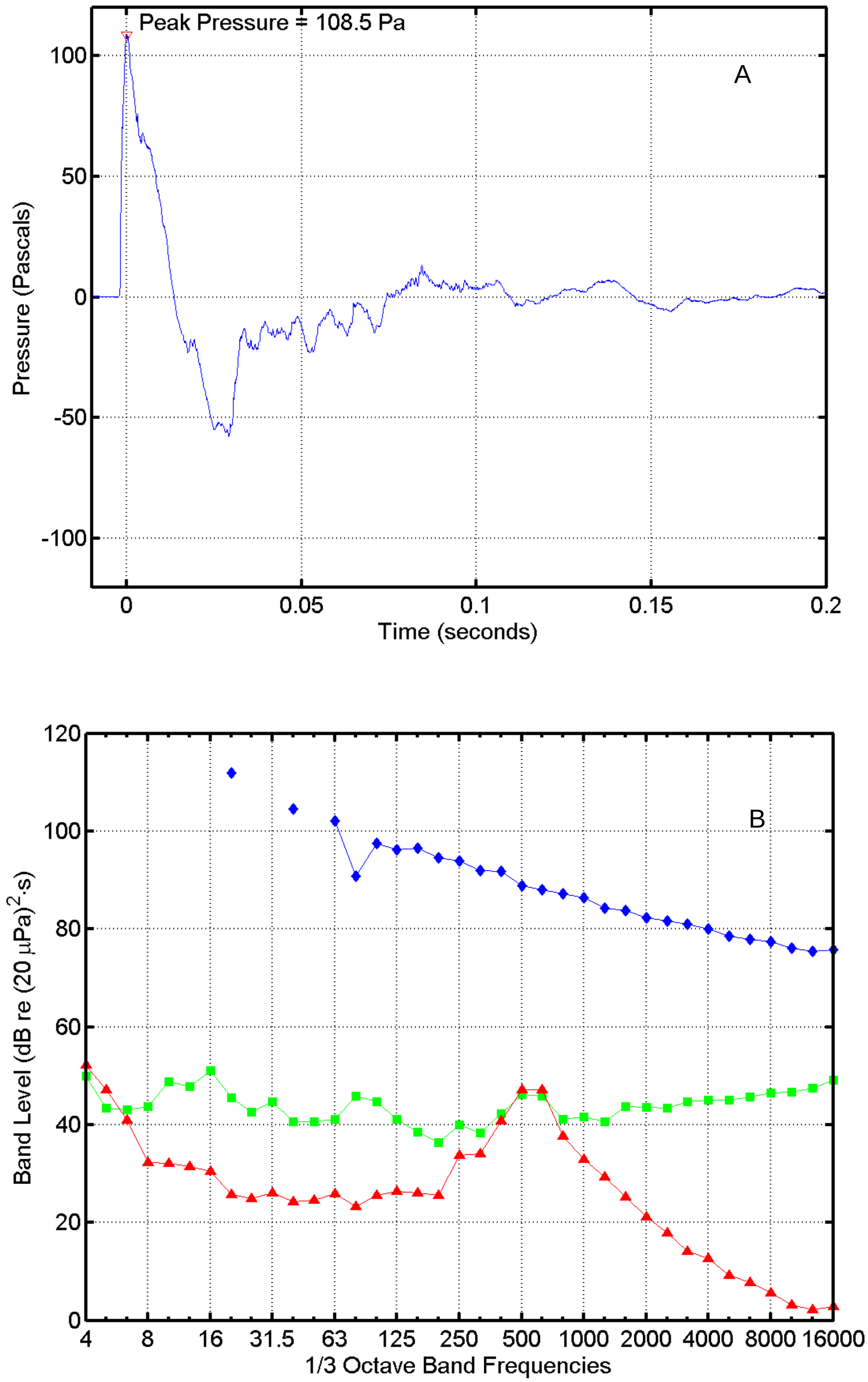
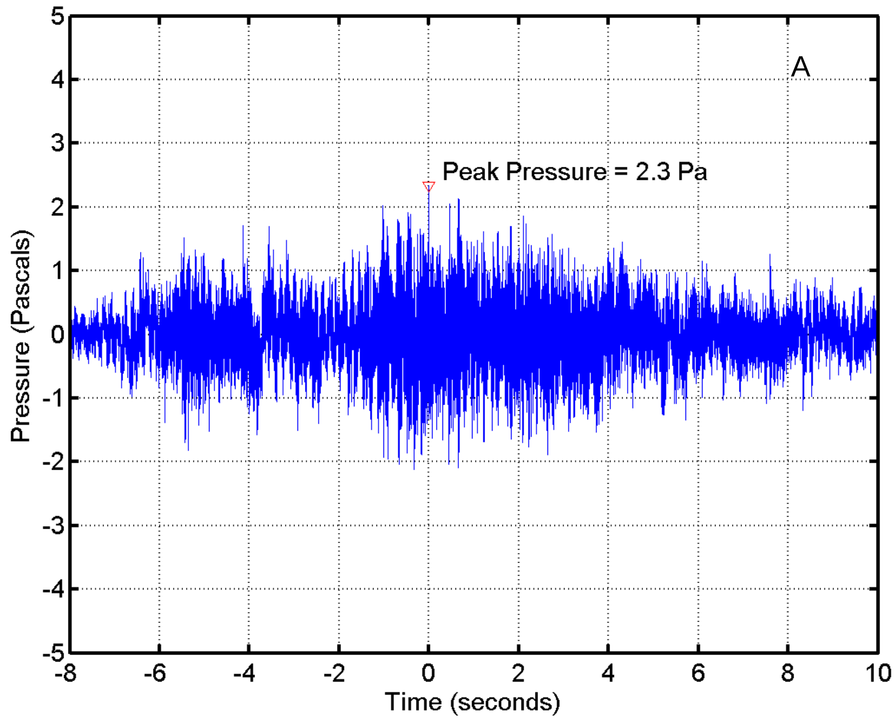


FIGURE C-24. (A) Pressure waveform and (B) one-third octave band levels for the AGS Slug launch at 15:43 on 26 July 2004 at "Dos Coves South". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).



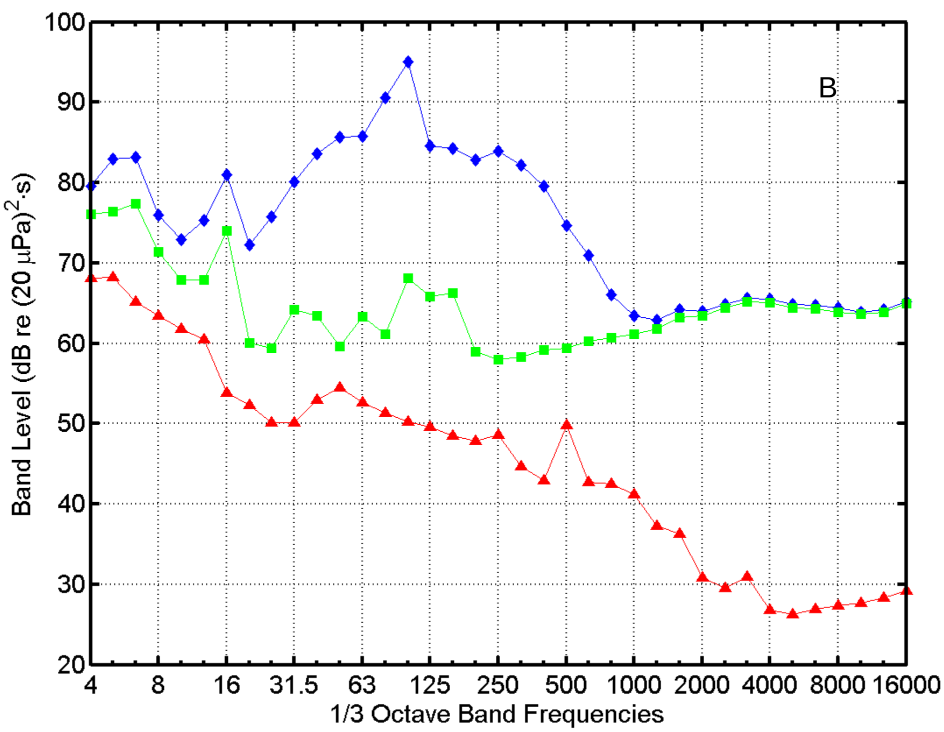


FIGURE C-25. (A) Pressure waveform and (B) one-third octave band levels for an Arrow flight at 10:20 on 29 July 2004 recorded "Vizcaino Point". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

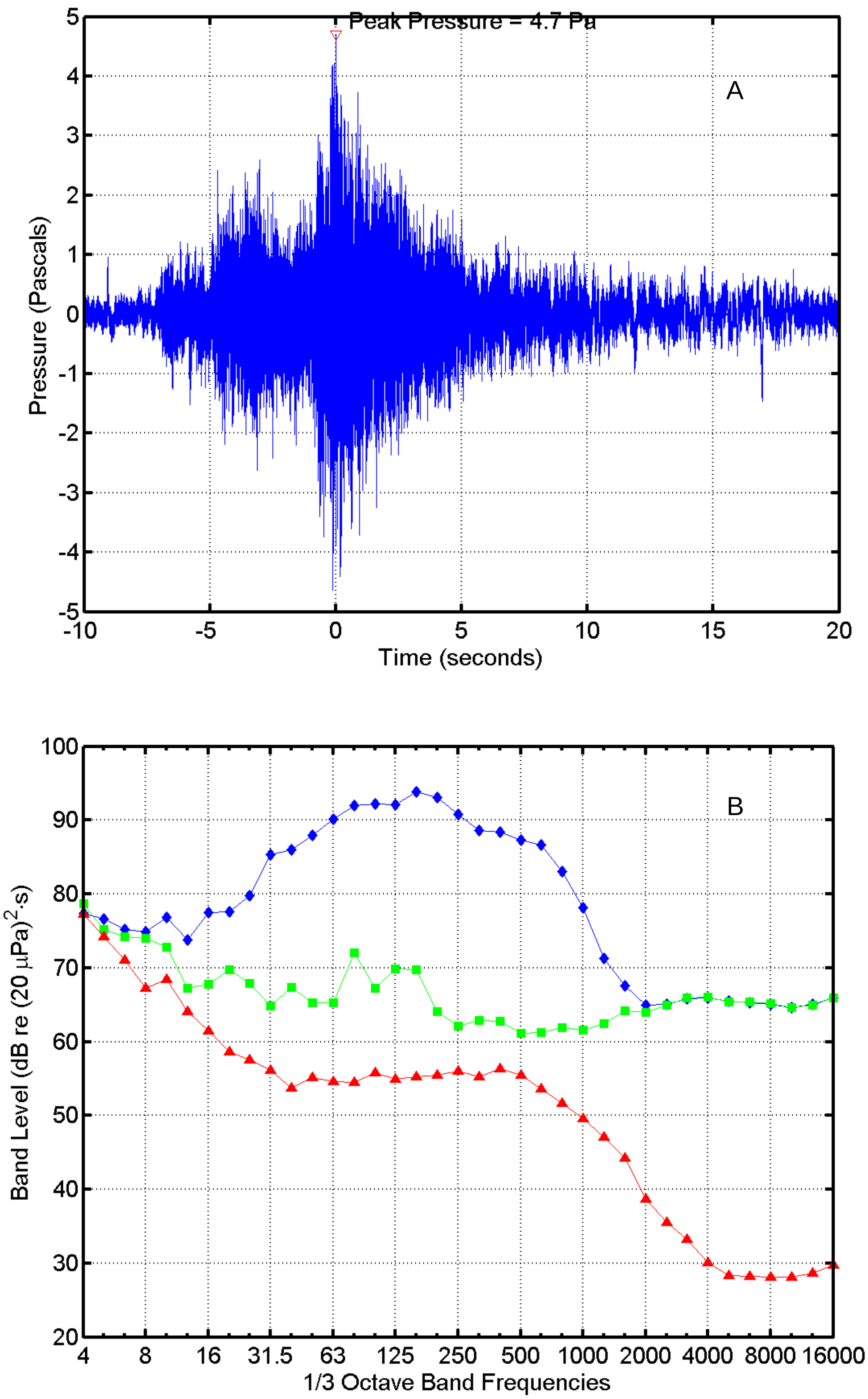
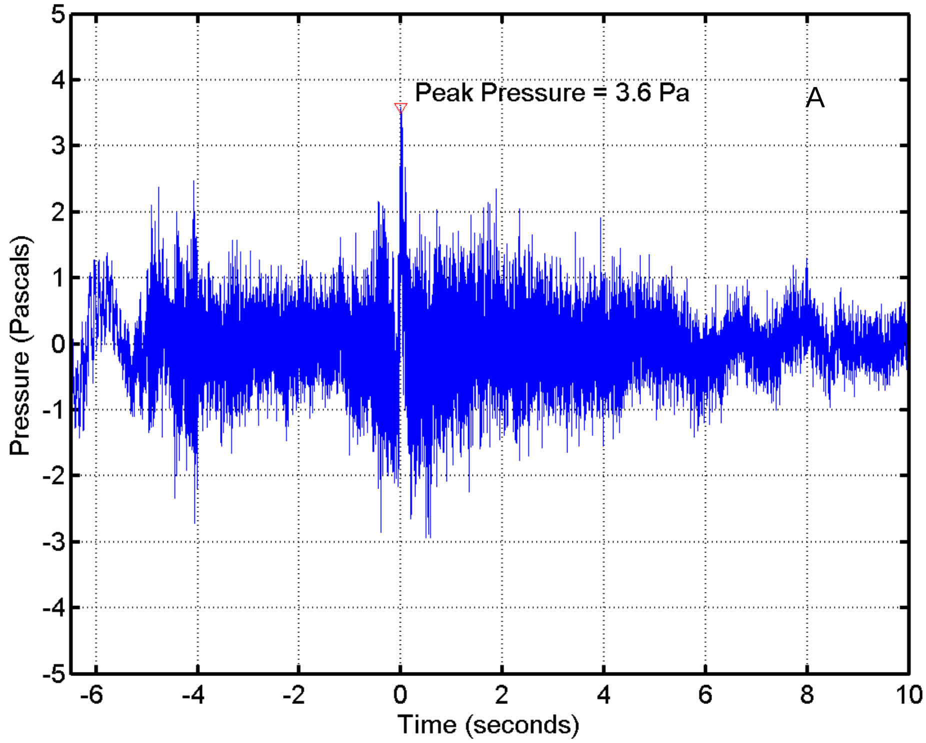


FIGURE C-26. (A) Pressure waveform and (B) one-third octave band levels for an Arrow flight at 10:20 on 29 July 2004 recorded "Bachelor Beach North". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).



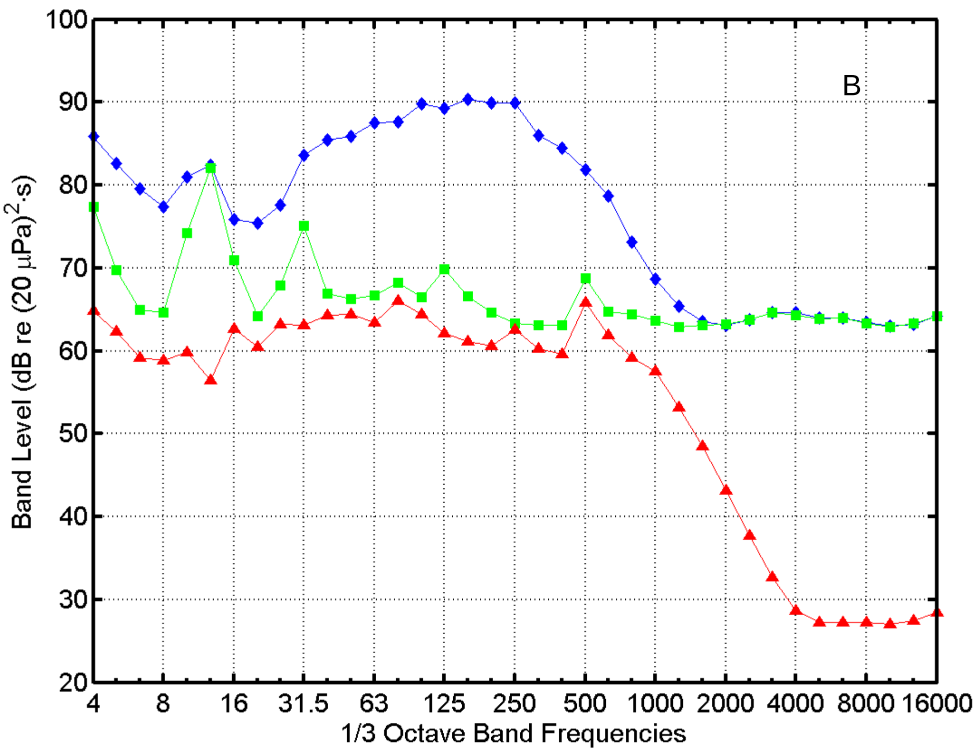


FIGURE C-27. (A) Pressure waveform and (B) one-third octave band levels for an Arrow flight at 10:20 on 29 July 2004 recorded "Dos Coves South". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

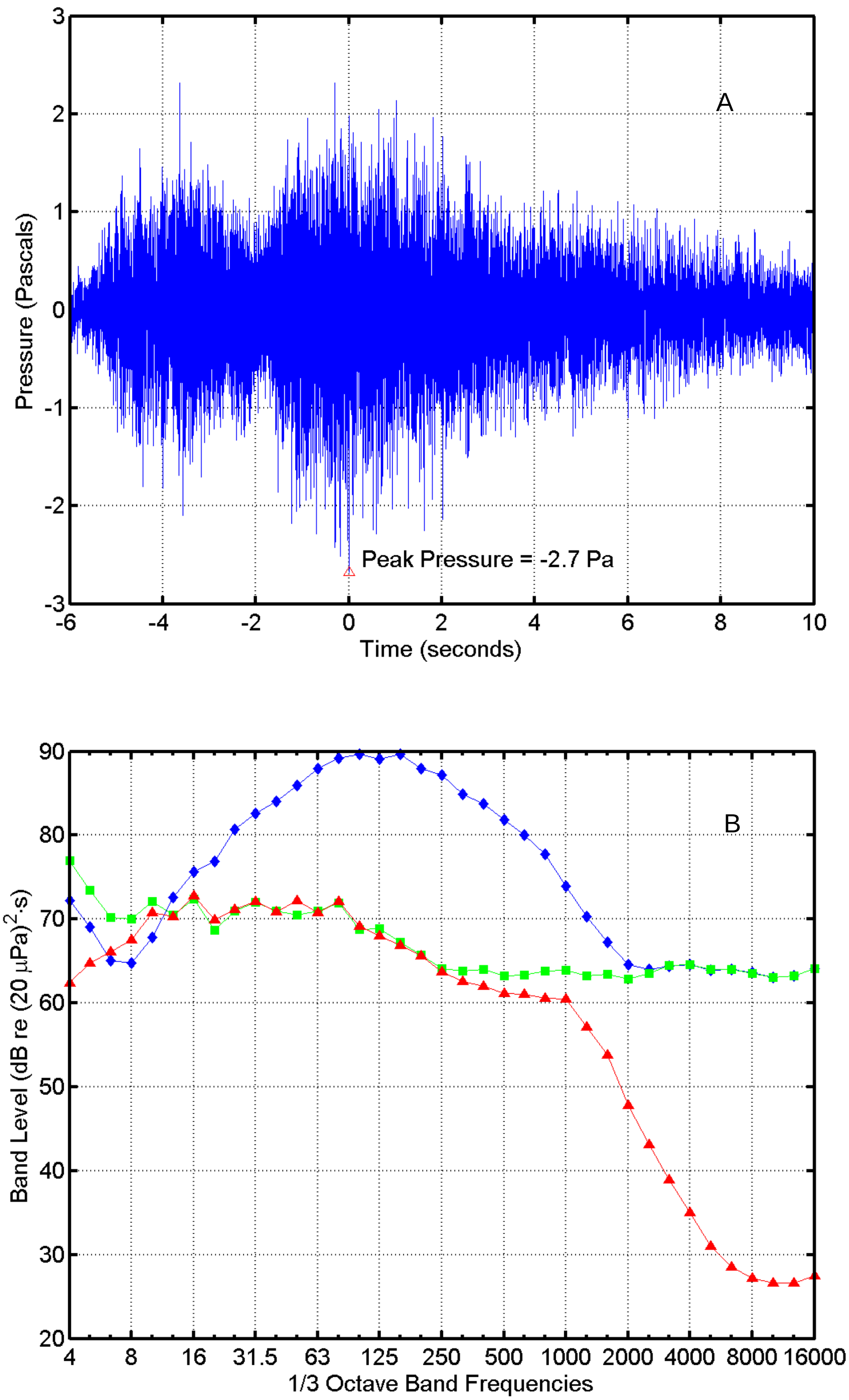


FIGURE C-28. (A) Pressure waveform and (B) one-third octave band levels for an Arrow flight at 10:08 on 26 August 2004 recorded "Dos Coves". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

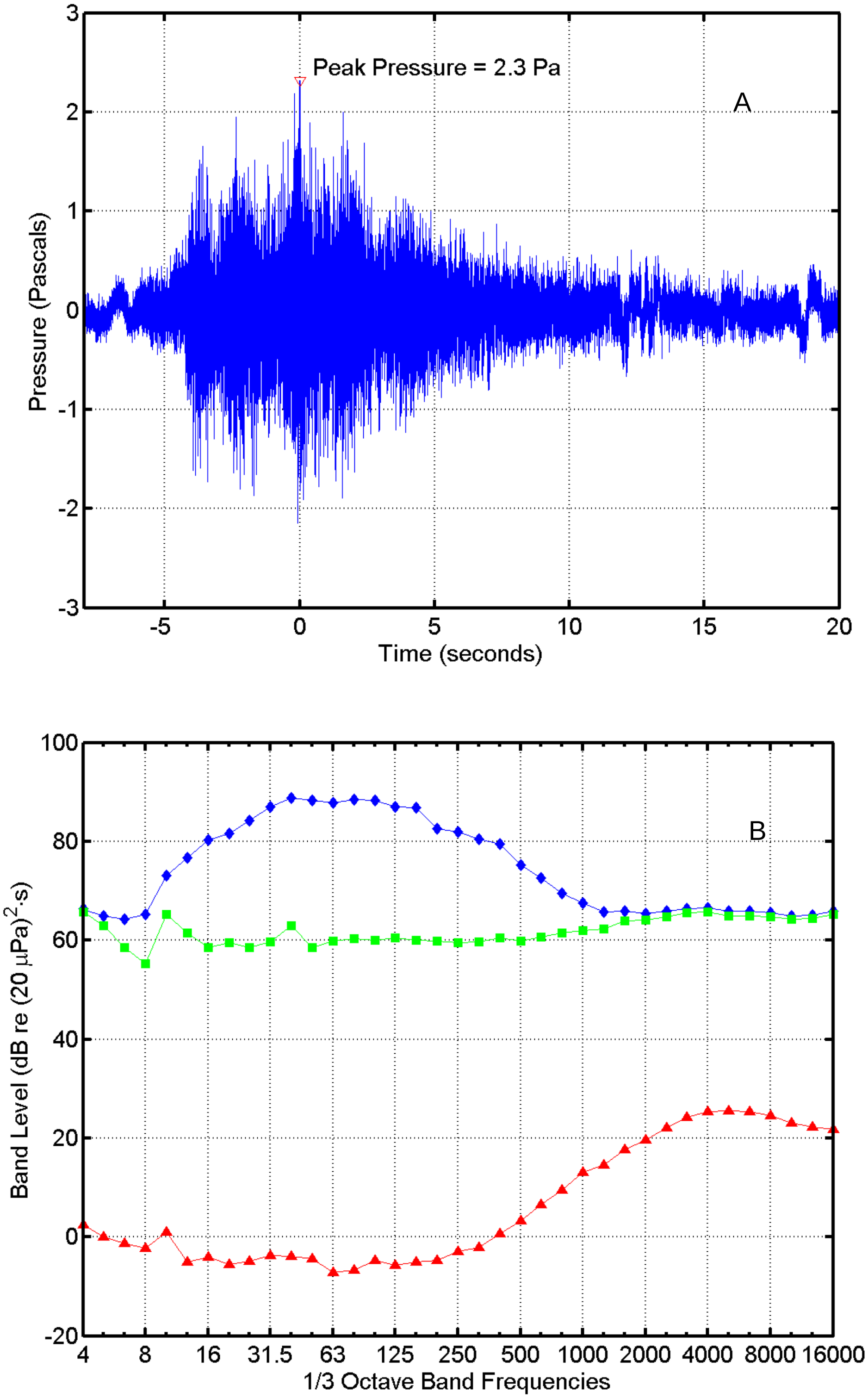
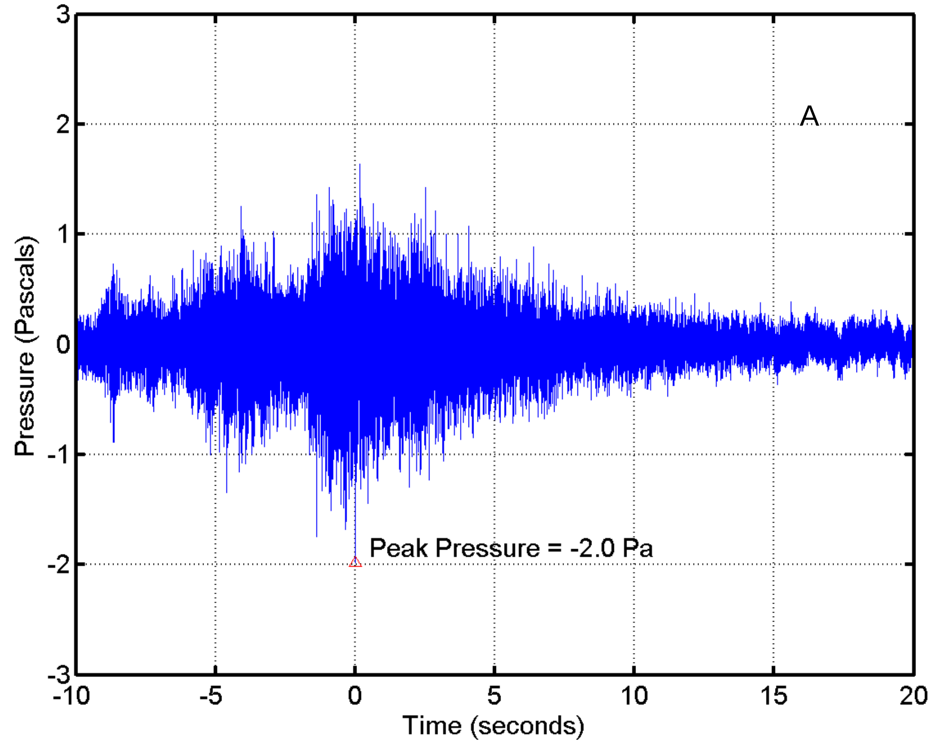


FIGURE C-29. (A) Pressure waveform and (B) one-third octave band levels for an Arrow flight at 10:08 on 26 August 2004 recorded “Phoca Reef”. In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).



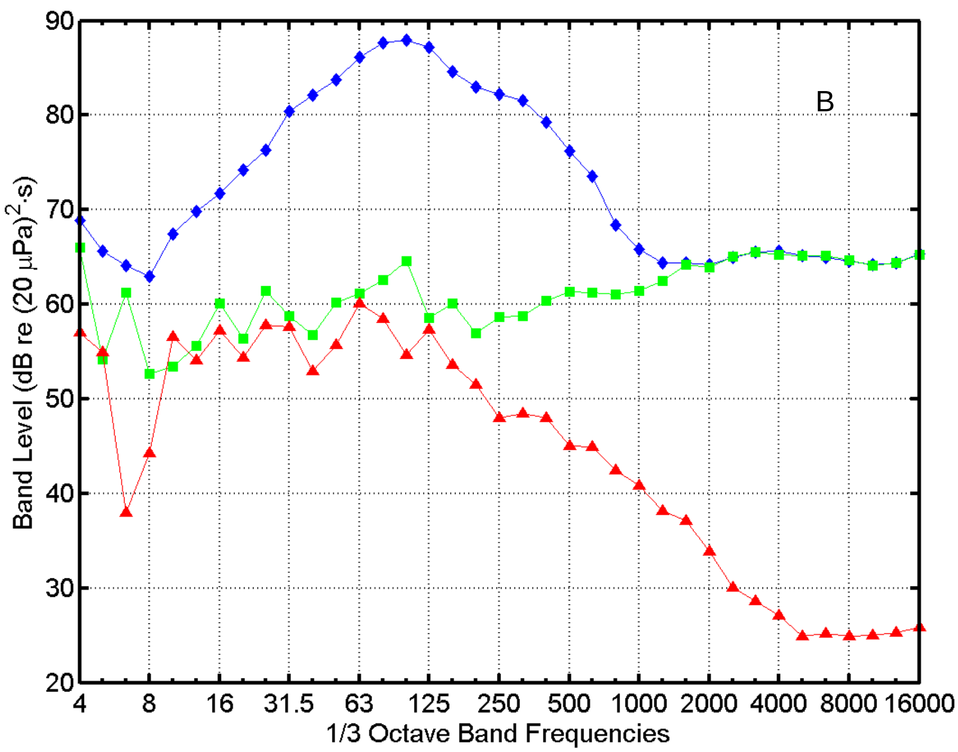


FIGURE C-30. (A) Pressure waveform and (B) one-third octave band levels for an Arrow flight at 10:08 on 26 August 2004 recorded "Vizcaino Point". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

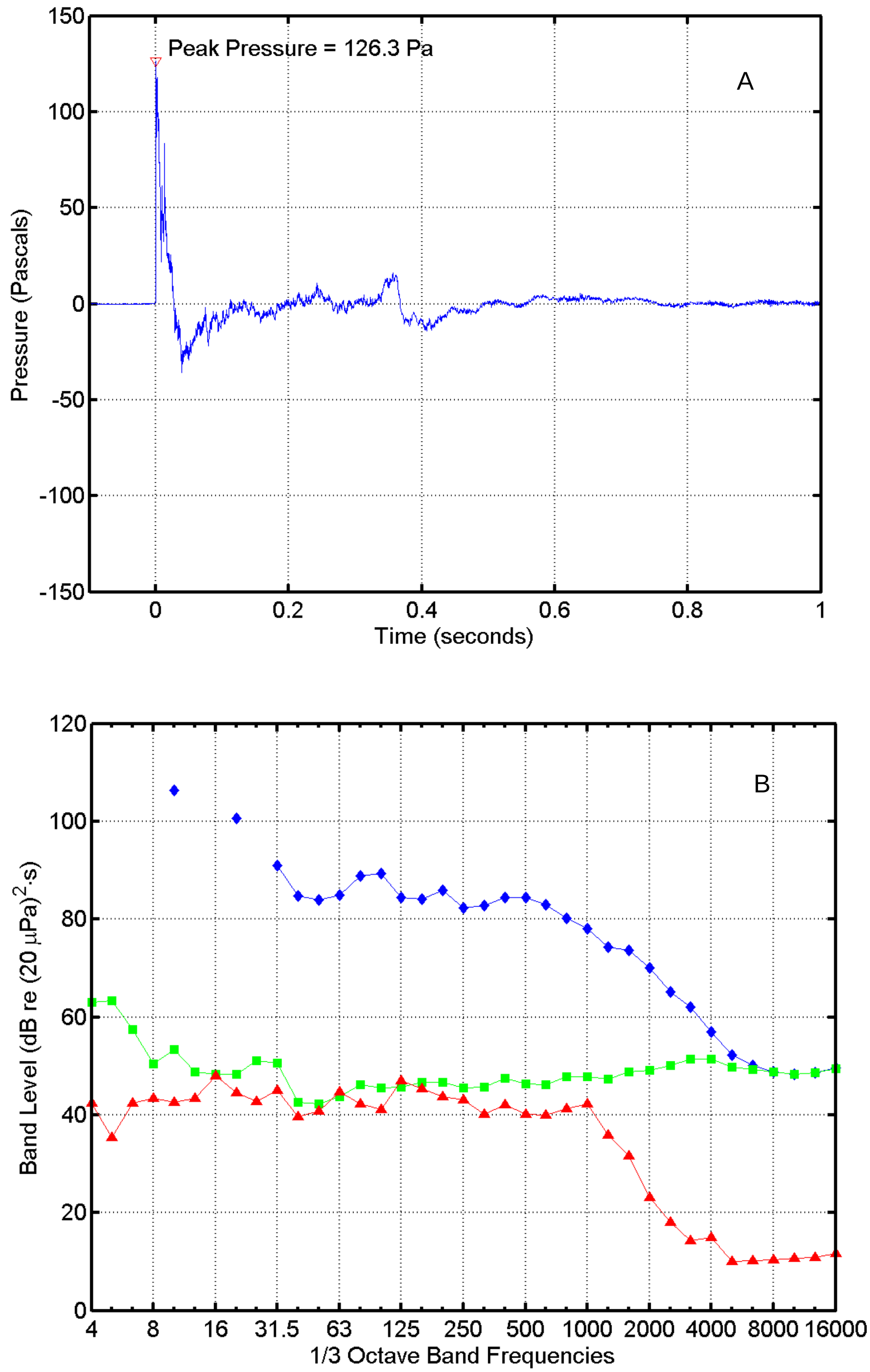
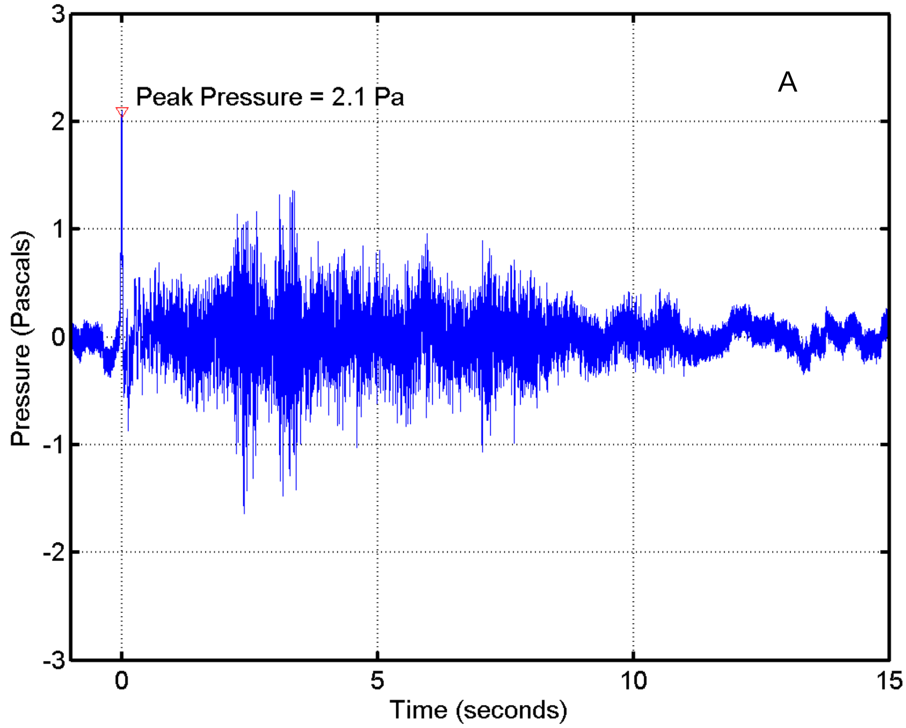


FIGURE C-31. (A) Pressure waveform and (B) one-third octave band levels for a SSST launch at 16:30 on 27 August 2004 recorded "Dos Coves". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).



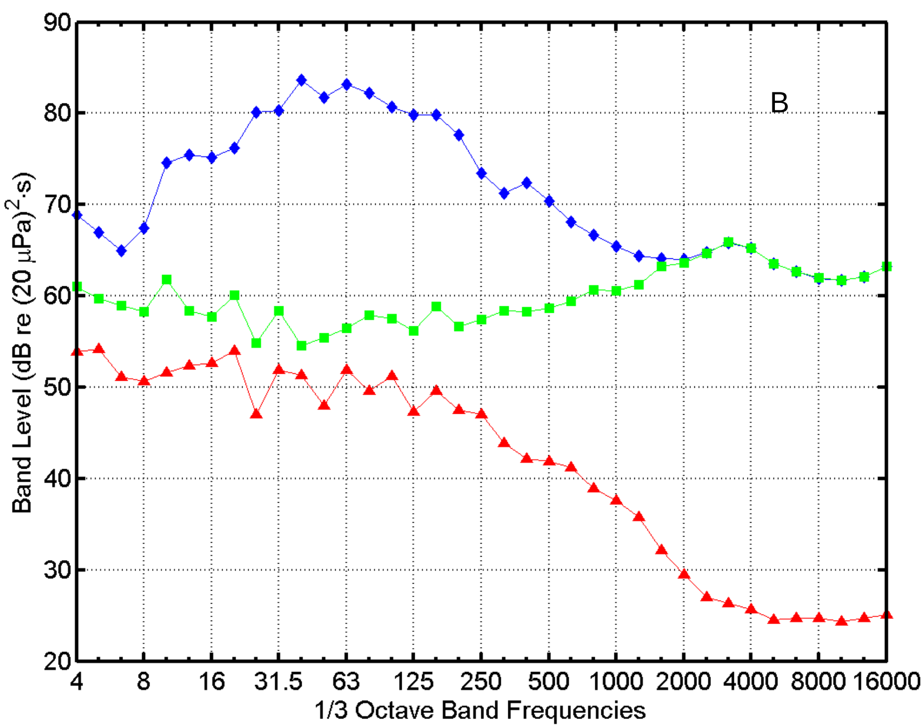


FIGURE C-32. (A) Pressure waveform and (B) one-third octave band levels for the SSST launch at 16:30 on 27 August 2004 recorded "Phoca Reef". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

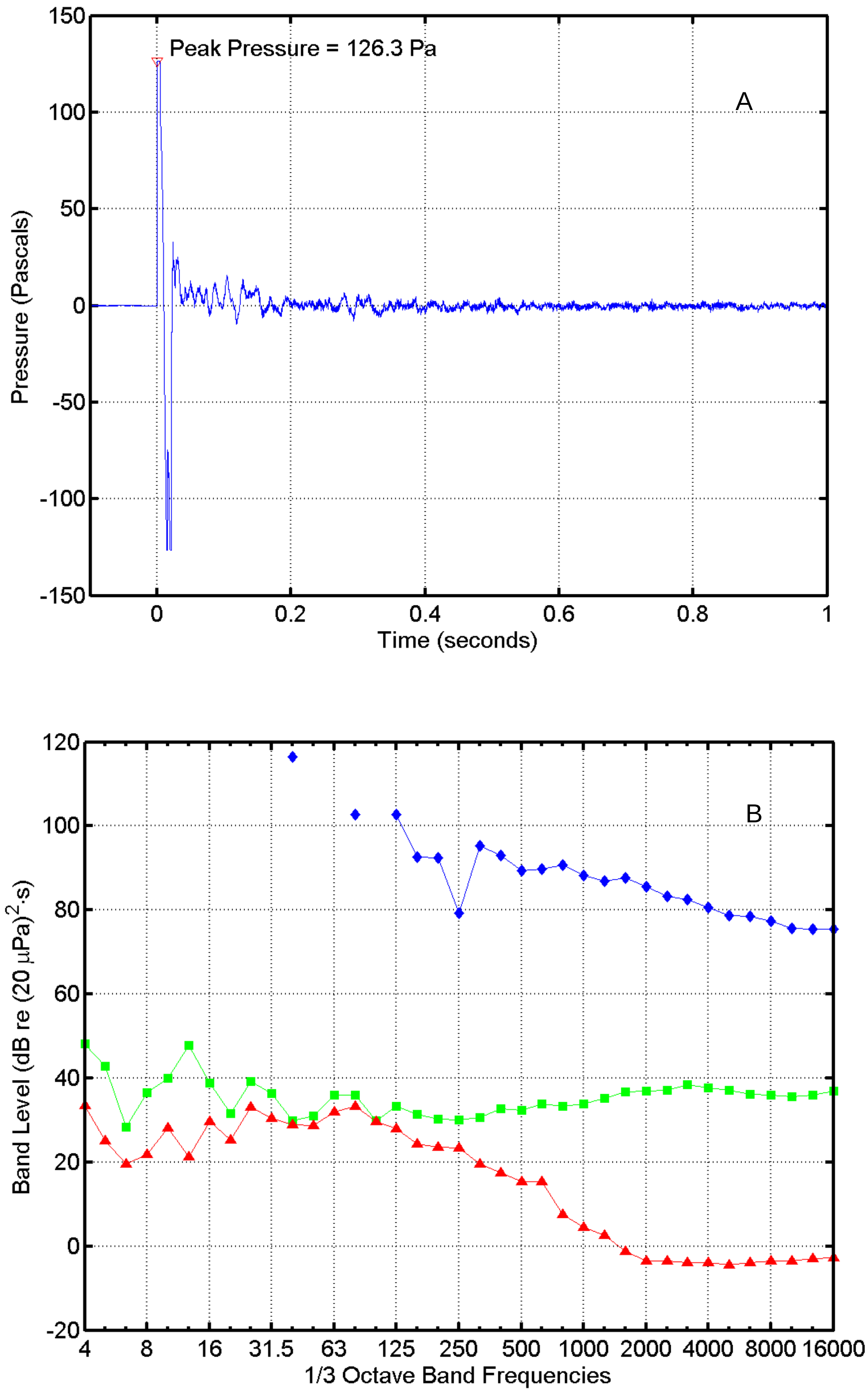


FIGURE C-33. (A) Pressure waveform and (B) one-third octave band levels for the SSST launch at 16:30 on 27 August 2004 recorded "Vizcaino Point". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

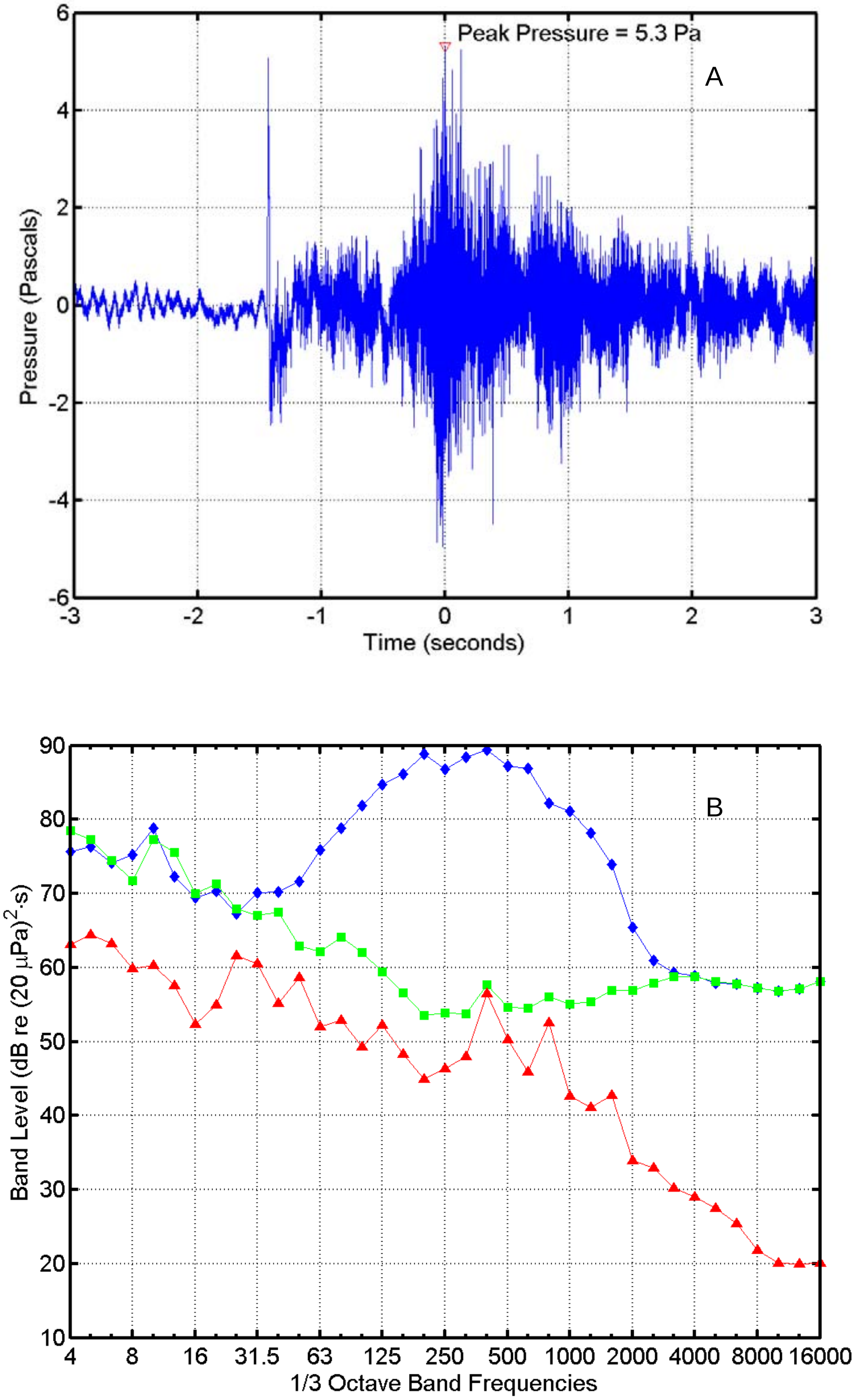


FIGURE C-34. (A) Pressure waveform and (B) one-third octave band levels for a RAM flight at 9:56 on 22 September 2004 recorded "Dos Coves South". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; ∆ = ambient noise power. Band frequencies in Hertz (Hz).

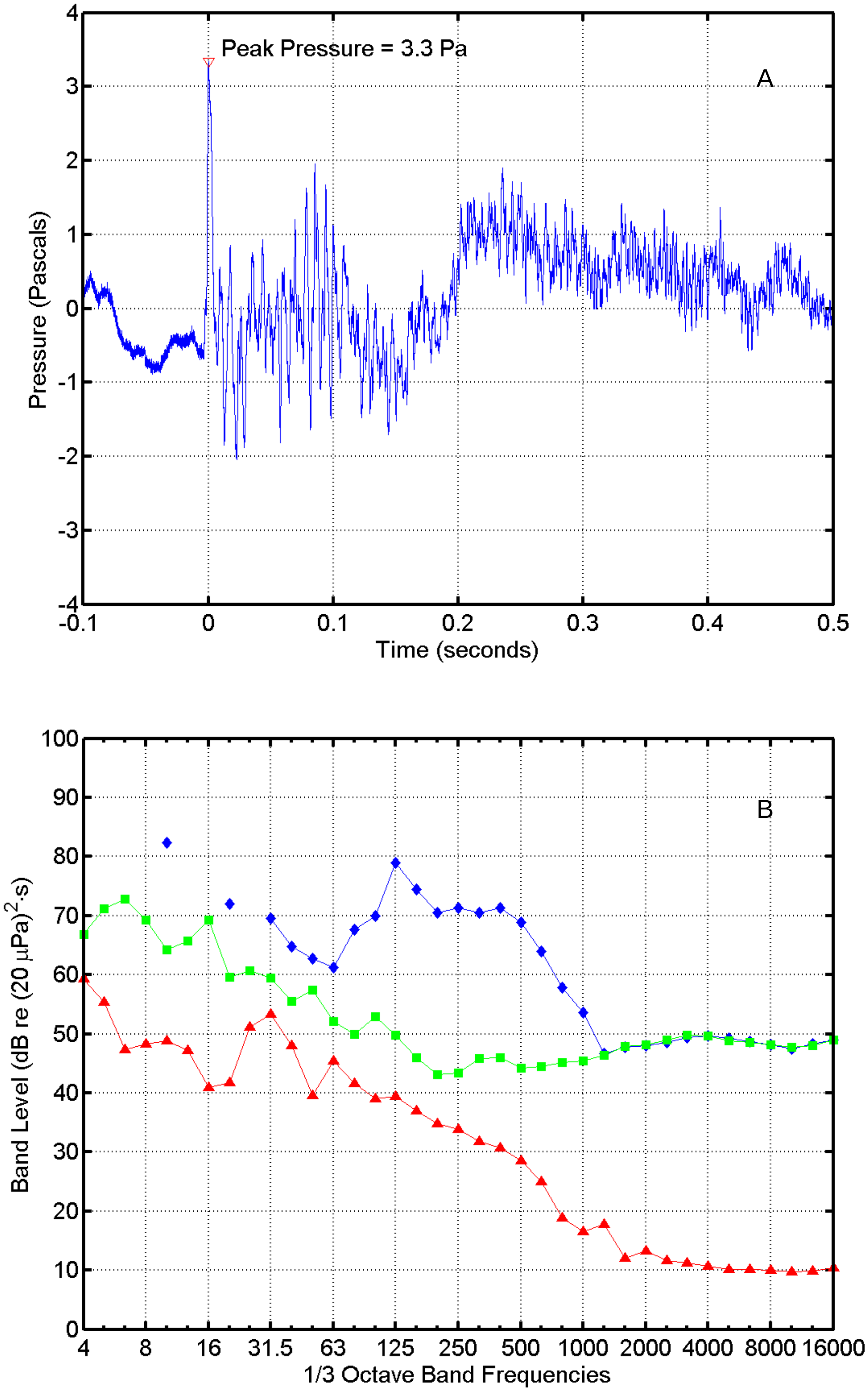


FIGURE C-35. (A) Pressure waveform and (B) one-third octave band levels for a RAM flight at 9:56 on 22 September 2004 recorded "Vizcaino Point". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

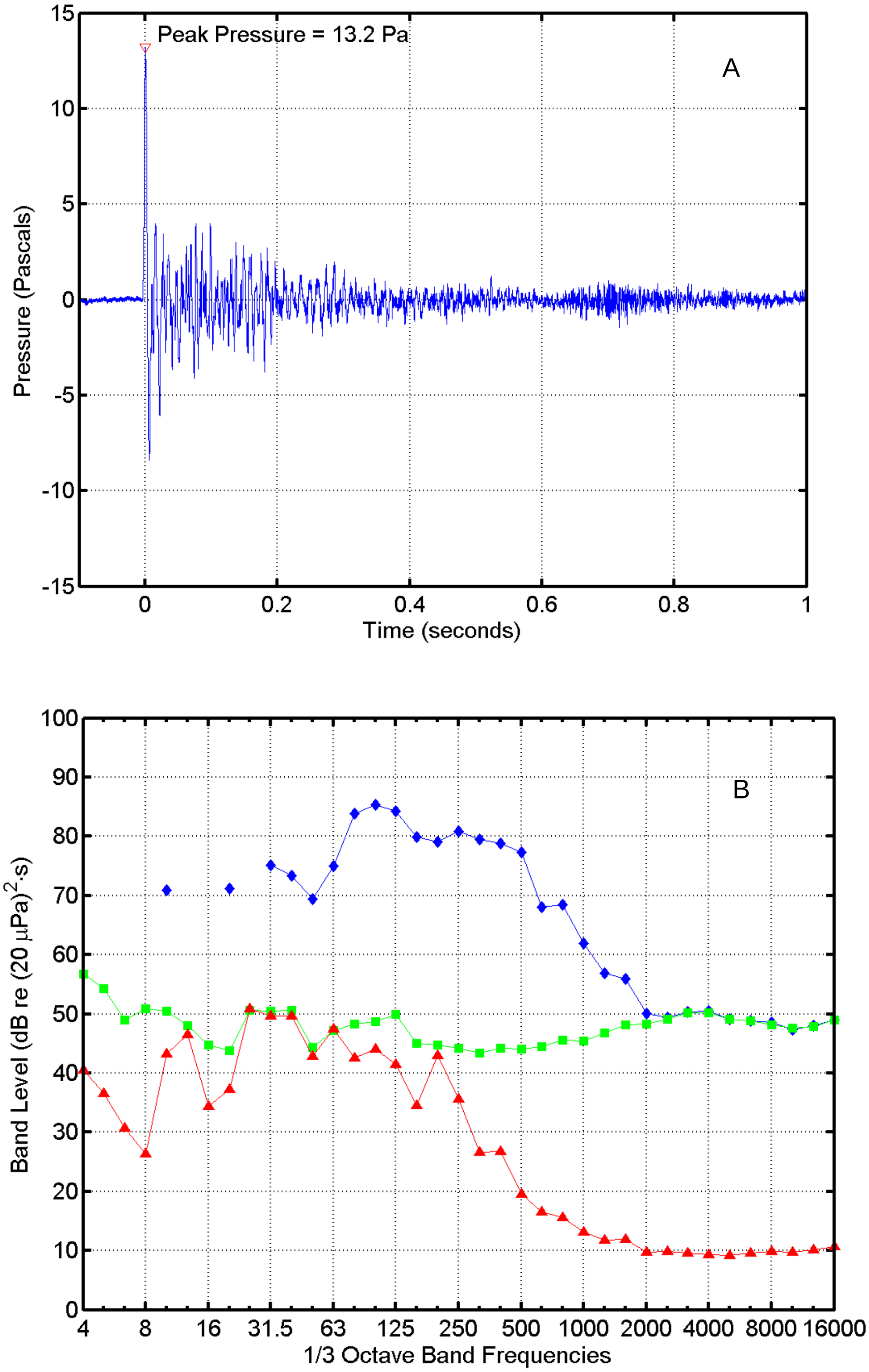


FIGURE C-36. (A) Pressure waveform and (B) one-third octave band levels for a RAM flight at 9:56 on 22 September 2004 recorded "The Y". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

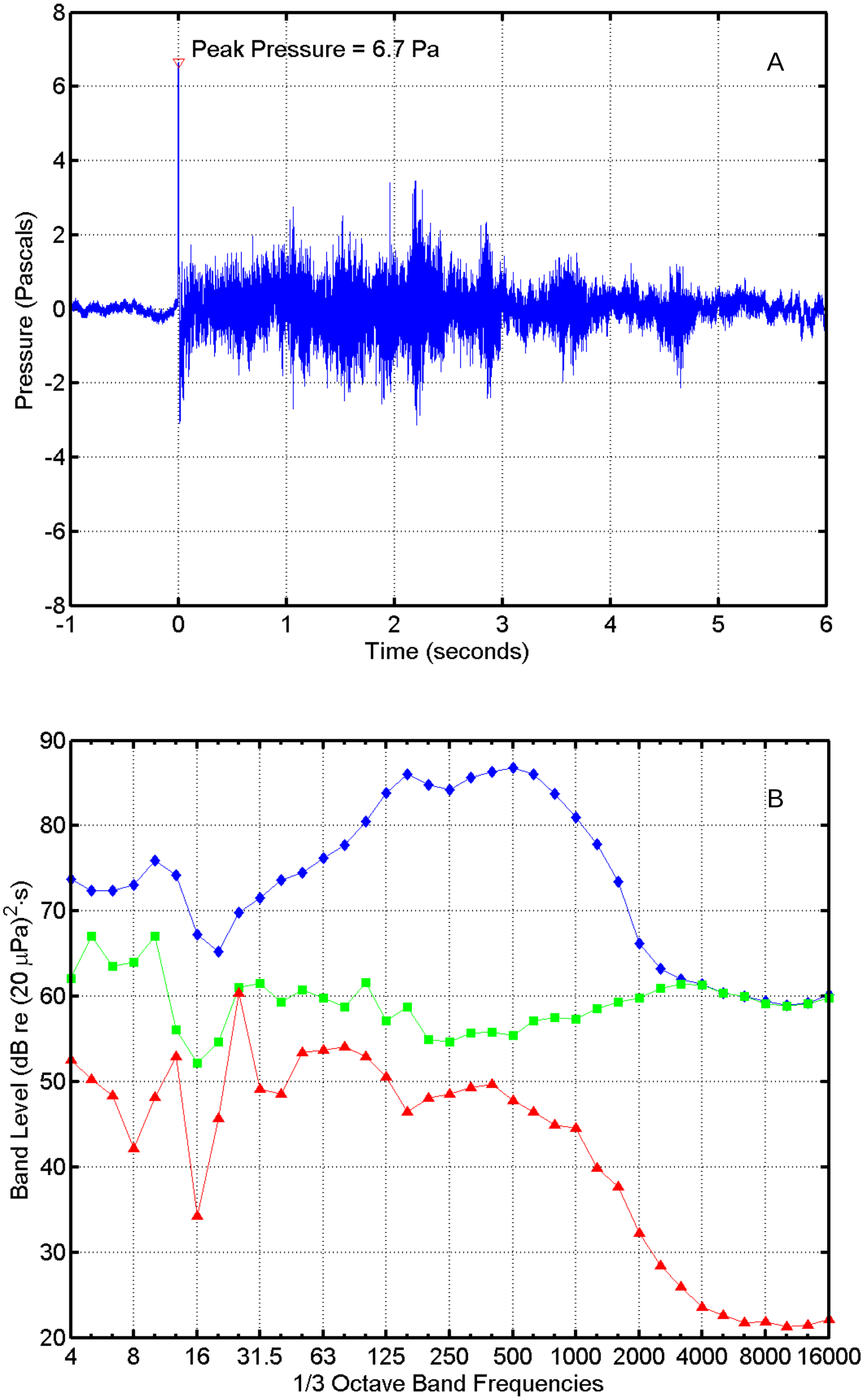


FIGURE C-37. (A) Pressure waveform and (B) one-third octave band levels for a RAM flight at 10:57 on 22 September 2004 recorded "Dos Coves South". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

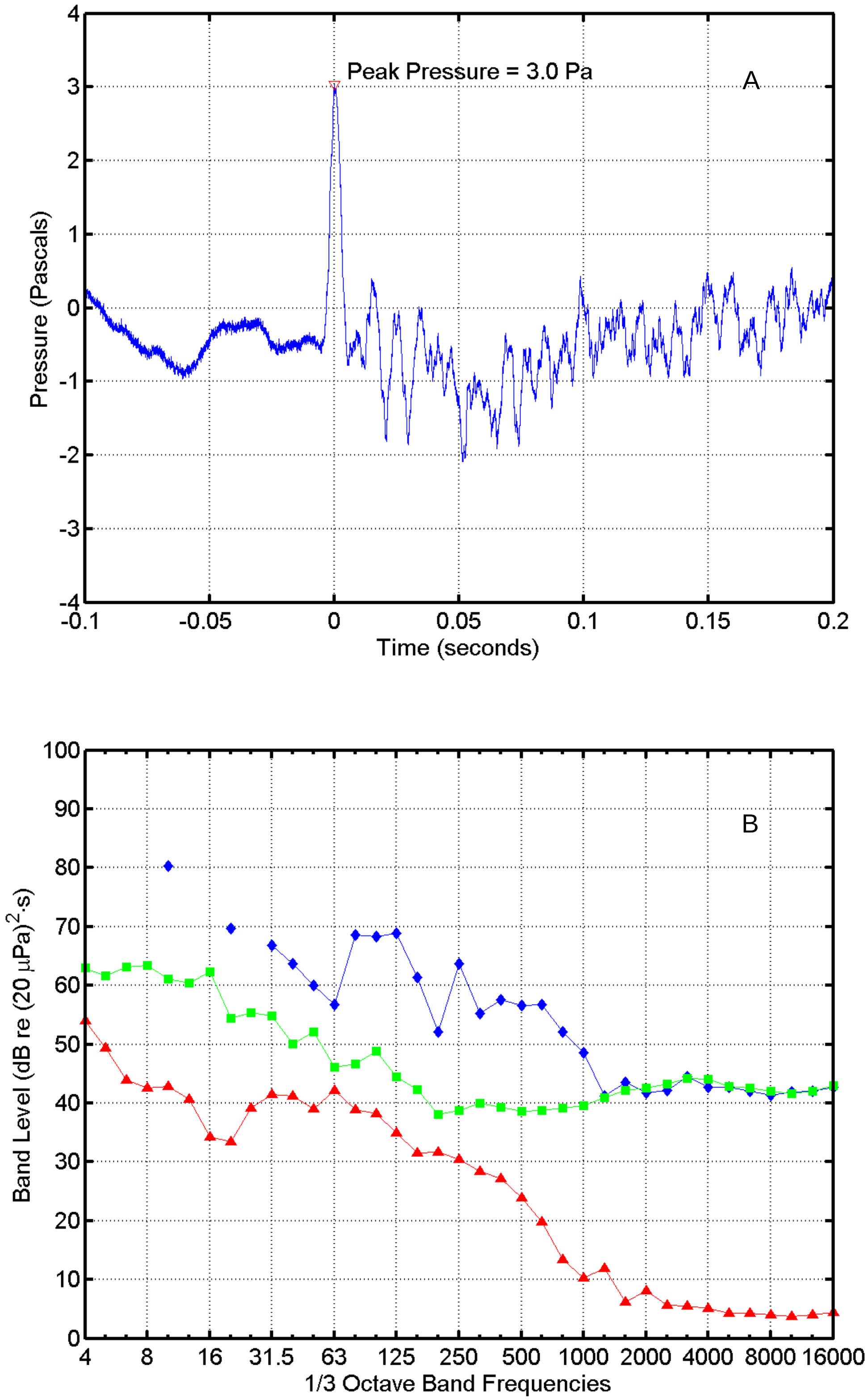


FIGURE C-38. (A) Pressure waveform and (B) one-third octave band levels for a RAM flight at 10:57 on 22 September 2004 recorded "Vizcaino Point". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

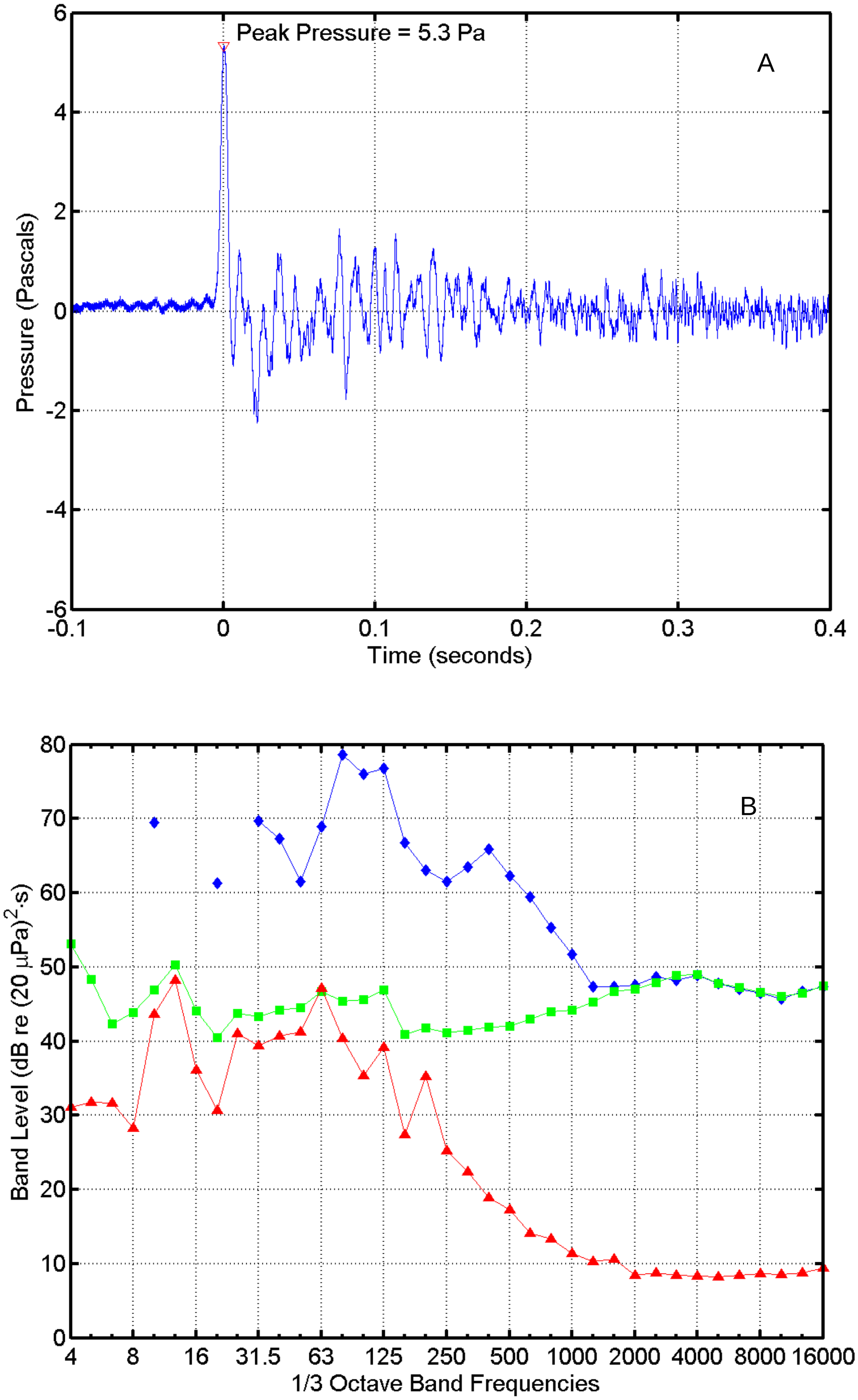
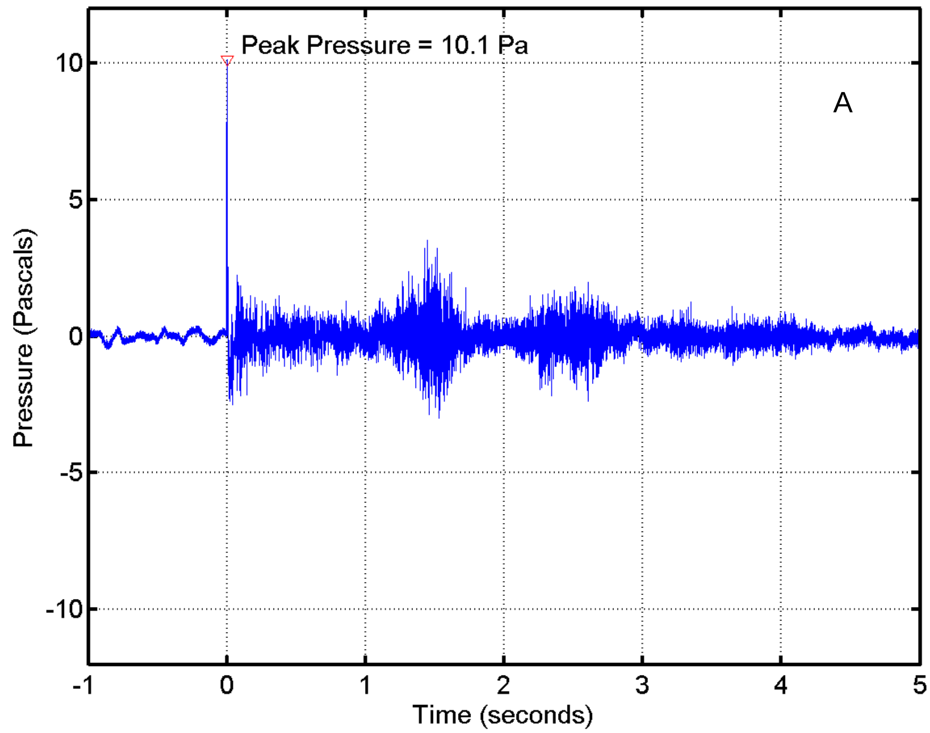


FIGURE C-39. (A) Pressure waveform and (B) one-third octave band levels for a RAM flight at 10:57 on 22 September 2004 recorded "The Y". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).



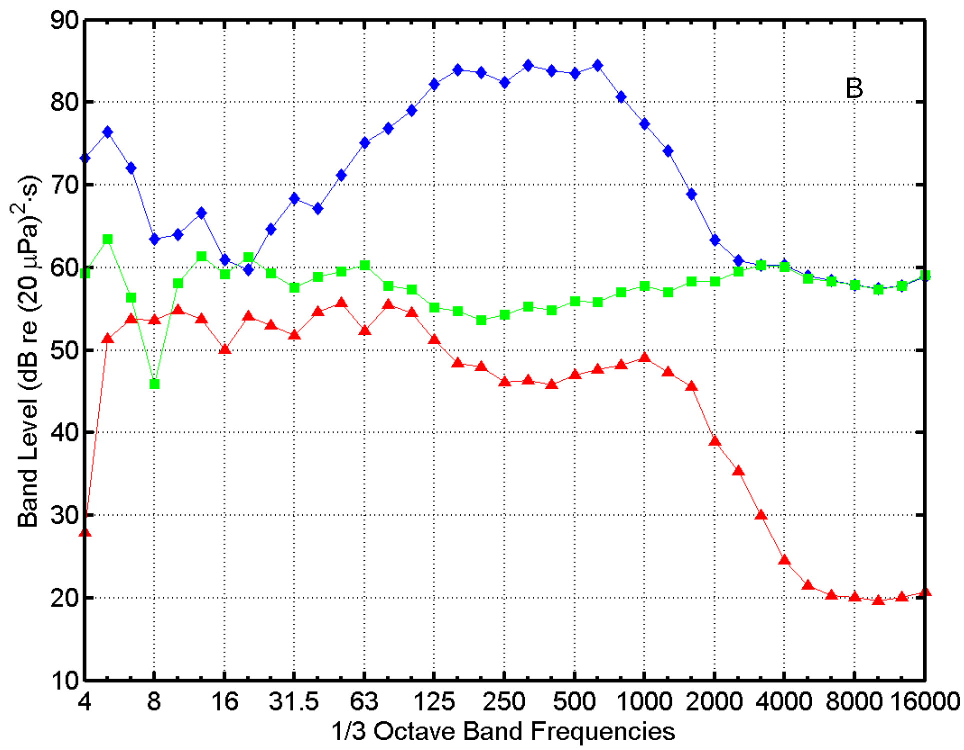
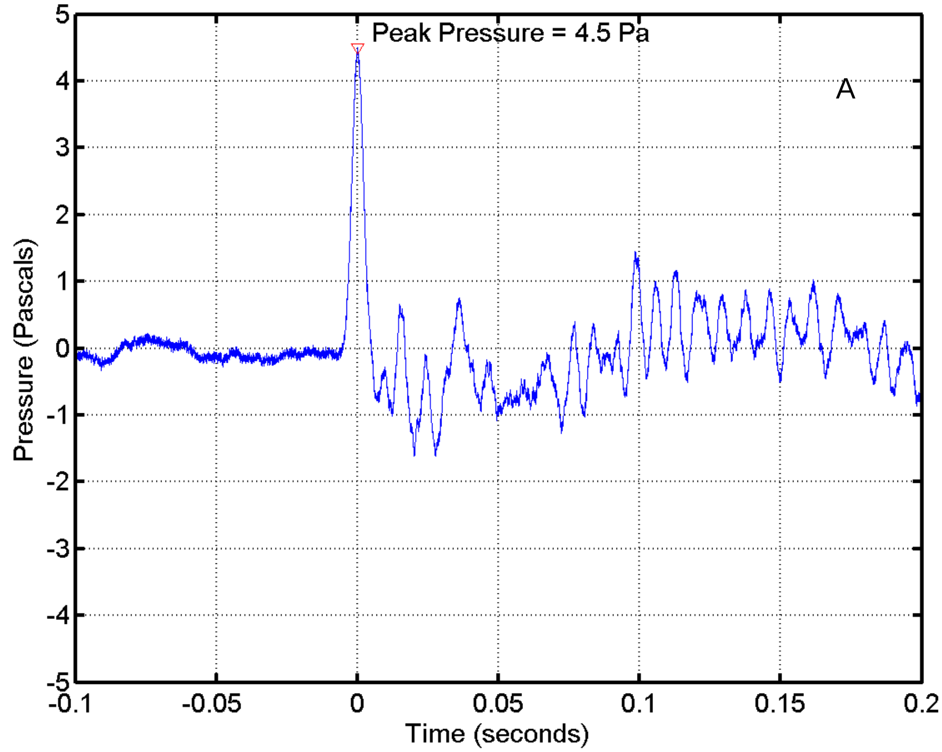


FIGURE C-40. (A) Pressure waveform and (B) one-third octave band levels for a RAM flight at 11:19 on 22 September 2004 recorded "Dos Coves South". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).



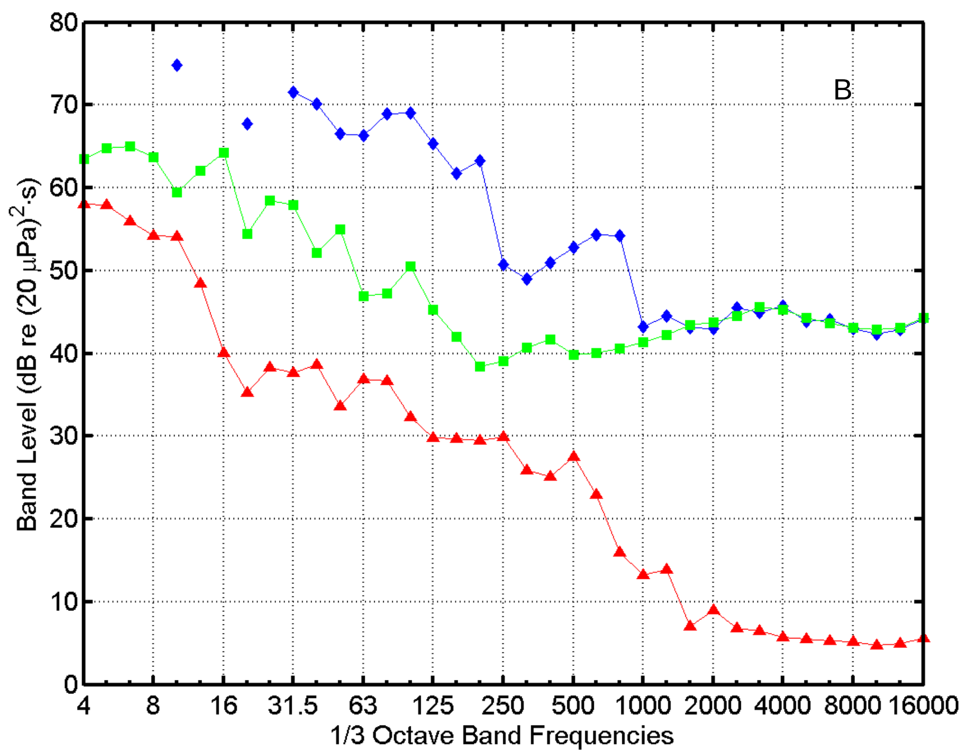


FIGURE C-41. (A) Pressure waveform and (B) one-third octave band levels for a RAM flight at 11:19 on 22 September 2004 recorded "Vizcaino Point". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

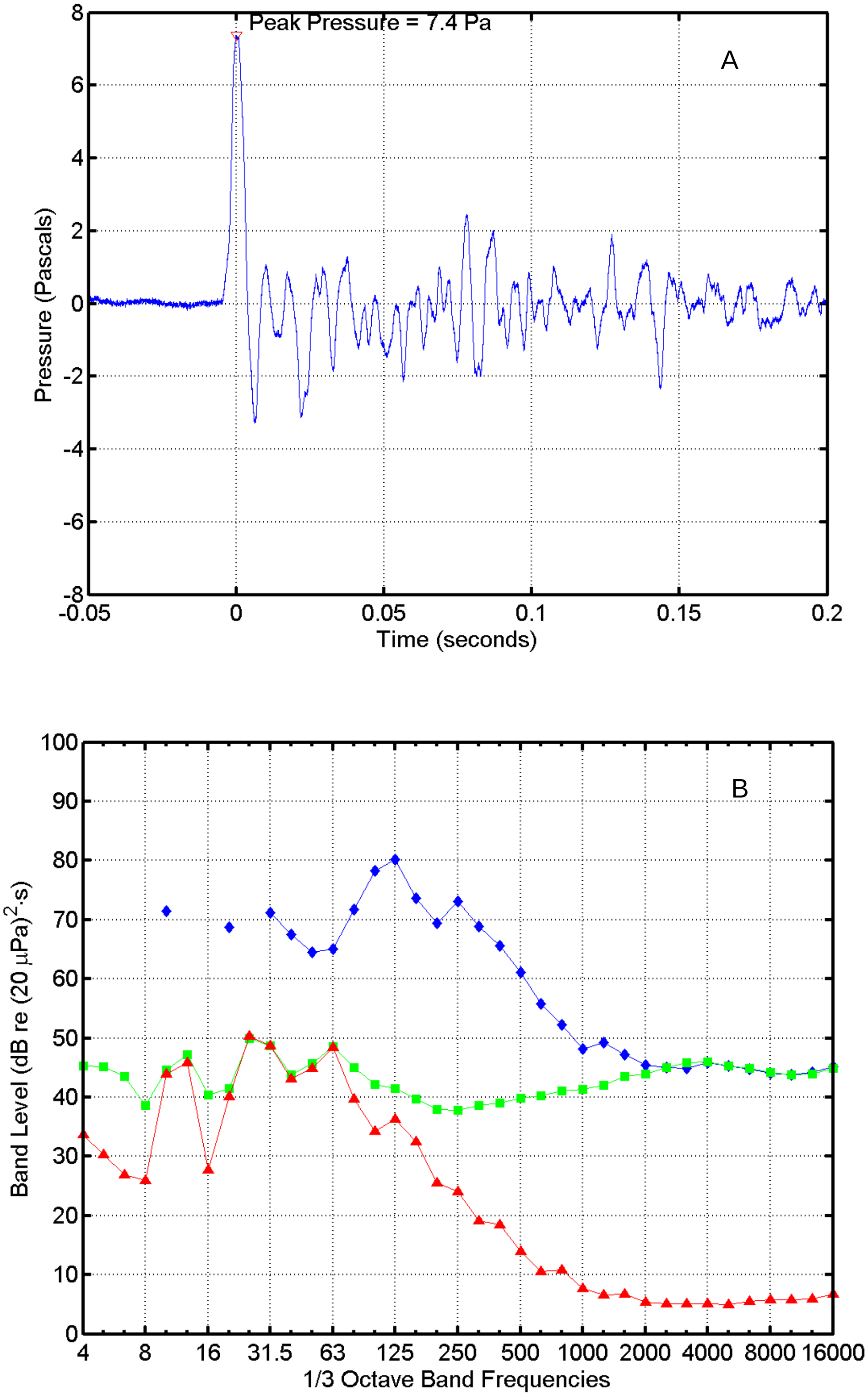
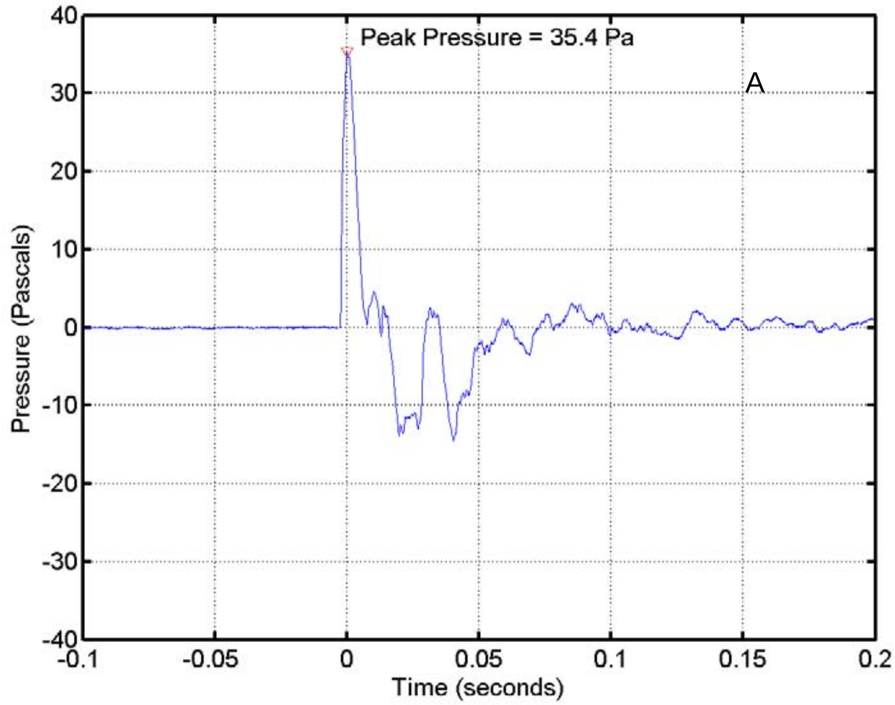


FIGURE C-42. (A) Pressure waveform and (B) one-third octave band levels for a RAM flight at 11:19 on 22 September 2004 recorded "The Y". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).



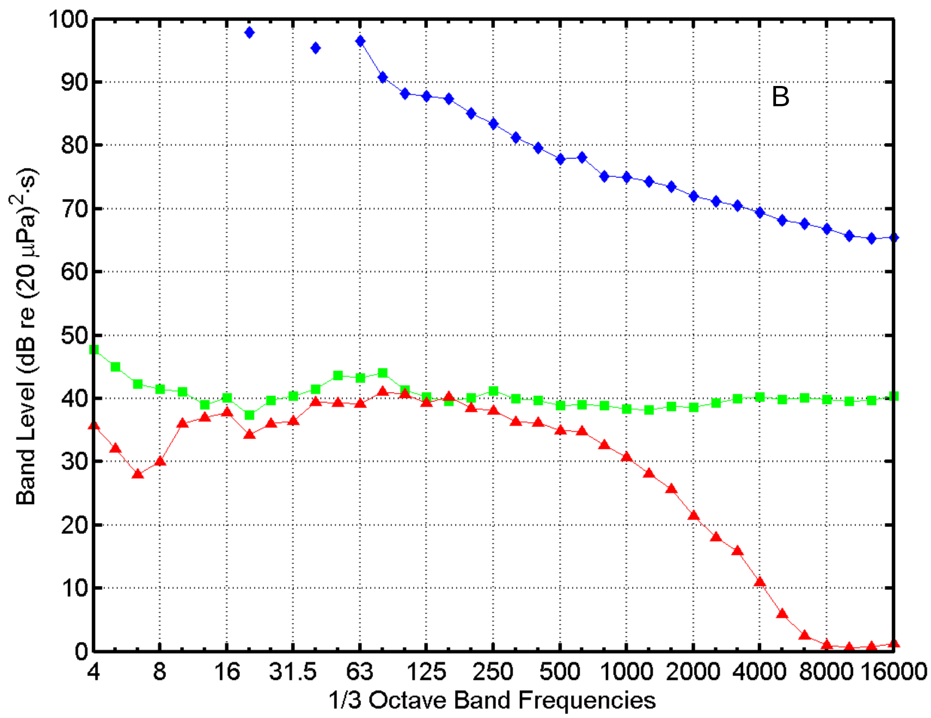


FIGURE C-43. (A) Pressure waveform and (B) one-third octave band levels for an AGS Slug flight at 8:59 on 27 January 2005 recorded at "Bachelor Beach North". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

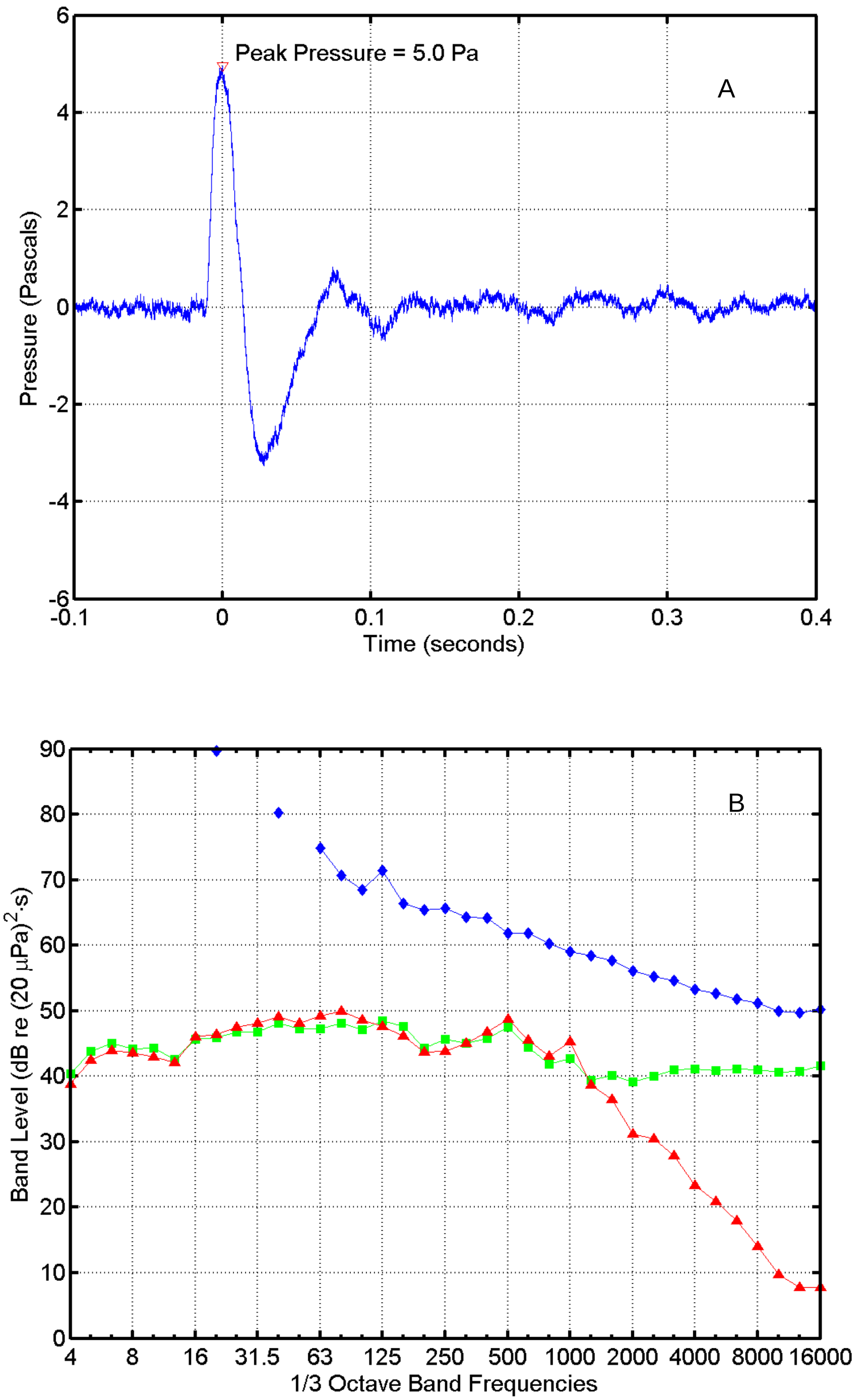


FIGURE C-44. (A) Pressure waveform and (B) one-third octave band levels for an AGS Slug flight at 8:59 on 27 January 2005 recorded at “Redeye I”. In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

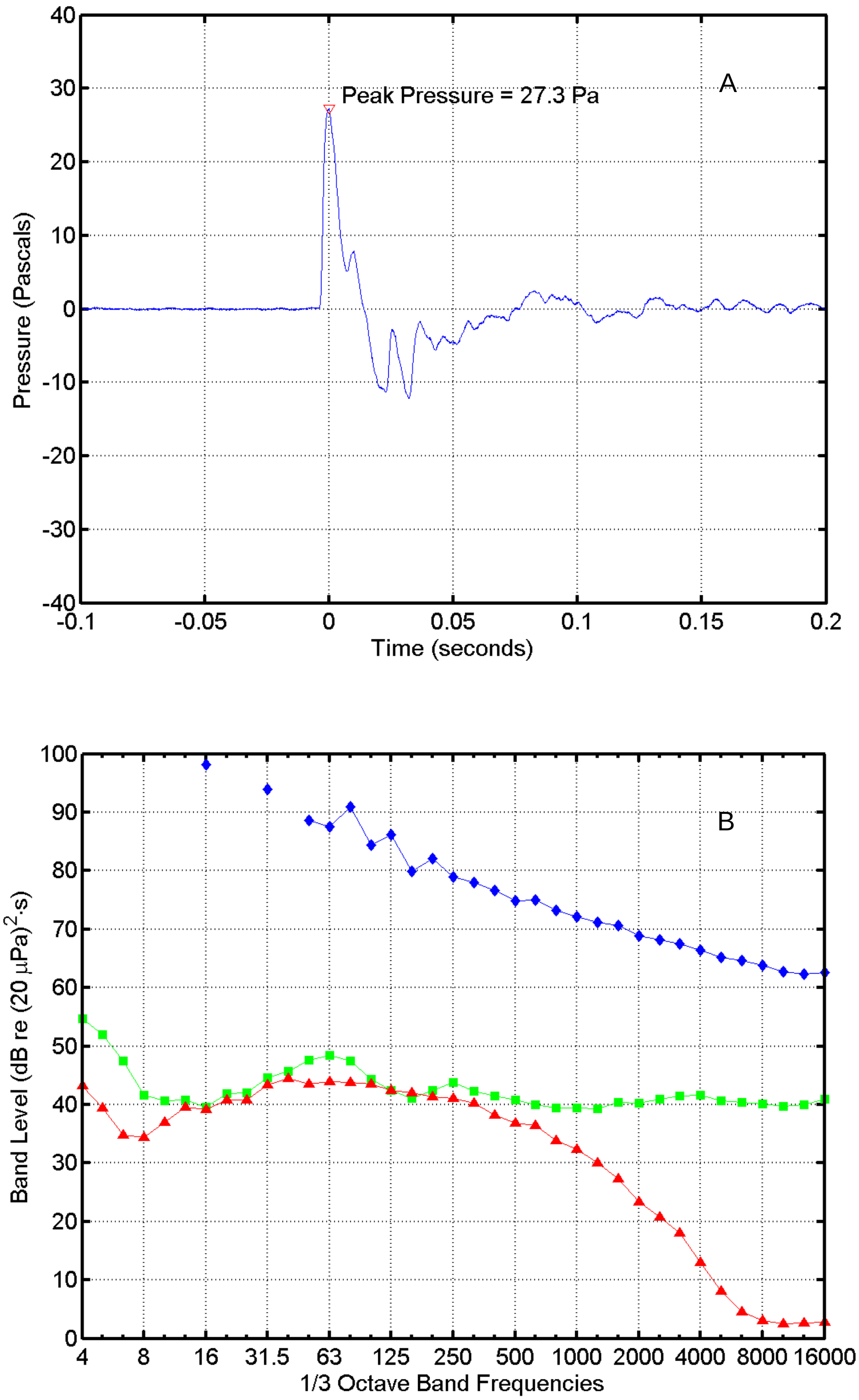


FIGURE C-45. (A) Pressure waveform and (B) one-third octave band levels for an AGS Slug flight at 11:41 on 27 January 2005 recorded at "Bachelor Beach North". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

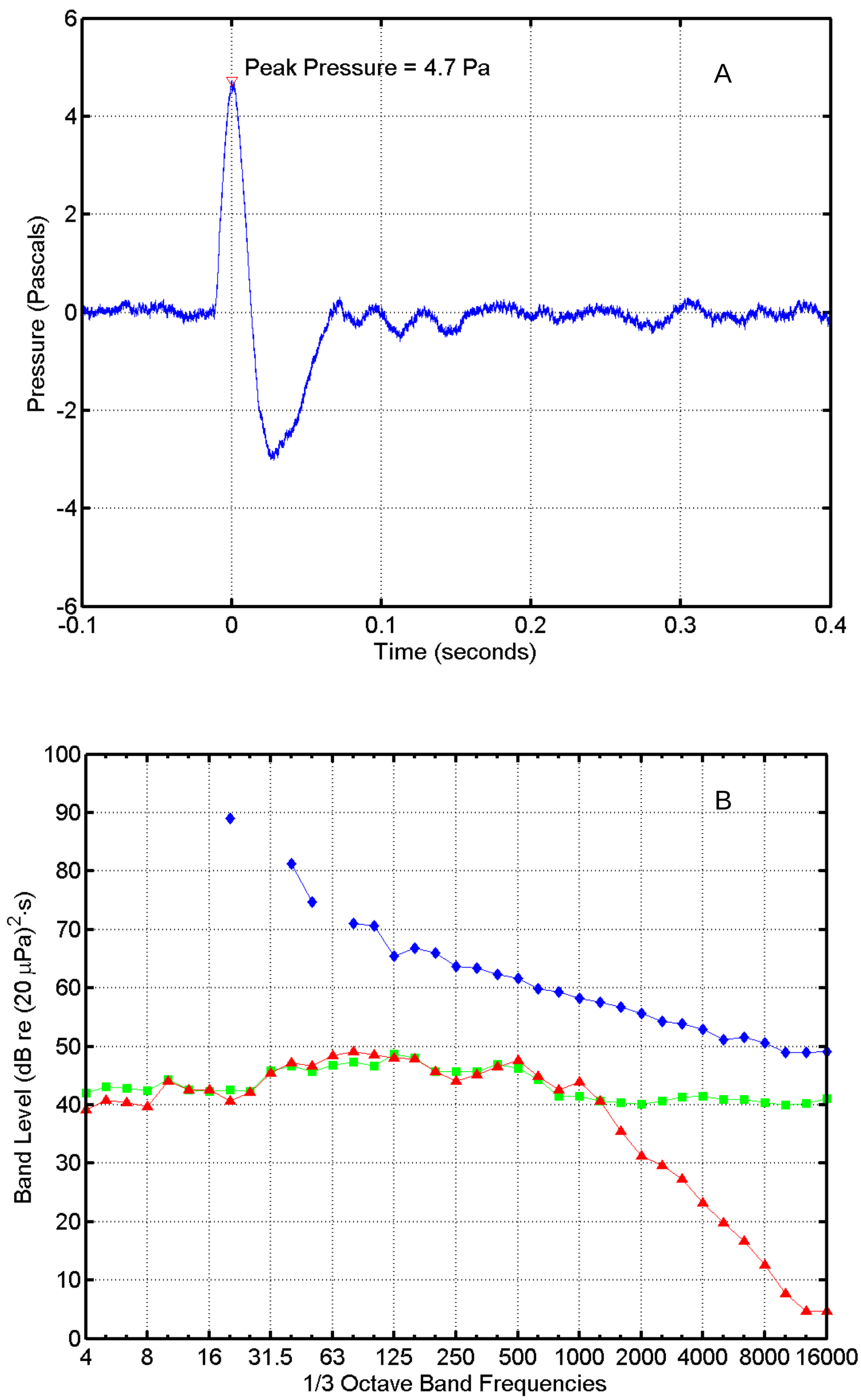


FIGURE C-46. (A) Pressure waveform and (B) one-third octave band levels for an AGS Slug flight at 11:41 on 27 January 2005 recorded at "Redeye I". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

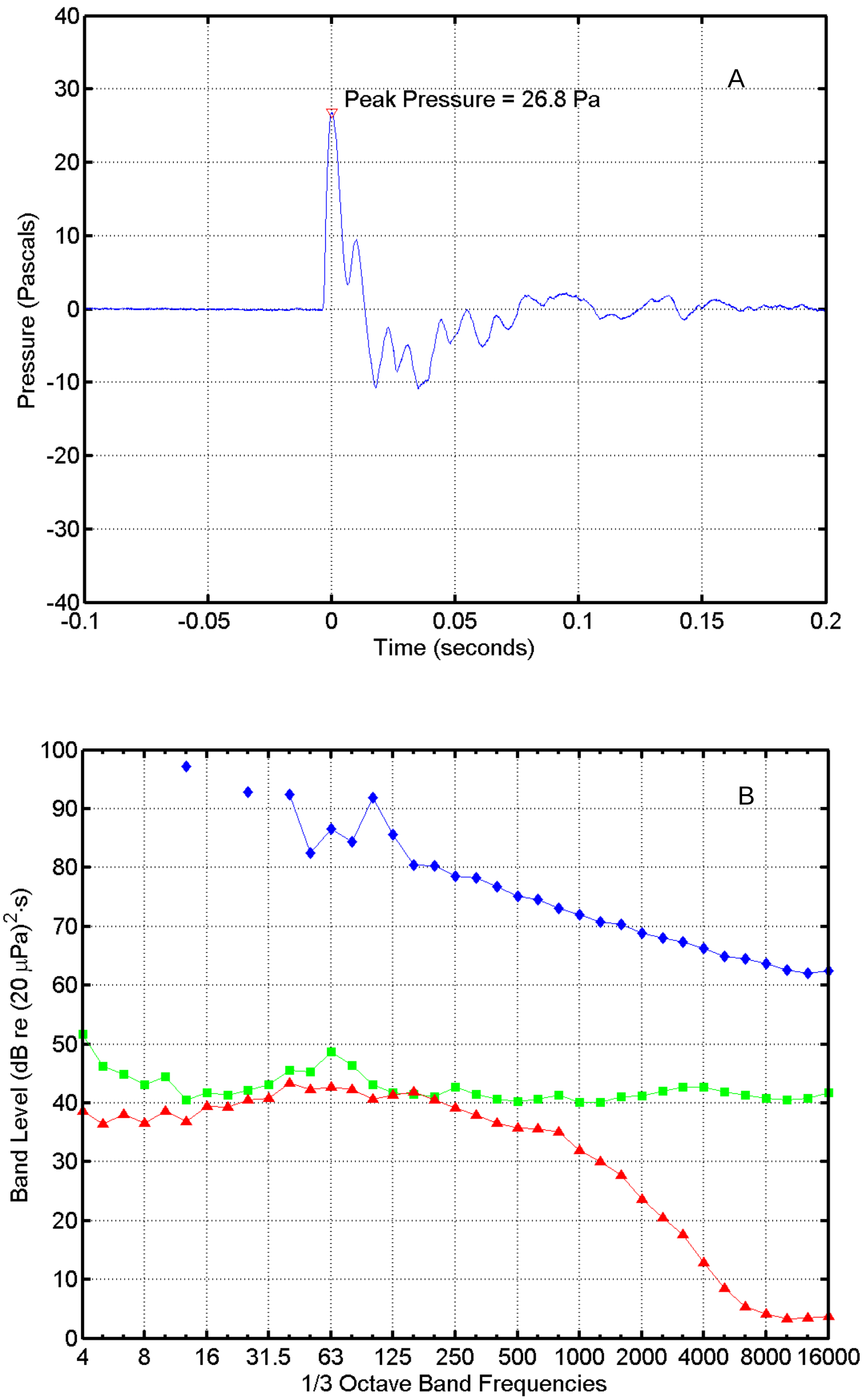
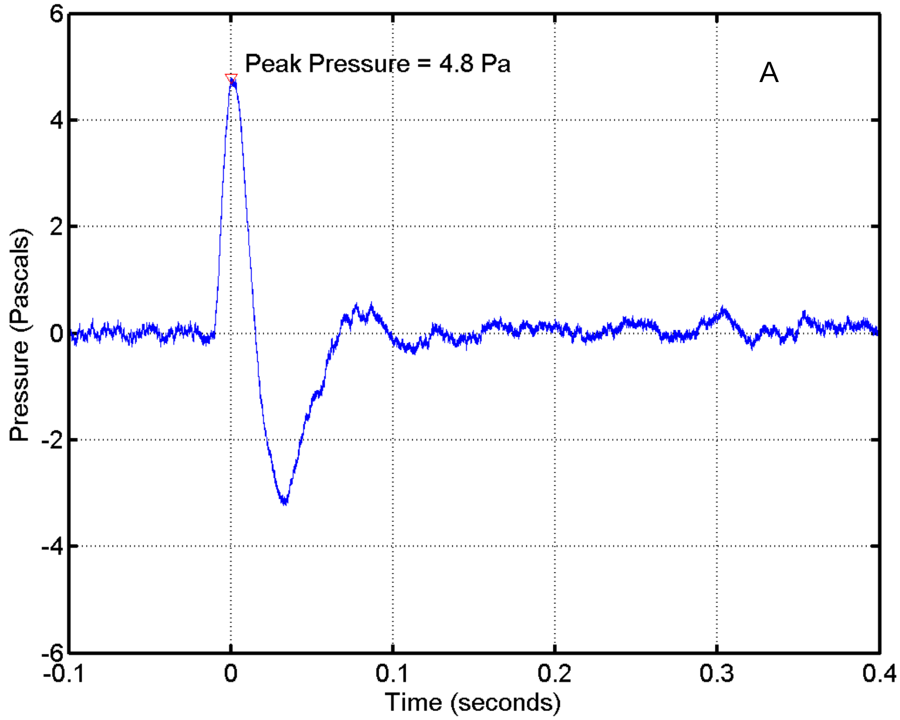


FIGURE C-47. (A) Pressure waveform and (B) one-third octave band levels for an AGS Missile flight at 13:29 on 27 January 2005 recorded at "Bachelor Beach North". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power.



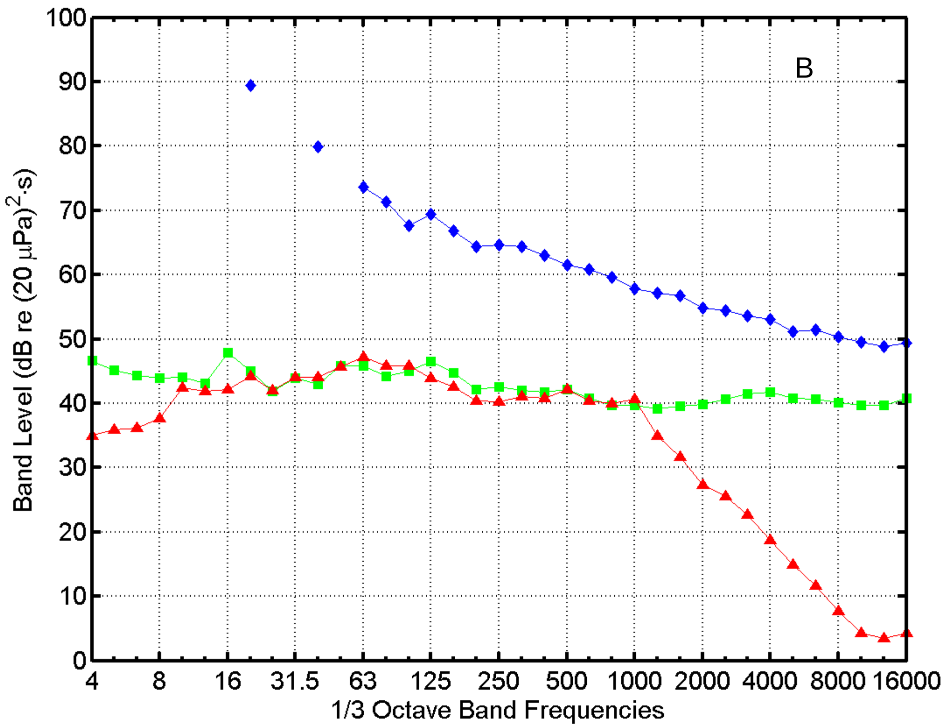


FIGURE C-48. (A) Pressure waveform and (B) one-third octave band levels for an AGS Missile flight at 13:29 on 27 January 2005 recorded at "Redeye I". In (B), ◊ = missile sound energy; □ = instrumentation noise energy; Δ = ambient noise power. Band frequencies in Hertz (Hz).

APPENDIX D: DETAILS OF VEHICLE LAUNCHES, SOUND EXPOSURE LEVELS, AND PINNIPED REACTIONS AT SAN NICOLAS ISLAND DURING AUGUST 2001 TO AUGUST 2003

TABLE D.1. Details of vehicle launches, sound exposure levels (SEL), and ***California sea lion*** reactions at San Nicolas Island during August 2001 – July 2002. Two launches occurred on each of 15 August 2001, 20 September 2001, 1 May 2002, and 26 June 2002. A dual RAM launch occurred on 21 June 2002. All vehicles were launched from the Alpha Launch Complex, except for the dual RAM, which was launched from Building 807 Launch Complex. Times are local time. Sound was not recorded at all monitoring sites.

Launch Date	Launch Time	Vehicle Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	3-D CPA distance (m)	Sound Exposure Levels [dB re (20 μPa)^2·s] flat-weighted/A-weighted	Behavioral Reaction of Animals to Launch
15 Aug. 01	12:56	Vandal	270°	8° / 1280 ft	809 Camera[n]	1044	N/A	Most adults lifted their heads and were more vigilant; a few animals entered the water. Pups in water rushed on shore.
					Dos Coves North and South[d]	388-398	N/A	Most adults lifted their heads, but did not move; a few animals entered the water. Adults settled within minutes; pups stayed active longer.
“	13:17	Vandal	270°	8° / 1280 ft	809 Camera[n]	1044	N/A	Sea lions appeared to show less reaction to second launch. Less than 5% of the adults and juveniles flushed into water.
					Dos Coves North and South[d]	388-398	N/A	Most adults lifted their heads, but did not move. Pups were more active prior to this launch compared to the first launch.
20 Sep. 01	08:30	Vandal	270°	8° / 1280 ft	Dos Coves North and South[d]	388-398	N/A	Adults looked up, some moved, but did not leave area; settled within minutes. Pups reacted vigorously by running around.
					809 Camera[n]	1044	119/101[†]	Sea lion pups in water swam about vigorously.*
“	17:02	Terrier Orion	232.3°	64.6° / 13,000 ft	Sea Lion Cove[s]	2360	96/83[#]	Little reaction by pups and adults in response to launch; animals settled within minutes.
					809 Camera[n]	3071	N/A	Sea lion pups in water swam vigorously and came ashore.*

TABLE D.1. Continued.

Launch Date	Launch Time	Vehicle Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	3-D CPA distance (m)	Sound Exposure Levels [dB re (20 μPa)^2·s] flat-weighted/A-weighted	Behavioral Reaction
5 Oct. 01	13:37	Vandal	273.3°	8° / 1300 ft	809 Camera[n]	846	N/A	Pups on shore moved around, but did not enter water. Some pups that were in water came ashore.
					Vizcaino Pt.[n]	1067	N/A	Sea lions looked and got up, but did not enter water; a few individuals left the area. Pups scattered more than adults.
19 Oct. 01	09:00	Vandal	270°	8° / 1280 ft	809 Camera[n]	1044	N/A	Some pups reacted to the launch by moving up on the beach. Several pups came out of the water and came ashore.
					Vizcaino Pt.[n]	1067	N/A	Most sea lions were startled and scattered; 10% left (these were mostly pups). Within 5 min animals resumed pre-launch activities.
19 Dec. 01	15:22	Vandal	273°	8° / 1300 ft	809 Camera[n]	895	121/103[†]	Most animals (60%) left the location were they had rested but did not enter the water.
6 Mar. 02	11:20	Vandal	273.1°	8° / 1300 ft	809 Camera[n]	895	121/106[†]	Most animals looked up and some moved. Only 16% of animals entered water; they were mostly juveniles.
1 May 02	15:53	Vandal	273°	6.5° / malfunctioned & hit land	809 Camera[n]	N/A	104/90	Sea lions showed no distinct reaction to the first launch.

TABLE D.1. Continued.

Launch Date	Launch Time	Vehicle Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	3-D CPA distance (m)	Sound Exposure Levels [dB re (20 μPa)^2·s] flat-weighted/A-weighted	Behavioral Reaction
1 May 02	17:00	Vandal	273°	42° / 9600 ft	809 Camera[n]	2312	103/90	Most sea lions looked up, and several moved in response to the launch sound (mostly younger animals).
8 May 02	14:54	Vandal	273°	8° / 1300 ft	809 Camera[n]	895	122/104[^,†]	All sea lions looked up, some got up and moved around, and 33% entered the water.
					Sea Lion Cove[s]	2138	N/A	Most sea lions looked up, but did not move.
19 June 02	15:07	AGS Test Slug	305°	63° / hit land	809 Camera[d]	N/A	N/A	Most sea lions sat up and some moved, but none entered the water.
21 June 02	12:53	RAM	240°	8° / 50 ft	Bachelor Beach North[s]	683	N/A	During the launch, most sea lions looked up and some moved slightly, but none entered the water.
					Dos Coves South[n]	581	N/A	Sea lions looked up during the launches, but did not move; they settled within minutes after the launch.
26 June 02	11:20	AGS Test Slug	300°	62.5° / 500 ft	Redeye Beach[s]	N/A	96/62	The sea lions did not show much reaction; some looked up and several moved slightly.
"	12:51	AGS Missile	300°	62.5° / 5300 ft	809 Camera[s]	622	94/64	The sea lions did not show much reaction; some looked up and several moved slightly.

TABLE D.1. Continued.

Launch Date	Launch Time	Vehicle Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	3-D CPA distance (m)	Sound Exposure Levels [dB re $(20\ \mu Pa)^2 \cdot s$] flat-weighted/A-weighted	Behavioral Reaction
18 July 02	11:54	Vandal	273°	8° / 1300 ft	Dos Coves North[d]	2134	128/110[†]	During the launch, all of the sea lions looked up, and 50% left the area immediately. All but one sea lion left the immediate area within several minutes after the launch.

Note: N/A means that data are not available.
[n] monitoring site located north of the launch azimuth.
[s] monitoring site located south of the launch azimuth.
[d] monitoring site located directly near launch azimuth.
[#] SEL taken at nearby Cormorant Rock Blind; situated < 0.5 km northwest of Sea Lion Cove.
* incidental sightings of sea lions at harbor seal haul-out sites.
[^] SEL taken nearby at Vizcaino Pt.; located < 0.5 km from 809 Camera.
[†] Sonic boom evident.

TABLE D.2. Details of vehicle launches, sound exposure levels (SEL), and ***northern elephant seal*** reactions at San Nicolas Island during August 2001 – July 2002. Two launches occurred on each of 20 September 2001, 22 February 2002, and 1 May 2002. All vehicles were launched from the Alpha Launch Complex, except for the dual RAM, which was launched from Building 807 Launch Complex. Times are local time. Sound was not recorded at all monitoring sites.

Launch Date	Launch Time	Vehicle Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	3-D CPA distance (m)	Sound Exposure Levels [dB re (20 μPa)^2·s] flat-weighted/A-weighted	Behavioral Reaction
20 Sep. 01	17:02	Terrier Orion	232.3°	64.6° / 13,000 ft	Bachelor Beach North[n]	2289	N/A	All seals glanced up, and some shuffled positions slightly, but did not move out of the area.
					Bachelor Beach South[n]	2306	96/83*	Most seals looked up, but did not move.
19 Oct. 01	09:00	Vandal	270°	8° / 1280 ft	Bachelor Beach South[s]	1561	N/A	Most animals looked up briefly; 20% of juveniles moved but did not enter water.
14 Feb. 02	11:33	Vandal	273°	8° / 1300 ft	Bachelor Beach North[s]	1206	123/107[†]	Elephant seals showed little reaction to launch; most seals looked up briefly, but no seals moved.
					Redeye Beach[n]	689	N/A	All seals looked up and several moved, but not into the water.
22 Feb. 02	12:13	Vandal	270°	42° / 7150 ft	Bachelor Beach North[s]	2093	N/A	Most seals glanced up, but hardly any seals moved or shifted position.
"	14:56	Vandal	270°	42° / 7150 ft	"	2093	N/A	Most elephant seals hardly reacted to second launch, although some animals looked up.
1 May 02	15:53	Vandal	273°	6.5° / malfunctioned & hit land	Pirates Cove[e]	N/A	N/A	The seals got up and moved, but likely in response to the startled harbor seals, not the launch sound. Several minutes after the launch, the seals walked up the beach.
"	17:00	Vandal	273°	42° / 9600 ft	Pirates Cove[e]	2389	N/A	No elephant seals were seen.

TABLE D.2. Continued.

Launch Date	Launch Time	Vehicle Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	3-D CPA distance (m)	Sound Exposure Levels [dB re (20 μPa)^2·s] flat-weighted/A-weighted	Behavioral Reaction
8 May 02	14:54	Vandal	273°	8° / 1300 ft	Pirates Cove[e]	2389	96/67	The seals looked up when the missile was launched, but settled within seconds after the launch.
					Sea Lion Cove[s]	2138	92/80	The seals looked up when the missile was launched, but settled within seconds after the launch.
					Redeye Beach[n]	689	N/A	The seals moved to the water several seconds after the launch.[#]
19 June 02	15:07	AGS Test Slug	305°	63° / hit land	Redeye I[n]	N/A	97/72^	Some seals looked up, but settled within seconds after the launch.
21 June 02	12:53	RAM	240°	8° / 50 ft	Bachelor Beach North[s]	683	N/A	All seals looked up during the launch, but none moved. They settled within seconds.

Note: N/A means data are not available.
[n] monitoring site was located north of the launch azimuth.
[s] monitoring site was located south of launch azimuth.
[e] monitoring site was located northeast of launch azimuth.
[*] SEL taken at nearby Cormorant Rock Blind; located < 0.5 km south of Bachelor Beach South.
^ SEL taken at nearby Redeye II; situated < 0.5 km from Redeye.
[#] Incidental sightings of elephant seals at harbor seal haul-out site.
[†] Sonic boom evident.

TABLE D.3. Details of vehicle launches, sound exposure levels (SEL), and ***harbor seal*** reactions at San Nicolas Island during August 2001 – July 2002. Two launches occurred on each of 15 August 2001, 20 September 2001, 1 May 2002, and 26 June 2002. All vehicles were launched from the Alpha Launch Complex. Times are local time. Sound was not recorded at all monitoring sites.

Launch Date	Launch Time	Vehicle Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	3-D CPA distance (m)	Sound Exposure Levels [dB re (20 μPa)^2·s] flat-weighted/A-weighted	Behavioral Reaction
15 Aug. 01	12:56	Vandal	270°	8° / 1280 ft	809 Camera[n]	1044	N/A	Most seals (66%) fled into the water; seals that remained on beach settled within 5 min.
"	13:17	Vandal	270°	8° / 1280 ft	"	1044	N/A	Less reaction to second launch; 40% fled into water.
20 Sep. 01	08:30	Vandal	270°	8° / 1280 ft	809 Camera[n]	1044	119/101[†]	Most seals (75%) entered the water; remaining seals settled within a few minutes.
"	17:02	Terrier Orion	232.3°	64.6° / 13,000 ft	"	1044	N/A	All seals entered water.
5 Oct. 01	13:37	Vandal	273.3°	8° / 1300 ft	809 Camera[n]	846	N/A	Most seals (70%) entered water; 10 min after launch, no seals were left on beach.
					Phoca Reef[e]	2426	94/*	Less than 10% of seals entered water; most looked up but did not move .
6 Mar. 02	11:20	Vandal	273.1°	8° / 1300 ft	809 Camera[n]	895	121/106[†]	Seals looked up or moved in response to launch but did not enter water
					Pirates Cove[e]	2389	N/A	All seals entered water; seals started to return to beach 16 min after launch.
					Redeye Beach[n]	689	N/A	Most seals (98%) entered the water, but some individuals took as long as 6 min to do so. Seals started to return to beach 13 min after launch.

TABLE D.3. Continued.

Launch Date	Launch Time	Vehicle Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	3-D CPA distance (m)	Sound Exposure Levels [dB re (20 µPa)^2·s] flat-weighted/A-weighted	Behavioral Reaction
1 May 02	15:53	Vandal	273°	6.5° / malfunctioned & hit land	Pirates Cove[e]	N/A	N/A	Most seals startled and looked up, but did not enter the water. Few moved (14%); those that did were pups.
"	17:00	Vandal	273°	42° / 9600 ft	Pirates Cove[e]	2389	N/A	Seals appeared to react more to the second launch; some seals scattered, and 38% fled into the water. The majority of seals that entered the water were pups.
8 May 02	14:54	Vandal	273°	8° / 1300 ft	Pirates Cove[e]	2389	96/67	All seals looked up and some moved slightly; 7% entered the water
					Redeye Beach[n]	689	N/A	All seals rushed into water; they started hauling out again 13 min after the launch.
					Sea Lion Cove[s]	2138	92/80	Most of the seals (90%) entered the water and did not return to the beach.
26 June 02	11:20	AGS Test Slug	300°	62.5° / 500 ft	Redeye Beach[n]	N/A	96/62	Seals looked up, but did not move.
"	12:51	AGS Missile	300°	62.5° / 5300 ft	Redeye Beach[n]	1542	93/ 64	Seals looked up, but did not move.

Note: N/A means data not available.
[n] monitoring site was located north of the launch azimuth.
[e] monitoring site was located north east of launch azimuth.
[s] monitoring site was located south of the launch azimuth.
*A-weighted SEL not available.
[†] Sonic boom evident.

TABLE D.4. Details of vehicle launches, sound exposure levels (SEL), and ***California sea lion*** reactions at San Nicolas Island during August 2002–August 2003. There were no recordings of sea lions from February to May 2003. A dual RAM launch occurred on 18 November 2002. The Tomahawk and RAM vehicles were launched from the Building 807 Launch Complex, whereas the SSSTs and Vandals were launched from the Alpha Launch Complex. Times are local time. Sound was not recorded quantitatively at all monitoring sites.

Launch Date	Launch Time	Vehicle Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	3-D CPA distance (m)	Sound Exposure Levels [dB re (20 μPa)^2·s] flat-weighted/A-weighted	Behavioral Reaction of Animals to Launch
23 Aug. 2002	14:09	Tomahawk	305°	90° / 1000 ft	Dos Coves South[n]	594	105/102	All 50 animals moved around vigorously on the beach; one pup entered the water; one pup came out of the water. Animals settled within minutes after launch. Launch was preceded by low-altitude aircraft overflights that caused disturbance.
18 Nov. 2002	11:03	RAM	240°	10° / 50 ft	Dos Coves South[n]	580	Launch sound audible on audio track of video recording	Most sea lion pups moved vigorously along beach; some adults looked or got up, but did not move any further; 57% of 70 animals reacted vigorously. Animals settled within minutes after the launch.
24 Jan. 2003	14:20	SSST	270°	20° / 3400 ft	Dos Coves South[c]	993 (overhead)	N/A	About 30 s after the launch, 40 sea lions were seen moving vigorously down the beach and possibly entered the water; most animals seen were pups
4 June 2003	12:35	SSST	270°	22° / 3500 ft	Near 809 Camera[n]	1429	116/99	Most sea lions (60% of 15) got up and moved 1-10 m; one adult female entered the water. Remain-ed vigilant for ~1.5 min after the launch.

TABLE D.4. Continued.

Launch Date	Launch Time	Vehicle Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	3-D CPA distance (m)	Sound Exposure Levels [dB re (20 μPa)^2·s] flat-weighted/A-weighted	Behavioral Reaction of Animals to Launch
26 June 2003	13:27	Vandal	285°	42° / 17,300 ft	Near 809 Camera[c]	2807 (overhead)	103/90	Most of the 10 sea lions looked up from their resting positions, but did not move. Settled back to their resting positions within seconds after launch.
					The "Y"[c]	2824 (overhead)	101/89	Majority of 20 sea lions looked up, but did not move. Settled back within seconds after launch.
					Bomber Cove[n]	3054 (overhead)	Launch sound audible on audio track of video recording	Most adult sea lions (92% of 100) looked up and some sat up, but did not move. One male and one female sea lion moved ~2 m. Six pups ran through the water. Animals settled several minutes after launch.
28 July 2003	16:27	Vandal	270°	8° / 1280 ft	Dos Coves South[c]	388 (overhead)	Launch sound audible on audio track of video recording	All 100 sea lions scattered; about 50% of the adults (~25) moved 2-3 m; the other 50% moved >10 m. All pups ran around on the beach, and several pups (~12 of 50) entered the water. After launch, adults remained vigilant and pups were still moving on beach.
					Near 809 Camera[n]	1081	122/106	All 35 sea lions startled and got up. Several animals (26%) moved 3-8 m, but none entered water. Several animals were more vigilant up to 10 min after launch.
					Bachelor Beach North[s]	1082	N/A	Several of the 7 animals looked up or got up, but none moved. Sea lions settled within 30 sec after launch.

Note: N/A means that sound exposure levels are not available for that location, and there is no audio track on the video recording for that site.
[n] monitoring site located north of the launch azimuth.
[c] monitoring site located near the launch azimuth.
[s] monitoring site located south of the launch azimuth.

TABLE D.5. Details of vehicle launches, sound exposure levels (SEL), and ***northern elephant seal*** reactions at San Nicolas Island during August 2002–August 2003. There were no recordings of elephant seals from February to June 2003. A dual RAM launch occurred on 18 November 2002. The Tomahawk and RAM vehicles were launched from Building 807 Launch Complex, whereas the Vandals and SSSTs were launched from the Alpha Launch Complex. Times are local time. Sound was not recorded quantitatively at all monitoring sites.

Launch Date	Launch Time	Vehicle Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	3-D CPA distance (m)	Sound Exposure Levels [dB re (20 μPa)^2·s] flat-weighted/A-weighted	Behavioral Reaction of Animals to Launch
23 Aug. 2002	14:09	Tomahawk	305°	90° / 1000 ft	Bachelor Beach North[s]	746	N/A	None of 10 seals responded to launch.
18 Nov. 2002	11:03	RAM	240°	10° / 50 ft	Bachelor Beach North[s]	683	97/92*	Some of the 60 seals likely reacted by looking up, but poor video quality.
					Dos Coves South[n]	580	Launch sound audible on audio track of video recording	All 10 seals looked up; 29% of animals moved a small distance along beach. Seals settled within seconds after launch.
10 Dec. 2002	8:49	Vandal	273°	8° / 1300 ft	Bachelor Beach North[s]	1206	117/102[†]	Majority of 40 seals looked up and several animals (38%; mainly pups) moved; one adult female seal entered water. Seals settled within a minute after launch.
24 Jan. 2003	14:20	SSST	270°	20° / 3400 ft	Bachelor Beach South[s]	1677	Launch sound audible on audio track of video recording	All 100 seals looked up and several (5%) moved. Seals settled quickly.
					Dos Coves South[c]	993 (overhead)	N/A	All 7 seals looked up and 3 of 7 moved a short distance; seals settled quickly.
28 July 2003	16:27	Vandal	270°	8° / 1280 ft	Bachelor Beach North[s]	1082	N/A	Majority of 7 seals looked up, but some did not respond to launch at all.

Note: N/A means that sound exposure levels are not available for that location, and there is no audio track on the video recording for that site.
[n] monitoring site was located north of the launch azimuth; [s] monitoring site was located south of the launch azimuth; [c] monitoring site was located near the launch azimuth.
[†] sonic boom
*SEL taken nearby Bachelor Beach South, located < 0.5 km south of Bachelor Beach North.

TABLE D.6. Details of vehicle launches, sound exposure levels (SEL), and ***harbor seal*** reactions at San Nicolas Island during August 2002–August 2003. There were no recordings of harbor seals from August 2002 to February 2003. A dual Vandal launch occurred on 4 April 2003. All launches were from the Alpha Launch Complex. Times are local time. Sound was not recorded quantitatively at all monitoring sites.

Launch Date	Launch Time	Vehicle Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	3-D CPA distance (m)	Sound Exposure Levels [dB re (20 μPa)^2·s] flat-weighted/A-weighted	Behavioral Reaction of Animals to Launch
14 Mar. 2003	9:13	Vandal	273°	8° / 1300 ft[e]	Sheephead Ranch[e]	2923	98/60	Most seals (4 of 5) entered water; one pup looked but did not move.
16 Mar. 2003	13:04	Vandal	273°	8° / 1300 ft[e]	Corral Harbor[e]	2589	100/71	All (8 of 8) seals entered water; some more slowly than others.
					Pirates Cove[e]	2389	N/A	Majority of 45 seals entered water; 20% did not but moved at least several feet on beach. A pup was knocked over by an adult seal, but did not appear hurt.
4 Apr. 2003	15:20	Dual Vandal	273°	8° / 1300 ft[e]	Phoca Point[e]	3274	101/63-66	Majority of 35 seals entered water; 11% of seals did not enter the water, but moved at least several feet on the beach. Two pups were knocked over by adult seals, but did not appear hurt.
					No Name Cove[e]	3514	101/67-68	Majority of 30 seals entered water, 10% did not and moved only short distances on beach.
4 June 2003	12:35	SSST	270°	22° / 3500 ft	Sheephead Ranch[e]	2923	102/87[†]	Six of 7 seals looked up in response to the launch, but did not move. One seal moved 0.5 m.

Note: N/A means that sound exposure levels are not available for that location, and/or there is no audio track on the video recording for that site.
[e] monitoring site located northeast (away) from the launch azimuth; "altitude over beach" pertains to the beach on the west end of San Nicolas Island where the launch azimuth went offshore—far from these pinniped monitoring sites. [†] sonic boom