Marine Mammal and Acoustical Monitoring of Missile Launches on San Nicolas Island, August 2001 – July 2002

submitted by

Naval Air Weapons Station
China Lake, California

to

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

prepared by

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King City, Ontario, Canada

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in association with

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MARINE MAMMAL AND ACOUSTICAL MONITORING OF MISSILE LAUNCHES ON SAN NICOLAS ISLAND, AUGUST 2001 – JULY 2002

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Lawson, J.W. 2002. Estimated numbers of pinnipeds affected by missile launches. p. 4-1 to 4-5 *In*: J.W. Lawson, E.A. Becker, and W.J. Richardson (eds.) … [as above].

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

The following list shows the meaning of acronyms and abbreviations used in this report.

AGS	Advanced Gun System
ASAR	Autonomous Seafloor Acoustic Recorder
ASEL	A-weighted Sound Exposure Level
ATAR	Autonomous Terrestrial Acoustic Recorder
ASL	Above Sea Level
cm	centimeter
CPA	closest point of approach
dB	decibel
Hz	hertz
IHA	Incidental Harassment Authorization
kg	kilogram
m	meter (1 m = 1.09 yards or 3.28 feet)
km	kilometer (1 km = 3281 ft, 0.62 st.mi., or 0.54 n.mi.)
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 statute miles or 1.853 km)
rms	root mean square (a type of average)
PTS	Permanent Threshold Shift
RAM	Rolling Airframe Missile
SEL	Sound Exposure Level
SPL	Sound Pressure Level
TTS	Temporary Threshold Shift
V/µPa	volts per micropascal
µPa	micropascal
WOSA	Weighted Overlapped Segment Averaging

EXECUTIVE SUMMARY

Naval Air Weapons Station (NAWS), China Lake, pursuant to 50 Code of Federal Regulations (C.F.R.) 216, Subpart I (61 Federal Register 15884 et. seq.), § 101 (a) (5) (D) of the Marine Mammal Protection Act (MMPA), 16 United States Code (U.S.C.) § 1371 (a) (5), was issued an Incidental Harassment Authorization (IHA) 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, California (NMFS 2001). The IHA was issued on 1 August 2001 and was valid for a one-year period. The IHA allowed for the "take by harassment" of small numbers of northern elephant seals (*Mirounga angustirostris*), harbor seals (*Phoca vitulina*), California sea lions (*Zalophus californianus*), and northern fur seals (*Callorhinus ursinus*), during routine launch operations on Navy-owned San Nicolas Island.

As part of the IHA Application, a Marine Mammal Monitoring Plan was developed to monitor any effects of launch activities on these marine mammals. This report describes the results of the marine mammal and associated acoustic monitoring program from 1 August 2001 to 31 July 2002. During this time, there were a total of 19 launches (including one dual launch) from San Nicolas Island on dates ranging from 15 August 2001 to 18 July 2002. The following subsections briefly summarize the monitoring program. Details are provided in subsequent chapters of this report.

Missile Launches and Monitoring Program Described

Most of the vehicles launched from San Nicolas Island were Vandals. The Vandal 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 cruise missile. Of the 19 launches in the monitoring period, 14 involved Vandals. The Navy also launched one Terrier Orion, which is a slightly smaller rocket that flies ballistic trajectories. In addition, an Advanced Gun System (AGS) missile and two slugs were launched, and there was a dual launch of Rolling Airframe Missiles (RAM). The dual launch consisted of two missiles that were launched within seconds of each other.

Launches occurred on 14 days, with single launches on eight days, two launches on each of five days, and one dual-launch on another day. On three days (15 August 2001, 22 February 2002, and 1 May 2002), two Vandals were launched sequentially, 21 min, 2 hr 43 min, and 1 hr 7 min apart, respectively. On 20 September 2001, a Vandal and a Terrier Orion were launched on the same day, 8 hr 32 min apart. On 26 June 2002, a slug was launched followed by an AGS missile, 1 hr 31 min later. A dual RAM launch occurred on 21 June 2002, when two missiles were launched within 3 sec of each other.

Almost all of the launches, including all Vandal launches, the Terrier Orion, and AGS, were from the Alpha Launch Complex. This launch site is 625 feet (190.5 m) above sea level on the west-central part of San Nicolas Island, California. Most of the Vandal launches in the monitoring period had low-angle (8º) launch profiles and were directed westward, crossing the west end of San Nicolas Island at an altitude of about 1,300 feet (396 m). However, on 22 February and 1 May 2002, a total of four Vandals, two launched on each day, had high-angle (42º) launch profiles, crossing the west end of the island at an altitude of about 9,600 ft (2,926 m). On 20 September 2001, the Terrier Orion had a high-angle (64.6º) launch trajectory, crossing the west end of the island at an altitude of about 13,000 feet (3,962 m). The AGS missile also had high-angle (62.5º) trajectory, with an altitude over the west end of the island of about 5,300 ft (1,615 m). The dual RAM was launched from the Building 807 Launch Complex, on the western end of San Nicolas Island. This site is approximately 35 ft (11 m) above sea level.

Acoustic Measurements During Missile Launches

The measured levels of missile flight sounds as received at various locations around the periphery of western San Nicolas Island compare well with the range of sound levels reported from previous measurements during Vandal flights at San Nicolas Island in 1997 and 1999. Four Vandal launches in 1997 and 1999 resulted in flat-weighted sound pressure levels (SPLs) ranging from 96 to 141 decibels (dB) re 20 micropascal (µPa) at five sites. That range compares with 90 to 142 dB for the Vandal SPLs for August 2001 – July 2002. The Terrier Orion SPLs (one launch recorded at three sites; flat-weighted) ranged from 89 to 138 dB, although the 138 dB value appears anomalously high given this missile's greater distance from the microphones. The three AGS launches resulted in SPLs ranging from 95 to 150 dB, with the latter high value being recorded 50 ft from the launcher. The SPL for the dual RAM launch was 126 dB, as measured 50 ft from the launcher.

The sonic booms from the Vandal flights were very short, on the order of 0.05 sec. However, the definition of duration as the time interval associated with receipt of 5 to 95% of the cumulative energy effectively extends the duration, because the propulsion noise following the sonic boom includes a substantial portion of the total energy. Consideration of these longer times results in lower SPLs because the SPL is an average over the defined duration, including the portion with comparatively low-level sounds. Another measure of each launch sound, the SEL or Sound Exposure Level, represents the total received energy. This ranged from 92 to 129 dB re $(20\ \mu Pa)^2 \cdot s$ for the Vandal launches and 93 to 138 dB for the Terrier Orion launch (flat-weighted). The SELs for the AGS launches ranged from 93 to 137 dB, and the dual RAM launch resulted in an SEL of 131 dB. A-weighted SPL and SEL values were generally several decibels lower.

None of the recorded sound pressures appears to be sufficiently strong to induce Temporary Threshold Shift (TTS), assuming that an SPL of 164 dB re 20 µPa from a single launch might cause TTS.

The measurements of Vandal launch noise obtained from August 2001 – March 2002 were used to estimate isopleths (contours) of A-weighted sound exposure level (ASEL) during Vandal launches from San Nicolas Island. The mapped isopleths are for the common launch condition of 8º elevation angle and 270º launch azimuth. Areas that would, on average, receive launch sounds at ASEL levels of 120, 110, 100, and 90 dB re 20 μPa^2-sec during such a launch were mapped. The resulting estimates differ somewhat from those predicted in an earlier (1998) analysis. Distances to a given ASEL value are generally lower than previously estimated.

Behavior of Pinnipeds During Missile Launches

Behavior of pinnipeds around the periphery of western San Nicolas Island during missile launches was monitored by unattended video cameras set-up before each launch and using a remotely-controlled video camera at location "809 Camera" at the west end of the island. These video data were supplemented by direct visual scans of the haul-out groups prior to and following the launches. Monitoring was attempted at three sites during each launch, with launch-to-launch variation in the locations monitored.

California sea lions were observed during 12 of the 14 launch dates, with observations at 1-3 sites on each of those 12 dates (total of 22 site–date combinations). Incidental observations at a fourth site were made on one occasion. As expected, responses of California sea lions to the missile launches varied by individual and age group. Some sea lions exhibited brief startle responses and increased vigilance for a short period 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. Some pups rushed into the water, while other pups in the water rushed onto shore.

Interestingly, it was not uncommon for sea lion pups playing in the shallow waters near haul-out sites to *leave* the water and rush ashore during a missile overflight. Adult sea lions already hauled out would mill about on the beach for a short period before settling, whereas those in the shallow water near the beach did not come ashore like the aforementioned pups. All age classes settled back to pre-launch behavior patterns within minutes of the launch time.

Harbor seals were observed at 1-3 sites during seven of the 14 launch dates (total of 12 site–date combinations). During the majority of launches, most individuals left their haul-out sites on rocky ledges to enter the water and did not return during the duration of the video-recording period (which sometimes extended up to several hours after the launch time). During post-monitoring the following day, harbor seals were usually hauled out again at these sites.

Northern elephant seals were observed at 1 or 2 sites during eight of the 14 launch dates (total of 11 site–date combinations). They exhibited little reaction to launch sounds. Most individuals merely raised their heads briefly upon hearing the launch sounds and then quickly returned to their previous activity pattern (usually sleeping). During some launches, a small proportion of northern elephant seals on the beach repositioned or moved a short distance away from their resting site, but usually settled within minutes.

There were interspecific differences in responses to launches. For northern elephant seals, inter-individual spacing, frequency of body position changes, and distance moved did not differ significantly between pre- and post-launch periods. In contrast, California sea lions made significantly more body position changes immediately following launches. California sea lions also moved significantly greater distances immediately following launches; this effect was primarily attributable to young sea lions. After launches, California sea lions were positioned significantly closer together than before launches. For harbor seals, inter-individual spacing significantly increased during post-launch periods. Harbor seals also showed a significantly greater number of body position changes after launches, and they moved significantly greater distances during post-launch periods. When the behavior of the three pinniped species before the launches was compared to their behavior during follow-up monitoring the day following the launches, no significant differences were found.

Launches did not occur when visibility was extremely restricted (e.g., by heavy fog), so it is not possible to assess the influence of horizontal visibility on the types or magnitudes of pinniped behavioral responses to launch sounds.

The relatively limited number of monitored haul-out sites resulted in elephant seals being seen on sandy substrates only. Harbor seals were seen hauled out on rock ledges (or in nearby waters) or on sand. California sea lions were seen on sand, cobble, or rocky ledges, as well as in shallow water. For individual species, there did not appear to be any discernible (or quantifiable) differences in the types or magnitudes of behavioral responses to launch sounds based on substrate type.

No evidence of injury or mortality was observed during or immediately succeeding the launches. However, one or two dead pups were reported during follow-up monitoring the day after launches on several occasions. Most of the dead pups were elephant seal pups, but several sea lion pups were also seen. Observations by Navy personnel indicated that the pups had died several days before the launches and not as a result of the launches.

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. Few if any pinnipeds were exposed to sound levels above 138 dB re 20 µPa Sound Exposure Level (SEL) on a flat-weighted basis, or 130 dB SEL on an A-weighted basis (see Chapter 2), so TTS is unlikely.

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 an estimate of the total number of pinnipeds affected. We considered pinnipeds that left the haul-out site, or exhibited prolonged movement or prolonged behavioral changes, as being affected.

Approximately 1042 California sea lions, 204 harbor seals, and 50 northern elephant seals on the monitored beaches are estimated to have been affected by launch sounds during the 19 launches monitored here. Of the California sea lions, most were young animals such as pups or juveniles. These numbers are probably underestimates because not all pinniped beaches around western San Nicolas Island could be monitored during any given launch. However, 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 pinnipeds on San Nicolas Island 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 site until the following low tide), and numbers occupying haul-out sites shortly after a launch, or the next day, were similar to pre-launch levels.

There was no evidence of injury or mortality on the day of any of the launches, and the haul-out sites continued to be occupied on subsequent days. Dead sea lion and elephant seal pups were seen on several occasions during post-monitoring observations the day following launches. However, on all occasions, launches were not considered the cause of death, because the pups appeared to have died several days previously.

1. MISSILE LAUNCHES AND MONITORING PROGRAM DESCRIBED[1]

Naval Air Weapons Station (NAWS), China Lake was issued an Incidental Harassment Authorization (IHA) 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, California (NMFS 2001). The IHA was issued on 1 August 2001 and was valid for a one-year period. The IHA allowed the "take by harassment" of small numbers of northern elephant seals (*Mirounga angustirostris*), harbor seals (*Phoca vitulina*), California sea lions (*Zalophus californianus*), and northern fur seals (*Callorhinus ursinus*) during routine launches from Navy-owned San Nicolas Island.

As part of the IHA Application, a Marine Mammal Monitoring Plan was developed to monitor any effects of launch activities on marine mammals. This report describes the results of the marine mammal and associated acoustic monitoring program from 1 August 2001 to 31 July 2002. During this time, 19 launches occurred from San Nicolas Island, on dates ranging from 15 August 2001 to 18 July 2002.

This report describes the missiles and their launch processes, the associated monitoring program, and the basic monitoring results for the launches conducted by the Navy at San Nicolas Island, California, from 1 August 2001 to 31 July 2002.

This report includes four chapters:

1. background, introduction, and description of the Navy's missile launches in August 2001 – July 2002 [this chapter];
2. acoustical monitoring during the missile launches [Chapter 2];
3. visual monitoring of pinnipeds [Chapter 3];
4. estimated numbers of pinnipeds affected by the missile sounds during these launches [Chapter 4].

1.1 Background Information on the 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 cruise missile (Figure 1.1). The Vandal is 25.2 feet (7.7 m) long, excluding the booster, and 28 in (71 cm) in diameter. There are three variants of the Vandal, the standard, ER, and EER; the EER variant, including booster, weighs 8,100 lb (3,674 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 a 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 San Nicolas Island.

Vandals are remotely-controlled, non-recoverable missiles that are launched from a land-based launch site on the western part of San Nicolas Island (Figure 1.2). The Vandal launch site, hereafter referred to as the Alpha Launch Complex, is 625 feet (190.5 m) above sea level (ASL) on the west-central part of San Nicolas Island (Figure 1.3).

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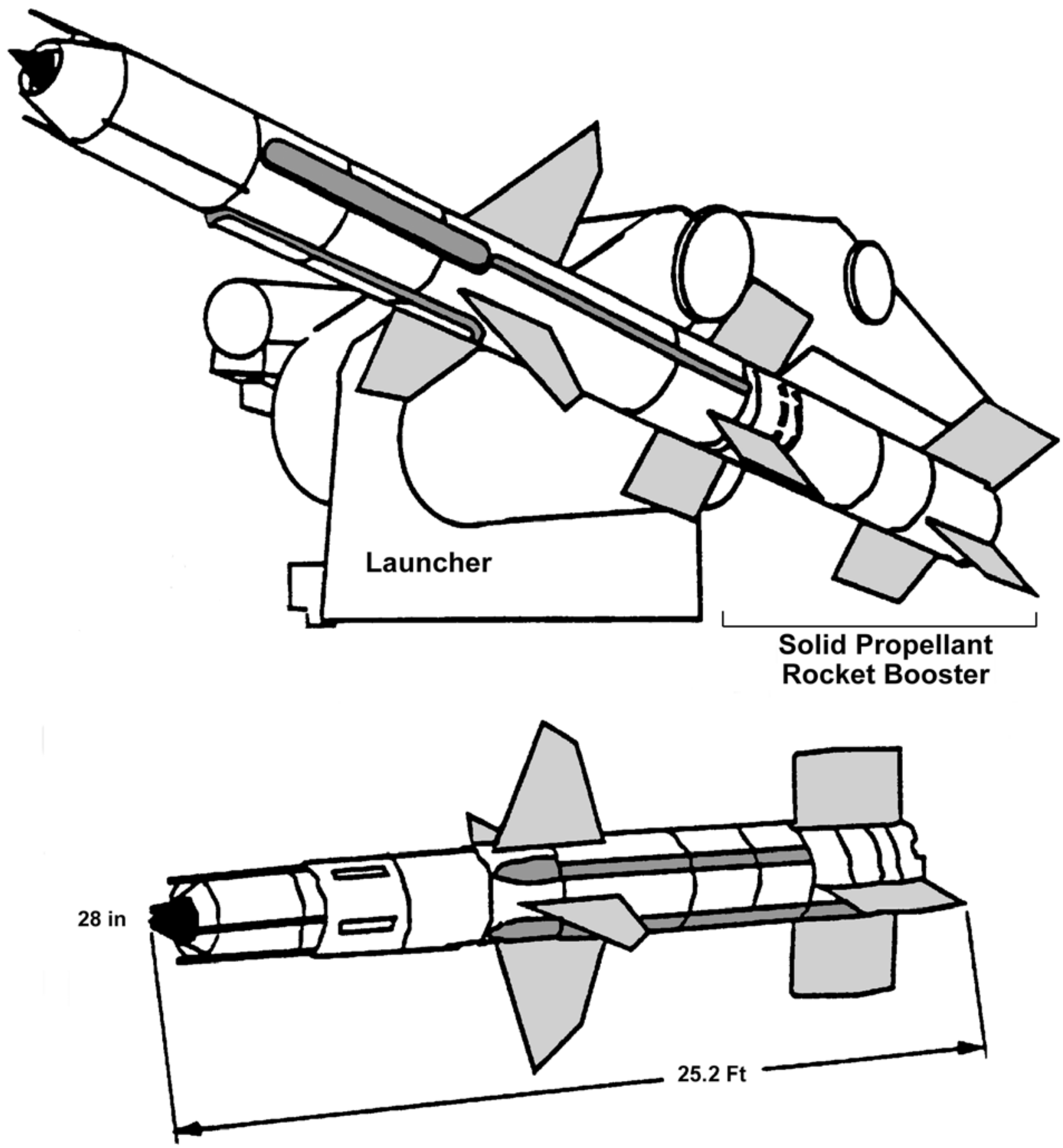

FIGURE 1.1. The Vandal is a supersonic vehicle that is accelerated to ramjet operational speed by a solid propellant rocket booster. The ER (top) and EER (bottom) Vandal variants are identical in dimensions, with the EER having greater range and weight. The Vandal is launched from a dedicated launcher system at the Alpha Launch Complex on San Nicolas Island.

Vandal launch trajectories can vary from near-vertical liftoff, crossing the west end of San Nicolas Island at an altitude of about 13,000 feet (3,962 m), to a nearly horizontal launch profile crossing the west end of San Nicolas Island at an altitude of about 1,000 feet (305 m). For trajectories =13 degrees, the Vandal can descend to a sea-skimming altitude several nautical miles (n.mi.) out at sea, or it can continue offshore at higher altitude.

The Vandal can be launched singly, or in some cases, in sequential launches spaced more closely together in time. In these cases, the two Vandals are launched in succession from the same pad (Figure 1.4).

1.2 Background Information on the Terrier Orion

The Navy also launched one Terrier Orion missile during the year. 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 (Figure 1.5). The two-stage Terrier vehicle has an overall length of approximately 33 feet (10 m), body diameter of 18 inches (45.7 cm; first stage) and 14 inches (35.6 cm; second stage), and a total weight at lift off of 3,976 lb (1,804 kg).

For launches at San Nicolas Island, Terrier Orions have no explosive warhead. At launch, the Terrier is accelerated for 6.4 sec by a solid propellant rocket booster. After 13.6 sec 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 sec. The expended booster rocket drops into the water west of San Nicolas Island, and the second stage and forebody impact approximately 5 min after launch.

Terrier Orions are non-recoverable missiles that are launched from the same launch site (Alpha Launch Complex) on the western part of San Nicolas Island as the Vandals. In 2001, the Terrier's launch trajectory was near-vertical (64.6 degrees), crossing the west end of San Nicolas Island at an altitude of about 13,000 feet (3,962 m). The Terrier Orion is launched singly.

1.3 Background Information on the 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 small missiles (Figure 1.6). It is 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 AGS will have a magazine with a capacity for between 600 and > 750 projectiles and associated propelling charges. The regular charge for the gun replaces 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. There may be several tests in which the gun is fired without a live missile (but with a slug), in order to check whether the gun is operating correctly before the actual missile is launched. At San Nicolas Island, a Howitzer was used to launch the missiles, as the AGS gun is still being developed. It was located at the Alpha Complex and was aimed at azimuths 300-305°, more to the northwest than the Vandal launches.

1.4 Background Information on the Rolling Airframe Missile (RAM)

The Rolling Airframe Missile (RAM) is a supersonic, lightweight, quick-reaction, missile (Figure .7). The 5-inch missile uses the infrared seeking 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.

The RAM is a solid-propellant rocket with a 5-inch (12.7 cm) diameter and a length of 9.2 feet (2.8 m). Its launch weight is 162 pounds (73.5 kg) and the warhead itself weighs 25 pounds (11.4 kg). At San Nicolas Island, RAMs were launched from the Building 807 Launch Complex.

1.5 Description of Missile Launches on San Nicolas Island

During the period from 1 August 2001 to 31 July 2002, there were a total of 19 launches from San Nicolas Island, including 18 missiles and two slugs (Table 1.1). Fourteen Vandals were launched on 11 dates, one Terrier Orion was launched on the same date as one of the Vandals, one AGS missile and two slugs were launched on two dates, and there was one dual RAM launch. The dual RAM launch is considered to be a single launch as the missiles were fired only 3 sec apart.

Weather during the launches was usually cool and the winds light, occasionally with a low-lying fog covering the west end of the island (Table 1.1). Despite fog banks (15 August launches) and drizzle (5 October launch), pinnipeds at the extreme camera range were usually visible on the west end of the island. Wave heights were small, and surf noise was relatively quiet (see Chapter 2).

All launches occurred during daylight hours (between 08:30 and 17:02 local time). There were single launches on eight days, two launches on each of five days, and a dual- launch on another day. Two Vandals were launched on each of three dates: on 15 August 2001, separated by 21 min; on 22 February 2002, separated by 2 hr 43 min; and on 1 May 2002, separated by 1 hr 7 min. A Vandal and Terrier Orion were launched 8 hr 32 min apart on 20 September 2001. On 26 June 2002, a slug and an AGS missile were launched in sequence, 1 hr 31 min apart. A dual RAM launch occurred on 21 June 2002, when two missiles were launched within 3 sec of each other.

All Vandals launched during the year in question had (similar) 270–273º launch azimuths from the Alpha Launch Complex, and passed over the shoreline at the western end of San Nicolas Island (Figure 1.3, 1.8). Most Vandals were launched at an 8º elevation angle. Allowing for the elevation of the launch pad (625 ft or 190 m ASL), this yielded an altitude of approximately 1,300 feet (396 m) as they passed over the island margin. Two Vandals launched on 22 February 2002 as well as on 1 May 2002 were launched at an angle of 42º, which yielded an altitude of approximately 9,600 ft (2,926 m) at the west end of the island. The Terrier Orion was launched at a higher angle of 64.6º, which yielded an altitude of approximately 13,000 feet (3,962 m) as it passed over the island margin. Unlike the Vandals launched during the monitoring period, the Terrier Orion was launched along an azimuth of 232.3º (see Figure 1.8B). The AGS missile also had high-angle (62.5º) trajectory, with an altitude over the west end of the island of about 5,300 ft (1,615 m), and launch azimuths of 300-305º (Figure 1.8M, 1.8K). The dual RAM was launched from the Building 807 Launch Complex, on the western end of San Nicolas Island. It had a launch azimuth of 240º (Figure 1.8L).

These launch azimuths caused the missiles to pass over or near various acoustic measurement sites with Autonomous Terrestrial Acoustic Recorders (ATARs), several wagon- or tripod-mounted cameras (Sony Hi-8 handicams), and a remotely-controlled fixed video camera (Figure 1.3, 1.8).

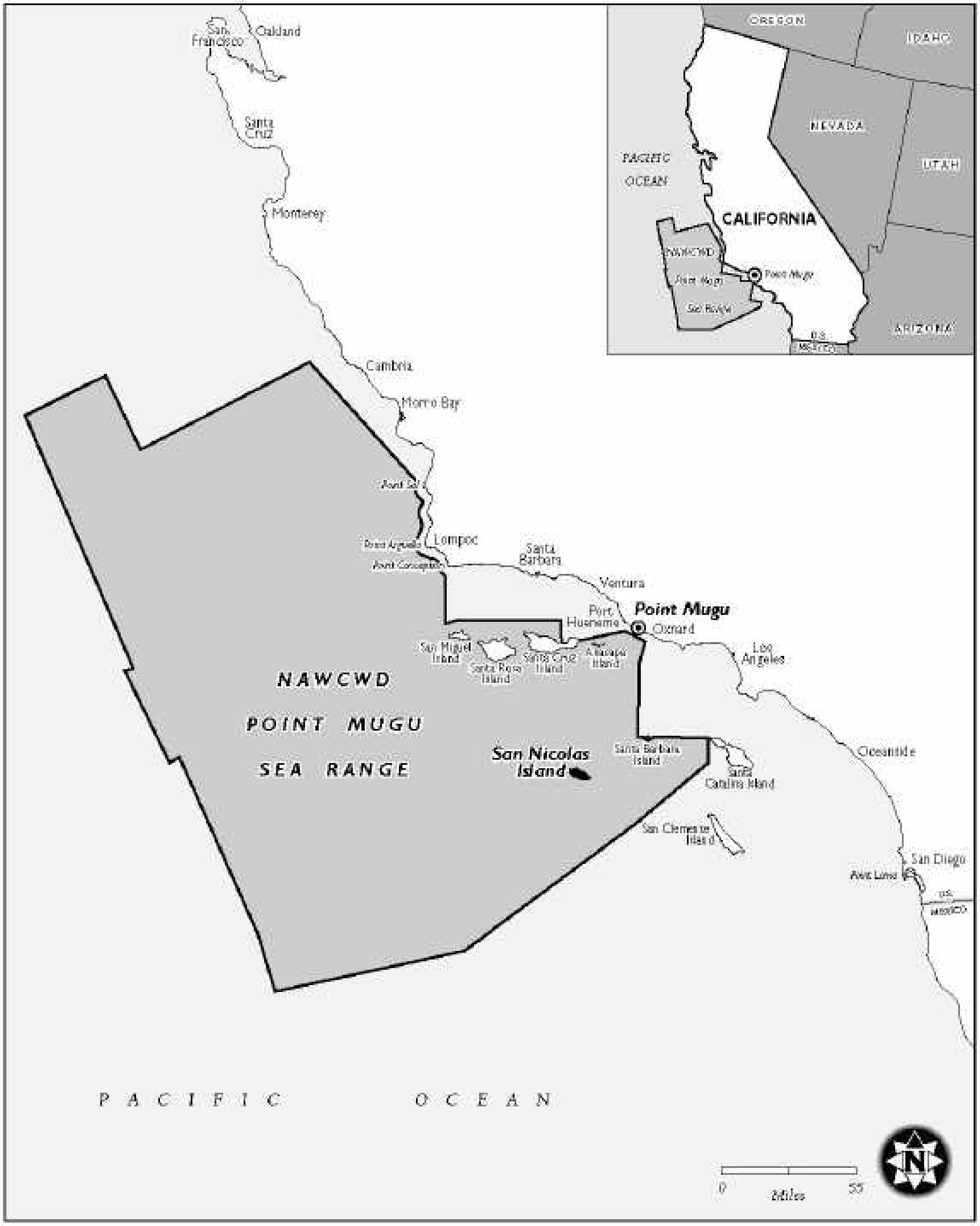

FIGURE 1.2. Regional site map of the Point Mugu Sea Range and San Nicolas Island (map by TEC).

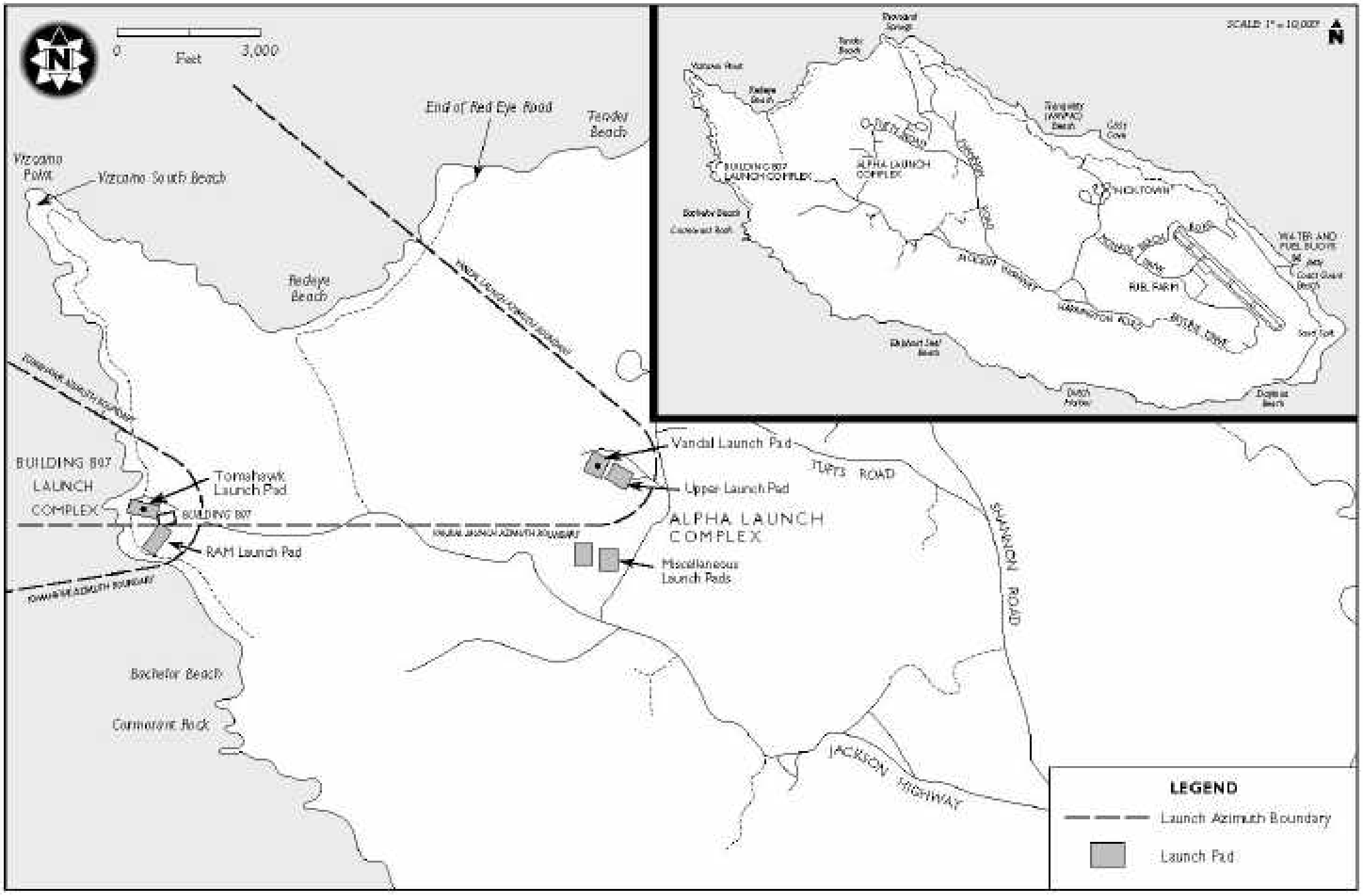

FIGURE 1.3. View of missile launch sites on San Nicolas Island. Shown are the Alpha Launch Complex and Building 807 Launch Complex (at lower elevation near the shoreline). Also shown are the maximum predicted extent of the launch azimuths for missiles leaving the two launch sites. Azimuth for one Terrier Orion launch during the present monitoring period was to the southwest, outside the range of azimuths shown here (see Fig. 1.6B).

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

FIGURE 1.5. View of Terrier Orion launch from the Alpha Launch Complex on San Nicolas Island (photograph by U.S. Navy).

FIGURE 1.6. View of the Advanced Gun Projectile Test System at the Alpha Complex on San Nicolas Island (photograph by U.S. Navy).

FIGURE 1.7. View of the Rolling Airframe Missile (RAM) launcher at the Building 807 Launch Complex on San Nicolas Island (photograph by U.S. Navy).

TABLE 1.1. Details of the 19 launches (14 dates) at San Nicolas Island during August 2001 – July 2002. Two launches occurred on each of 15 August 2001, 20 September 2001, 22 February 2002, 1 May 2002, and 26 June 2002. A dual launch, consisting of two missiles launched within seconds of each other, occurred on 21 June 2002. The weather data were collected at the San Nicolas Island airport, which is located at an elevation of 500 feet ASL toward the east end of San Nicolas Island; therefore weather conditions at haul-out sites differed somewhat (see text for details). Times are local time.

Launch Date	Launch Time	Missile Type	Launch Site	Launch Azimuth	Elevation Angle/Altitude Over Beach	Weather at San Nicolas Island Airport	Tide State	Video Quality	Audio Quality
15 Aug. 2001	12:56	Vandal	Alpha Launch Complex	270°	8° / 1,280 ft	20°C; winds 310° at 12 kt; low tide; fog at ~100 m	Low at 12:51	Good	2 of 3 ATARs over-loaded
"	13:17	Vandal	Alpha Launch Complex	270°	8° / 1,280 ft			Good	2 of 3 ATARs over-loaded
20 Sept. 2001	08:30	Vandal	Alpha Launch Complex	270°	8° / 1,280 ft	14°C; winds 300° at 6 kt; overcast	Low at 06:03	Good	1 of 3 ATARs failed
"	17:02	Terrier Orion	Alpha Launch Complex	232.3°	64.6° / 13,000 ft		Low at 18:51	Good	OK
5 Oct. 2001	13:37	Vandal	Alpha Launch Complex	273.3°	8° / 1,300 ft	16°C; winds 290° at 9 kt; overcast with drizzle	Low at 18:09	Good	2 of 3 ATARs failed
19 Oct. 2001	09:00	Vandal	Alpha Launch Complex	270°	8° / 1,280 ft	17°C; winds 320° at 10 kt; overcast	Low at 05:15	Good	2 of 3 ATARs over-loaded
19 Dec. 2001	15:22	Vandal	Alpha Launch Complex	273°	8° / 1,300 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 Launch Complex	273°	8° / 1,300 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 Launch Complex	270°	42° / 9,600 ft	27°C; winds 3 kt; sunny and warm	Low at 12:44	Good	1 of 3 ATARs failed
"	14:56	Vandal	Alpha Launch Complex	270°	42° / 9,600 ft			Good	1of 3 ATARs failed

TABLE 1.1. (continued)

Launch Date	Launch Time	Vehicle Type	Launch Site	Launch Azimuth	Elevation Angle/Altitude Over Beach	Weather at San Nicolas Island Airport	Tide State	Video Quality	Audio Quality
6 Mar. 2002	11:20	Vandal	Alpha Launch Complex	273.1°	8° / 1,300 ft	17°C; winds 270° at 9 kt; overcast	Low at 11:03	Good, 4 cameras	OK
1 May 2002	15:53	Vandal	Alpha Launch Complex	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 Launch Complex	273°	42° / 9,600 ft			Good, 2 cameras	1 of 3 ATARs failed
8 May 2002	14:54	Vandal	Alpha Launch Complex	273°	8° / 1,300 ft	18°C; winds 270° at 10 kt; sunny and clear	Low at 13:15	Good, 4 cameras	OK
19 June 2002	15:07	AGS Test Slug	Alpha Launch Complex	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	12:53:12/ 12:53:15	RAM	Building 807 Launch Complex	240°	8° / 50 ft	16°C; winds 270° at 12 kt; overcast	Low at 13:18	Good, 2 cameras	Only 1 ATAR used; OK
26 June 2002	11:20	AGS Test Slug	Alpha Launch Complex	300°	62.5° / 500 ft	17°C; winds 290° at 16 kt; foggy and overcast	Low at 05:50	Good, 2 cameras	OK
"	12:51	AGS Missile	Alpha Launch Complex	300°	62.5° / 5,300 ft			Good, 2 cameras	OK
18 July 2002	11:54:42	Vandal	Alpha Launch Complex	273°	8° / 1,300 ft	19°C; winds 340° at 4 kt; foggy and overcast	Low at 10:04	Good, 1 camera	2 of 3 ATARs failed

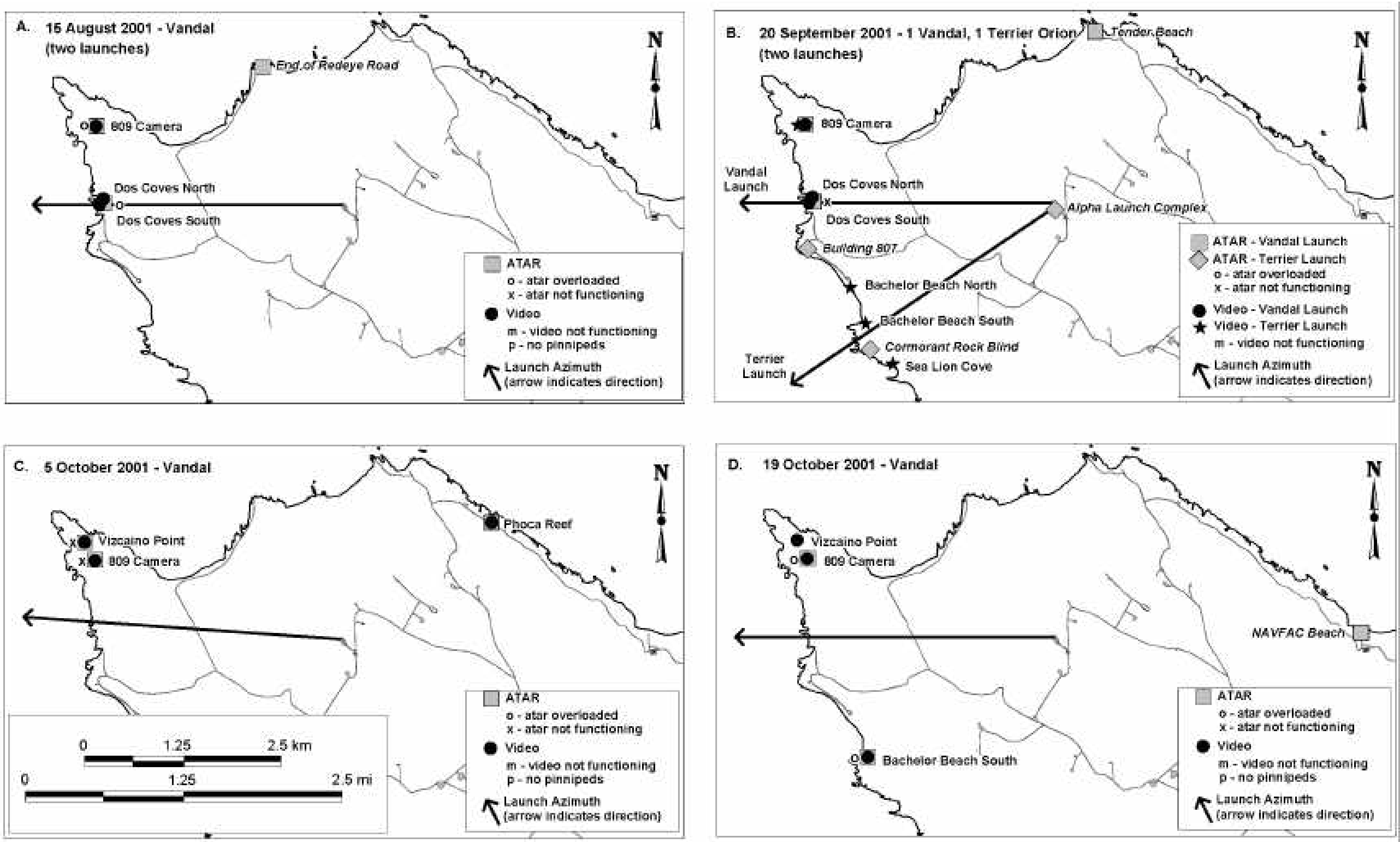

FIGURE 1.8. Launch azimuths, acoustic recording sites (ATARs), and video recording sites for all launches at San Nicolas Island from 15 August 2001 to 18 July 2002. All launches, except the dual RAM launch, were from Alpha Launch Complex, and passed over the shore at the west or southwest end of San Nicolas Island. The dual RAM launch was from the Building 807 Launch Complex. Length of launch azimuth line represents distance traveled by vehicle (if line is extended past island, the vehicle traveled well offshore).

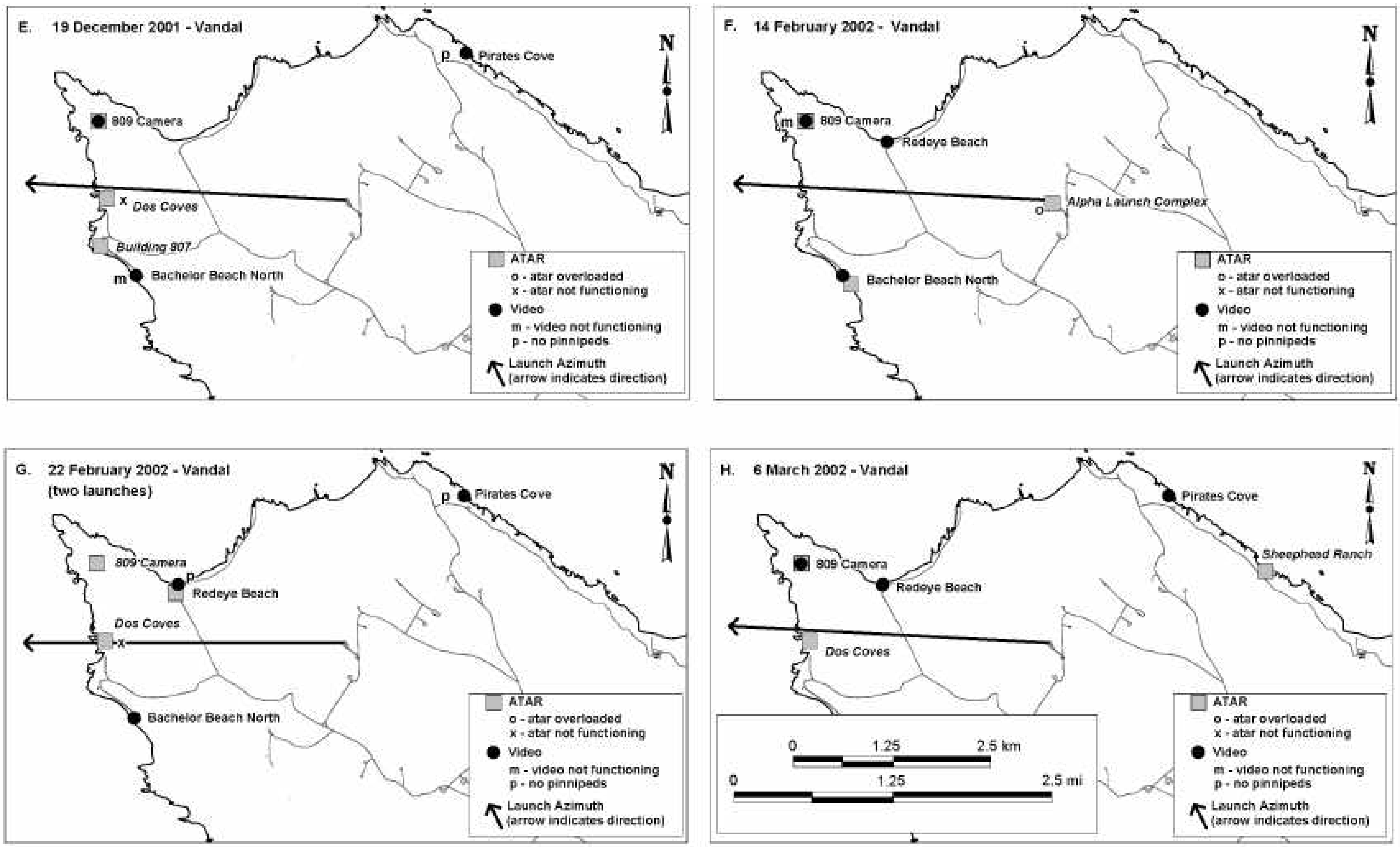

FIGURE 1.8. continued.

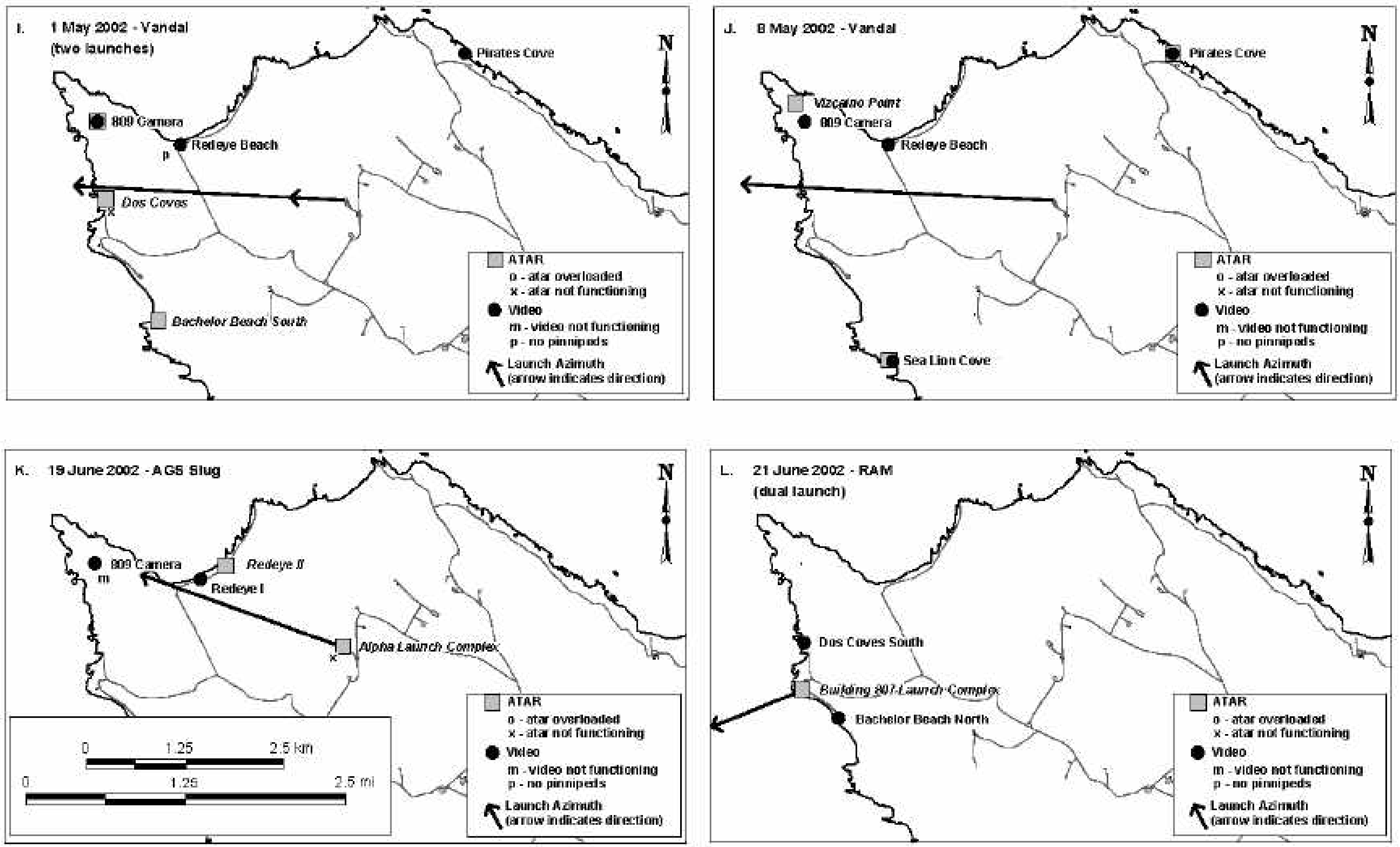

FIGURE 1.8. continued.

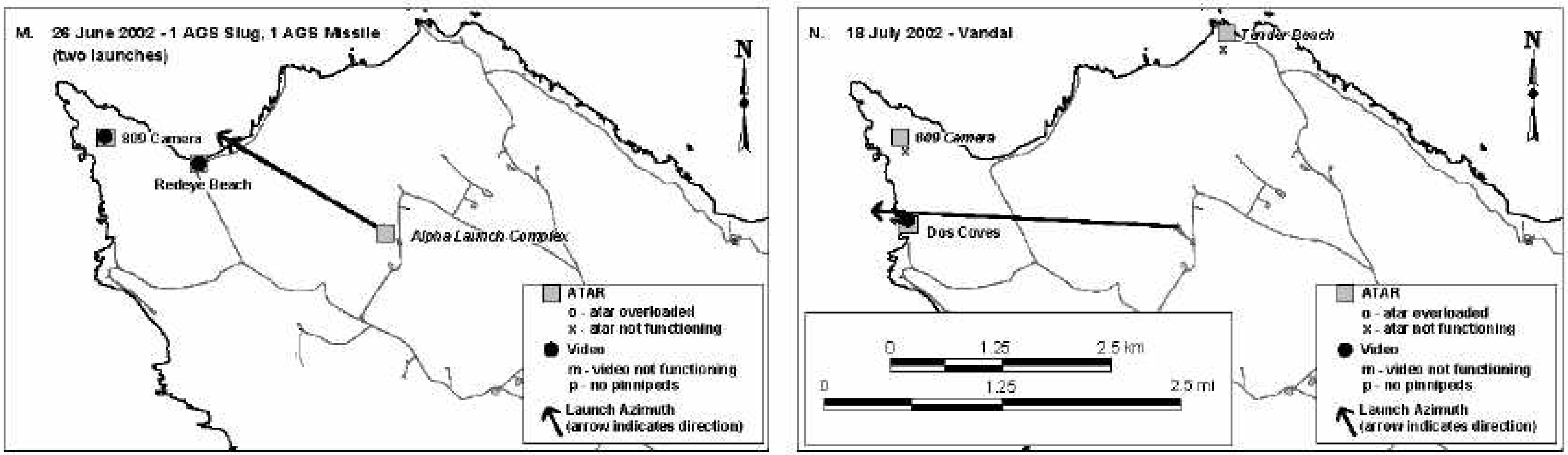

FIGURE 1.8. continued.

1.6 Acoustical Monitoring of the Missile Launches

Audio recordings were obtained to document launch sounds at several distances from the azimuth of the missiles. 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 magnitude and characteristics of launch sounds at several distances from the azimuth of the missiles;
2. documenting the magnitude 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 missile 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, the sound levels that might cause notable disturbance for each of the pinniped species is variable and context-dependent. For a review of published and reported behavioral responses to anthropogenic sound by pinnipeds hauled out in the Sea Range, see Lawson et al. (1998). Their estimate of the minimum received level (on a "Sound Exposure Level" or SEL basis) that might elicit substantial disturbance was 100 dB re 20 µPa (Table 1.2). After reviewing video recordings from launches at San Nicolas Island during 2001-2002, the 100 dB level seems reasonable as a minimum received level (SEL) that might elicit disturbance for California sea lions. However, 90 dB SEL seems more appropriate for harbor seals, as they showed a strong response to most launches, including a number of launches where received levels were 90-100 dB SEL. Elephant seals typically did not respond overtly to launch sounds of various levels and generally showed no evidence of disturbance. Speculative criteria for sound exposures that might result in TTS are also mentioned in Table 1.2; these may vary by species. A detailed description of the Methods for the acoustical monitoring can be found in Section 2.2 of Chapter 2.

1.7 Visual Monitoring of Pinnipeds During Missile Launches

The Navy conducted video and visual monitoring of marine mammals during the missile launches from San Nicolas Island in the August 2001 – July 2002 period, supplemented by simultaneous autonomous audio recording of launch sounds (see Chapter 2). The video and visual monitoring provided data required to characterize the extent and nature of disturbance effects. In particular, it provided the information needed to document the nature, frequency, occurrence, and duration of any changes in pinniped behavior that may have resulted from the missile launches, including the occurrence of stampedes from haul-out sites.

The video records were 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;

TABLE 1.2. Assumed in-air sound pressure criteria for significant disturbance and for Temporary Threshold Shift (TTS) in pinnipeds. Criteria are in dB re 20 µPa SEL. Adapted from Lawson et al. (1998).

Criterion Type	Criterion Level
Disturbance from prolonged sounds[a]	100[b]
TTS from transient sounds	145 for harbor seals & California sea lions[c] 165 for northern elephant seals[c]

[a] For the purposes of this report, prolonged sounds were considered to last "several seconds". It is arguable whether the launch sounds should be considered to be "prolonged".

[b] Based on a review of published and reported behavioral responses to anthropogenic sound by pinnipeds hauled out in the Sea Range (Lawson et al. 1998).

[c] Based on speculative inference from in-air human TTS values (Kryter 1985; Richardson et al. 1995) and data of Kastak et al. (1999) concerning onset of TTS following prolonged sound exposure; details in Lawson et al. (1998).

2. compare pre- and post-launch behavioral data on launch day (and approximately 24 hours after launch) to quantify the interval required for pinniped numbers and behavior to return to normal[2] if there was a change as a result of launch activities;
3. compare received levels of launch sound with pinniped responses, based on acoustic and behavioral data from monitoring sites at different distances from the launch site and flightline during each launch; from the data accumulated across a series of launches, establish the "dose-response" relationship[3] for missile sounds under different launch conditions;
4. ascertain periods or launch conditions when pinnipeds were most and least responsive to launch activities, and
5. document numbers of pinnipeds affected by missile launch sounds and, although unlikely, any mortality or injury.

The number of launches with paired acoustic and pinniped data from the same site was limited, especially when considering a specific type of missile launched at a given elevation angle. Determination of the dose-response component (3) and conditions when pinnipeds were most or least responsive to launch sounds (4) will require additional data. (Additional data are being collected during a second year of monitoring, commencing in August 2002—not considered in this report.) A few generalizations on these points are given in Section 3.4.11 of Chapter 3. A detailed description of the Methods for the visual monitoring can be found in Section 3.2 of Chapter 3.

1.8 Incidental Harassment Authorization

The monitoring program for the Navy's 2001-2002 missile launch program was designed, in part, to provide the data needed to estimate the numbers of pinnipeds affected by the launches and the manner

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[2] If numbers and/or behavior had not returned to "normal" within the duration of the autonomous recording, the duration of the period with reduced numbers is reported as "greater than *x* minutes".

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

in which they were affected. Given that the pinniped reactions to the launches were brief (or in the case of most elephant seals, negligible), the Navy has estimated the numbers of pinnipeds that might have been affected by the launch sounds. The Navy, consistent with NMFS (1996, 2000, 2001), assumes that those pinnipeds exhibiting momentary alert or startle reactions with no large-scale movement, and no biologically significant effects, are not significantly affected. NMFS (2000) defines a biologically significant behavioral response as one "…that affects biologically important behavior, such as survival, breeding, feeding and migration, which have the potential to affect the reproductive success of the animal."

An IHA to authorize possible harassment takes of pinnipeds hauled out at San Nicolas Island during missile launches was first issued to the Navy on 1 August 2001 (NMFS 2001). Following discussions between NMFS and the Navy, this authorization was modified slightly and re-issued on 26 September 2001. The IHA was in effect until 31 July 2002. Acoustic and visual monitoring has been conducted during all launches from San Nicolas Island from August 2001 to July 2002, and the present report describes the results. (A second IHA was issued by NMFS in August 2002 for a second 1-year period, and similar acoustic and visual monitoring is continuing.)

1.9 Summary

From 15 August 2001 to 18 July 2002, Naval Air Warfare Center Weapons Division (NAWCWD) conducted a total of 19 launches, including 18 missiles and two slugs on 14 days. Sixteen of the missiles plus the two slugs were launched from the elevated Alpha Launch Complex on the west-central part of San Nicolas Island, California. Two small RAMs were launched (3 sec apart) from a different site, the Building 807 Launch Complex on the western end of the island. Overall, there were launches of 14 Vandals, one Terrier Orion, one AGS missile and two slugs from the Alpha Complex, plus the dual RAM launch from Building 807. These missiles passed along flight azimuths that took them over or near groups of pinnipeds hauled out on the western end of the island.

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 and results of the acoustic and visual monitoring during August 2001 – July 2002 are described in Chapters 2 and 3.

2. ACOUSTICAL MEASUREMENTS OF MISSILE LAUNCHES, AUGUST 2001 – JULY 2002[1]

2.1 Introduction

A total of 18 missiles were launched from San Nicolas Island from 15 August 2001 to 18 July 2002. In addition, there were two launches of slugs from the Advanced Gun 'Test' System on 19 and 26 June 2002. On five dates, two separate launches occurred, and on a sixth date (21 June 2002) there was a dual launch, consisting of two missiles launched within seconds of each other. Including the test launches of slugs as launches, and counting the dual launch as a single launch, 19 launches occurred in total, on 14 different dates. Table 2.1 lists the launch dates, times, and types of vehicles. Figure 1.6, in Chapter 1, shows the launch azimuth and monitoring locations for each launch date. The sounds of each missile and associated background sounds were recorded at up to three sites on the island during each launch. Of 57 possible recordings (19 launches $\times$ 3 recording sites per launch), 54 recordings were attempted, 42 recordings were obtained, and 35 launch recordings were useable for quantitative analysis (Table 2.1). The sounds at these 35 sites were recorded without distortion. The missile sounds overloaded (saturated) the acoustic recorder at seven of the 42 sites; in these cases the amplifier gains were inadvertently set too high. ATAR readings were obtained from those same locations on subsequent launches.

TABLE 2.1. Vehicle launches at San Nicolas Island from 15 August 2001 to 18 July 2002. Launches were at 8° elevation angle except where noted.

Date	Time	Vehicle	Acoustic Recording Sites	Acoustic Data
15 Aug. 2001	12:55	Vandal	3	2 overloaded
"	13:16	Vandal	3	2 overloaded
20 Sept. 2001	08:29	Vandal	3	2 sites OK
"	17:00	Terrier Orion †	2 + Launcher	OK
5 Oct. 2001	13:36	Vandal	3	1 site OK
19 Oct. 2001	08:59	Vandal	3	2 overloaded
19 Dec. 2001	15:20	Vandal	3	2 sites OK
14 Feb. 2002	11:33:00	Vandal	2 + Launcher	1 overloaded
22 Feb. 2002	12:13:04	Vandal †	3	2 sites OK
"	14:56:22	Vandal †	3	2 sites OK
6 Mar. 2002	11:20:38	Vandal	3	OK
1 May 2002	15:53:20	Vandal †	3	1 site OK
1 May 2002	17:00:23	Vandal †	3	2 sites OK
8 May 2002	14:54:02	Vandal	3	OK
19 June 2002	15:07:00	AGS Test Slug	1 + Launcher	1 site OK
21 June 2002	12:53:12 & 12:53:15	RAM †	Launcher only	OK
26 June 2002	11:20:00	AGS Test Slug	3	OK
26 June 2002	12:51:00	AGS Missile†	3	OK
18 July 2002	11:54:42	Vandal	3	1 site OK

† launch at high elevation angle (64.6° for Terrier Orion; 42° for Vandals on 22 Feb & 1 May 2002; 63° for AGS Test Slug on 19 June 2002; 62.5° for AGS Test Slug and Missile on 26 June 2002.

[1] By **Charles R. Greene**, **Jr**., Greeneridge Sciences Inc. and **Charles I. Malme**, Engineering & Scientific Services, Hingham, MA.

2.2 Field Methods

2.2.1 Field Approach

Acoustical recordings were usually obtained at three locations during each missile launch. "Autonomous Terrestrial Acoustic Recorders" (ATARs) were usually positioned so that, given the planned launch azimuth, at least one ATAR was near the launch azimuth and others were positioned at locations to the side of the azimuth where it was of interest to monitor sounds (see Figure 1.6 in Chapter 1). These recordings were planned to be suitable for quantitative analysis of the levels and characteristics of the received launch sounds. In addition to providing information on the magnitude, characteristics, and duration of sounds to which pinnipeds were exposed to during each launch, these acoustic data were examined in relation to pinniped behavioral data acquired at some of the same places and times (see Chapter 3). The ultimate objective was to determine if there is a "dose-response" relationship between received sound levels and pinniped behavioral reactions and, if so, to characterize that relationship. However, additional data (presently being conducted) will be needed to fully meet that objective (see Section 3.4.11 in Chapter 3).

The Navy's acoustical contractor, Greeneridge Sciences Inc. (Santa Barbara, CA), provided three autonomous audio recorders (described below). During most launches, these were located as close as practical to three pinniped haul-out sites at various distances from the launch site. These three sites typically included locations (1) as close as possible to the vehicle's planned flight path, (2) where the received sound levels were estimated to reach approximately 100 dBA re 20 $\mu Pa^2 \cdot s$ (SEL), as shown in Figure 16 in Lawson et al. (1998), and (3) midway between sites 1 and 2. ATARs were deployed at the recording locations on the launch day well before the launch time and were retrieved later the same day. The ATARs were designed to record continuously and unattended for up to 48 hours. It was necessary to use autonomous recorders because safety considerations required all personnel to leave the monitoring sites one hour prior to the planned launch. The extended recording capabilities of the ATAR units, as compared with DAT audio recording units used previously (e.g., Greene 1999), were important in accommodating any launch delays.

Acoustic data from launches were used to characterize sound exposure vs. distance downrange and laterally from the launch azimuth. The one type of launch that occurred sufficient times during the year in question to allow such an analysis was launches of Vandals at low elevation angle (8°). Section 2.5 of this report provides estimates of the typical levels of sound received at coastal locations during such a launch, based on low-elevation Vandal launches in the 15 August 2001 to 6 March 2002 period.

2.2.2 ATAR Design and Components

The ATARs are much like the Autonomous Seafloor Acoustic Recorders (ASARs) employed during several recent projects involving monitoring of underwater industrial sounds in the Beaufort Sea (e.g., Burgess et al. 1999). The ASARs and ATARs, designed and assembled by Greeneridge Sciences, can record sounds for extended periods (dependent on sampling rate) without intervention. Thus, an ATAR can still make recordings of launch sounds even if prolonged launch delays occur. The ATARs can record a bandwidth of 3 to 20,000 Hz at a 44.1 kHz sample rate. The ATAR is designed to record both high-level and normal background sounds. The principal components of an ATAR are two calibrated 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.

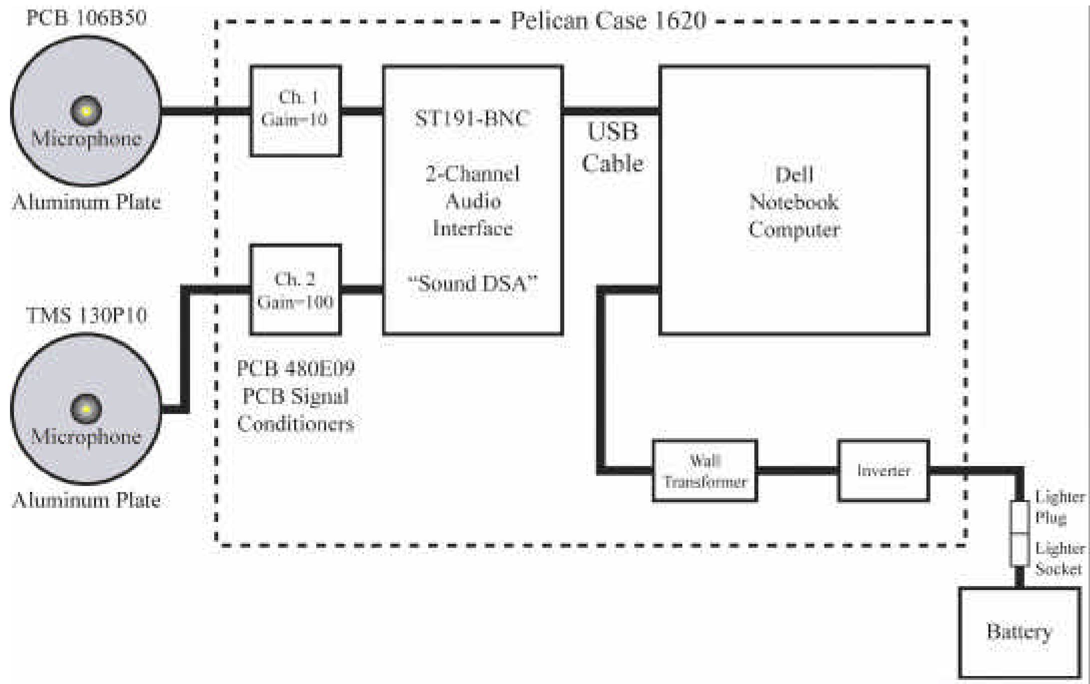

FIGURE 2.1. Block diagram of an Autonomous Terrestrial Acoustic Recorder (ATAR).

PCB 106B50 quartz microphones (PCB Piezotronics Inc., Depew, NY) were used to transduce sound pressure to voltage at all sites. These relatively insensitive microphones, with sensitivity –202 dB re 1 volt per micropascal (V/µPa), were designed for transduction of strong signals with received sound levels up to 185 dB re 20 µPa. To record ambient sounds concurrently, more sensitive microphones (the TMS 130P10; –157 dB re 1 V/µPa) were used to provide additional dynamic range. Each ATAR includes two microphones, one of each type. Both microphone signals are sampled at 44.1 kHz and digitized to a 16-bit two-byte integer.

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, respectively, to 0, 20 and 40 dB). These signal conditioners were mounted in Pelican cases with the remaining equipment, excluding the battery.

2.2.3 Deployment and Use of ATARs

Prior to the launch of each missile, Navy personnel typically deployed three ATAR units at three sites, usually with video cameras operating at each of the ATAR sites as well (see Figure 1.6 in Chapter 1). Most sites were selected on the basis of distance from the anticipated launch trajectory and the presence of pinnipeds on shore. However, in some situations ATARs were deployed at locations without pinnipeds and without a video camera in order to document sounds under specific circumstances. For example, on 15 August 2001 the third and most distant site was empty of pinnipeds, and an ATAR was deployed there to begin gathering data at a location that expected to be useful in estimating the 100 dB contour. On other occasions, an ATAR was deployed at the Alpha Launch location, distant from pinnipeds, in order to document sounds near the launcher (Table 2.1).

The locations of the three ATARs varied from launch to launch, although the Navy distributed the ATARs such that, over the year of monitoring effort, recordings were made at a variety of different distances and locations relative to the missile's launch trajectory (Table 2.2; see also Figure 1.6).

At each of the monitoring sites, the microphones were placed in hemispherical windscreens and positioned so they were 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 inches thick and 22 inches in diameter. The two base plates were set on the ground or sand in an area generally free of vegetation (Figure 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).

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.

For the Vandal sounds, previous and current measurements at San Nicolas Island have provided information about expected sound levels (Burgess and Greene 1998; Greene 1999). However, recording levels for several launches early in the present 1-year monitoring period were nonetheless too high to provide adequate gain, and on other occasions there was evidence of sound clipping. Signals were also recorded on a second data channel with a higher sensitivity. This provided data suitable for measuring ambient sound levels before and after the launches.

TABLE 2.2. Locations of ATAR recording devices (see Figure 1.6 in Chapter 1).

Launch Date	Vehicle	ATAR Locations
15 Aug 2001	Vandal	End of Redeye Road; 809 Cameraº; Dos Covesº
20 Sep 2001	Terrier	Alpha Launch Complex; Building 807; Cormorant Rock Blind
20 Sep 2001	Vandal	809 Camera; Tender Beach; Dos Coves*
5 Oct 2001	Vandal	Phoca Reef; 809 Camera*; Vizcaino Point*;
19 Oct 2001	Vandal	NAVFAC Beach; 809 Cameraº; Bachelor Beach Southº
19 Dec 2001	Vandal	809 Camera; Building 807; Dos Coves*
14 Feb 2002	Vandal	809 Camera; Bachelor Beach North; Alpha Launch
22 Feb 2002	Vandal	809 Camera; Redeye Beach; Dos Coves*
6 Mar 2002	Vandal	809 Camera; Dos Coves; Sheephead Ranch
1 May 2002	Vandal	809 Camera‡; Bachelor Beach South; Dos Coves*
8 May 2002	Vandal	Pirates Cove; Sea Lion Cove; Vizcaino Point
19 June 2002	AGS Test Slug	Redeye II; Alpha Launch Complex*
21 June 2002	RAM	Building 807 Launch Complex
26 June 2002	AGS Test Slug & Missile	809 Camera; Launch Pad; Redeye Beach
18 July 2002	Vandal	809 Camera*; Dos Coves; Tender Beach*

Note: A permanent video camera was installed at 809 Camera (N33°16'21.9", W119°34'20.8"; see Figure 3.1 in Chapter 3). º ATAR overloaded; * ATAR otherwise malfunctioned; ‡ ATAR malfunctioned at this location only during the first launch at 15:53:20.

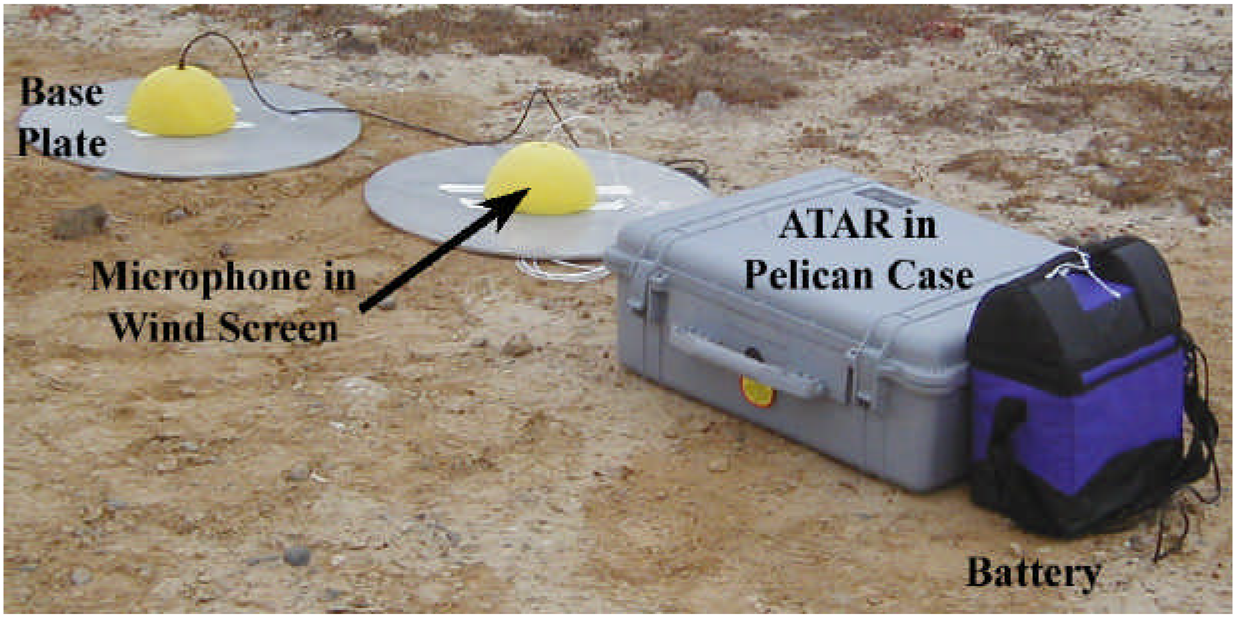

FIGURE 2.2. Typical field installation of an Autonomous Terrestrial Acoustic Recorder (ATAR) at the west end of San Nicolas island, California (photograph by J. Lawson, LGL).

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 sound pressure level (SPL), root mean square (RMS) SPL, and sound exposure level (SEL). Frequency-domain results included estimation of sound pressure levels in one-third octave bands for center frequencies from 4 to 16 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 launch, the acoustical contractor 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:

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

where *x* represents all data points in an event file, *n* represents only background noise data points before the launch, 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 launch 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.

SEL was defined as 90% of E, representing total exposure to acoustic energy in units of $Pa^2 \cdot s$.

SPL was defined as the SEL divided by the duration, representing average sound pressure level during the duration of the launch sound. SPL is equivalent to the RMS (root-mean-square) level of the signal, less background noise, over the duration.

The **peak instantaneous level** was defined as the largest sound pressure magnitude (positive or negative) exhibited by the signal, even if the signal reached that level only momentarily.

2.3.2 Frequency-Domain Analysis

Frequency-domain analysis was used to estimate how signal power was distributed in frequency. 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 both for the signal and for pre-signal background noise. These spectral density values were then summed into one-third octave bands.

For these analyses the acoustical contractor defined the "signal" as consisting of the recorded data (missile signal plus background noise) occurring within ± 5 sec of the instantaneous peak pressure. This time series was segmented into 16,384-sample blocks (0.37 sec long) and overlapped by 75%. The resulting spectral densities (of the missile signature and the channel noise) had cells spaced by 2.69 Hz. Background noise data recorded on the high sensitivity channel, consisting of 20 sec of data selected from before or after the missile signal, were segmented into 44,100-sample blocks overlapped by 50%, resulting in 1-Hz cell spacing.

Processing began with calculation of power spectral densities. The 0.37-sec blocks were each windowed by a Blackman-Harris window (Harris 1978), Fourier transformed, squared, and averaged together. Windowing controls "leakage" of energy into adjacent cells but results in wider cells (less resolution in frequency). The effective width of the signal spectral densities is 4.58 Hz and of the background noise, it is 1.7 Hz. The spectral density values were integrated across standard one-third octave band frequencies to obtain summed power 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).

2.3.3 A-Weighting

Time-series results 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, p. 280; Richardson et al. 1995, p. 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. 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.

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.

2.4 Results

Results are presented for the missile flight sounds recorded at all the sites without overloading. Results are presented separately for “flat-weighting” and “A-weighting”. The background sound levels are reported at the end of the section

2.4.1 Missile Flight Sounds

Four parameters are reported for the missile flight sounds: peak pressure level, sound pressure level (SPL), sound exposure level (SEL), and duration. These parameters are explained in Section 2.3. Table 2.3 presents the results based on flat-weighting. The flight sound durations are sometimes long because of the rocket noise reverberation.

Graphs are presented below for the pressure signature (time waveform) and for the one-third octave band energy levels of the missile sounds and background instrumentation noise from the low-sensitivity channel (Figures 2.3-2.37). The latter was recorded from the same sensor that was used to measure the missile sounds, but at a time in advance of the missile sounds. Because of the low sensitivity of this sensor (necessary to avoid overloading by strong missile sound), much of this background noise is from the instruments, not the natural ambient sound. The third curve on each Figure shows the ambient sound pressure levels for one-third octave bands, based on data from the high-sensitivity channel. Because the ambient sounds are continuous, it is not normal practice to compute energies for such data. However, for purposes of comparison with the energy in the received missile flight sounds, one can consider the sound pressure levels to be the energies in a 1-sec period.

Of the sounds recorded without distortion at the 35 sites, nine Vandal missile recordings (on six dates) manifested a strong sonic boom:

- 20 September at 809 Camera
- 19 December at Building 807 and 809 Camera
- 14 February at 809 Camera and Bachelor Beach North
- 6 March at Dos Coves and 809 Camera
- 8 May at Vizcaino Point
- 18 July at Dos Coves.

In addition, two Advanced Gun System (AGS) signatures manifested a strong sonic boom:

- 26 June, twice 50 ft from the launcher.

On 5 October, the impulsive nature of the pressure signature at “Phoca Reef” implies a sonic boom from the Vandal missile, but the peak pressure with flat-weighting was very low, only 109 dB re 20 µPa. Also, this monitoring location was behind (and to the side) of the launch location, so the trajectory did not pass near the microphones (Figure 1.6C). The high pressures recorded at “Building 807” on 20 September during a high-angle Terrier Orion missile flight (Figure 1.6B) appear to be anomalous, as though an amplifier gain might not have been as recorded. However, the corresponding short duration, 0.93 sec, does imply high-speed missile passage.

The sounds recorded near the launcher during AGS launches on 26 June 2002 were among the strongest recorded (Table 2.3). However, these sounds were measured 50 ft from the Advanced Gun

TABLE 2.3. Pulse parameters for flat-weighted sound from missile flights at San Nicolas Island. The peak and sound pressure levels are in decibels relative to 20 µPa, the sound exposure levels (energy levels) are in decibels relative to $(20\ \mu Pa)^2 \cdot s$, and the durations are in seconds. See Figure 1.6 for maps of monitoring locations.

Date	Time	Vehicle	Site	Peak	SPL	SEL	Duration
15 Aug. 01	12:55	Vandal	End of Redeye Road	109	95	100	3.28
"	12:55	Vandal	Dos Coves**		Overloaded		
"	12:55	Vandal	809 Camera		Overloaded		
15 Aug. 01	13:16	Vandal	End of Redeye Road	112	96	100	2.61
"	13:16	Vandal	Dos Coves**		Overloaded		
"	13:16	Vandal	809 Camera		Overloaded		
20 Sept. 01	08:29	Vandal	Tender Beach	116	102	107	3.66
"	08:29	Vandal	809 Camera	140	133	119	0.044 *
20 Sept. 01	17:00	Terrier †	Building 807	153	138	138	0.93
"	17:00	Terrier †	100 ft from Launcher‡	103	89	93	2.85
"	17:00	Terrier †	Cormorant Rock Blind**	104	91	96	2.82
5 Oct. 01	13:36	Vandal	Phoca Reef	109	90	94	2.92
19 Oct. 01	08:59	Vandal	Bachelor Beach South		Overloaded		
"	08:59	Vandal	809 Camera		Overloaded		
"	08:59	Vandal	NAVFAC Beach	133	121	120	0.82
19 Dec. 01	15:20	Vandal	Building 807	144	136	123	0.052 *
"	15:20	Vandal	809 Camera	142	134	121	0.050 *
14 Feb. 02	11:33:00	Vandal	150 ft from Launcher‡		Overloaded		
"	11:33:00	Vandal	809 Camera	134	123	116	0.19 *
"	11:33:00	Vandal	Bachelor Beach North	144	135	123	0.065 *
22 Feb. 02	12:13:04	Vandal †	809 Camera	110	93	97	2.48
"	12:13:04	Vandal †	Redeye Beach	111	96	101	3.30
22 Feb. 02	14:56:22	Vandal †	809 Camera	109	92	99	4.56
"	14:56:22	Vandal †	Redeye Beach	111	96	102	3.74
6 Mar. 02	11:20:38	Vandal	Dos Coves**	149	142	129	0.053 *
"	11:20:38	Vandal	Sheephead Ranch	109	98	95	0.57
"	11:20:38	Vandal	809 Camera	143	133	121	0.059 *
1 May 02	15:53:20	Vandal	Bachelor Beach South	110	102	102	0.97
1 May 02	17:00:23	Vandal †	Bachelor Beach South	115	95	104	6.93
"	17:00:23	Vandal †	809 Camera	112	96	103	5.39
8 May 02	14:54:02	Vandal	Vizcaino Point	144	131	122	0.121*
"	14:54:02	Vandal	Sea Lion Cove	104	85	92	5.80
"	14:54:02	Vandal	Pirates Cove	111	96	96	1.04
19 June 02	15:07:00	AGS Test Slug †	Redeye II	111	95	97	1.43
21 June 02	12:53:12 &12:53:15	RAM x2	RAM Launcher at Building 807	147	126	131	3.19
26 June 02	11:20:00	AGS Test Slug †	50 ft from Launcher‡	158	150	137	0.051*
"	11:20:00	AGS Test Slug †	Redeye Beach	110	100	96	0.407
"	11:20:00	AGS Test Slug †	809 Camera	109	97	96	0.808
26 June 02	12:51:00	AGS Missile †	50 ft from Launcher‡	157	148	136	0.056*
"	12:51:00	AGS Missile †	Redeye Beach	108	102	93	0.120
"	12:51:00	AGS Missile †	809 Camera	107	98	94	0.411
18 July 02	11:54:42	Vandal	Dos Coves**	149	139	128	0.069*

† launch at high elevation angle. ‡ launcher at Alpha Launch Complex. * strong sonic boom evident. ** near azimuth.

'Test' System positioned at the Alpha Launch Complex, well inland. Measured levels at coastal sites during AGS launches were, as expected, relatively low (Table 2.3).

Levels recorded 50 ft from the Rolling Airframe Missile (RAM) launcher during the dual launch on 21 June 2002 were moderately high, as might be expected close to the launcher. No measurements were taken at greater distances from the RAM trajectory, mainly because the launcher was near the beach and the trajectory was almost entirely over water. However, at corresponding distances, levels from a small RAM missile would be expected to be less than those from a larger missiles (e.g., a Vandal).

Table 2.4 presents the corresponding results based on A-weighting. This is a standard weighting used in airborne sound measurements (see Section 2.3.2, above). It down-weights the frequencies below 1000 Hz and above 6000 Hz, roughly inverting the hearing sensitivity curve for human beings. A-weighted levels will almost always be less than the flat-weighted levels, because the sonic boom noise is strong at frequencies below 1000 Hz. No graphs are presented for A-weighted waveforms.

The following 35 pairs of Figures illustrate the pressure waveforms and the corresponding one-third octave band levels of the measured missile sounds. In part (B) of each Figure, the highest curve shows the one-third octave band levels corresponding to the missile sound, as recorded via the low-sensitivity channel. The middle curve shows the background noise, mainly instrumentation noise, just before the onset of the missile sound; these data were also recorded on the low-sensitivity channel. The lowest curve represents ambient sound just before the onset of the missile sound, as recorded on the high-sensitivity channel.

2.4.2 Ambient Noise Levels

Table 2.5 shows ambient noise levels. The entry for flat-weighting on 15 August at 13:16 (74 dB re 1 µPa) appears strong compared to the level at the same location 21 min earlier, at 12:55 (62 dB). The noise at 12:55 was concentrated at very low frequencies, below 20 Hz, while the noise at 13:16 extended up to about 200 Hz, accounting for the higher level at that time.

2.5 Prediction of ASEL Contours for Vandal Launches[2]

2.5.1 Introduction and Summary of Results

The acoustic signature data for Vandal missile launches in the period 15 August 2001 to 6 March 2002, as reported above by Greeneridge Sciences, were used as the basis for estimating isopleths (contours) of A-weighted sound exposure level (ASEL)[3] on San Nicolas Island. This analysis was done

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[2] This section prepared by **C.I. Malme**, Engineering & Scientific Services, Hingham, MA, April 2002.

[3] The ASEL has been developed as a metric for predicting the response of human populations to impulsive noise. For impulsive sound with durations around a second or less, the human hearing response has been found to be more correlated with the total acoustic energy of the pulse rather than with its peak or average pressure level. This same result has also been found in the few tests that have been performed with pinnipeds. The best accuracy in measuring mammalian behavioral response to noise levels is obtained when the noise spectrum is filtered using a filter response shaped like the species hearing response curve. For humans this is the "A-weighting" response curve. This curve has also been found to be a good approximation of pinniped hearing response. As a result the ASEL metric is produced by squaring and integrating the A-weighted noise pulse pressure signature to obtain its total acoustic energy (referred to 20 µPa-squared) and adjusting the resulting energy level to a duration of 1 sec by adding 10 Log (duration in sec) to the energy level. This permits comparing the energy level of pulses of various durations. The resulting ASEL is the equivalent sound pressure level of a pulse 1-sec long that would have the same loudness as the original pulse.

TABLE 2.4. Pulse parameters for A-weighted sound from missile flights at San Nicolas Island. The peak and sound pressure levels are in decibels relative to 20 µPa, the sound exposure levels (energy levels) are in decibels relative to (20 µPa)^2·s, and the durations are in seconds. See Figure 1.6 for maps of monitoring locations.

Date	Time	Vehicle	Site	Peak	SPL	SEL	Duration
15 Aug. 01	12:55	Vandal	End of Redeye Road	102	84	90	3.57
"	12:56	Vandal	Dos Coves**		Overloaded		
"	12:55	Vandal	809 Camera		Overloaded		
15 Aug. 01	13:16	Vandal	End of Redeye Road	103	85	89	2.38
"	13:16	Vandal	Dos Coves**		Overloaded		
"	13:16	Vandal	809 Camera		Overloaded		
20 Sept. 01	08:29	Vandal	Tender Beach	108	89	95	4.07
"	08:29	Vandal	809 Camera	130	100	101	1.32 *
20 Sept. 01	17:00	Terrier †	Building 807	145	131	130	0.80
"	17:00	Terrier †	100 ft from Launcher‡	94	77	82	3.01
"	17:00	Terrier †	Cormorant Rock Blind**	93	78	83	3.37
5 Oct. 01	13:36	Vandal	Phoca Reef	No signal after A-weighting			
19 Oct. 01	08:59	Vandal	Bachelor Beach South		Overloaded		
"	08:59	Vandal	809 Camera		Overloaded		
"	08:59	Vandal	NAVFAC Beach	No signal after A-weighting			
19 Dec. 01	15:20	Vandal	Building 807	134	107	106	0.82 *
"	15:20	Vandal	809 Camera	133	106	103	0.52 *
14 Feb. 02	11:33:00	Vandal	150 ft from Launcher‡		Overloaded		
"	11:33:00	Vandal	809 Camera	116	105	91	0.036 *
"	11:33:00	Vandal	Bachelor Beach North	138	118	107	0.077 *
22 Feb. 02	12:13:04	Vandal †	809 Camera	98	80	85	2.80
"	12:13:04	Vandal †	Redeye Beach	104	87	92	2.71
22 Feb. 02	14:56:22	Vandal †	809 Camera	102	82	88	3.55
"	14:56:22	Vandal †	Redeye Beach	103	87	92	3.04
6 Mar. 02	11:20:38	Vandal	Dos Coves**	142	119	113	0.23 *
"	11:20:38	Vandal	Sheephead Ranch	No signal after A-weighting			
"	11:20:38	Vandal	809 Camera	137	119	106	0.052 *
1 May 02	15:53:20	Vandal	Bachelor Beach South	No signal after A-weighting			
1 May 02	17:00:23	Vandal †	Bachelor Beach South	112	86	92	4.00
"	17:00:23	Vandal †	809 Camera	105	85	90	3.15
8 May 02	14:54:02	Vandal	Vizcaino Point	136	117	104	0.052*
"	14:54:02	Vandal	Sea Lion Cove	96	73	80	4.59
"	14:54:02	Vandal	Pirates Cove	84	60	67	4.85
19 June 02	15:07:00	AGS Test Slug†	Redeye II	86	68	72	2.50
21 June 02	12:53:12	RAM	RAM Launcher at	146	124	130	3.19
26 June 02	11:20:00	AGS Test Slug†	50 ft from Launcher‡	153	137	125	0.059*
"	11:20:00	AGS Test Slug†	Redeye Beach	80	57	62	2.86
"	11:20:00	AGS Test Slug†	809 Camera	88	59	64	2.92
"	12:51:00	AGS Missile †	50 ft from Launcher‡	148	133	122	0.072*
"	12:51:00	AGS Missile †	Redeye Beach	80	57	64	4.85
"	12:51:00	AGS Missile †	809 Camera	91	72	64	0.15
18 July 02	11:54:42	Vandal	Dos Coves**	140	122	110	0.065*

† launch at high-elevation angle. ‡ launcher at Alpha Launch Complex. * strong sonic boom evident. **near azimuth.

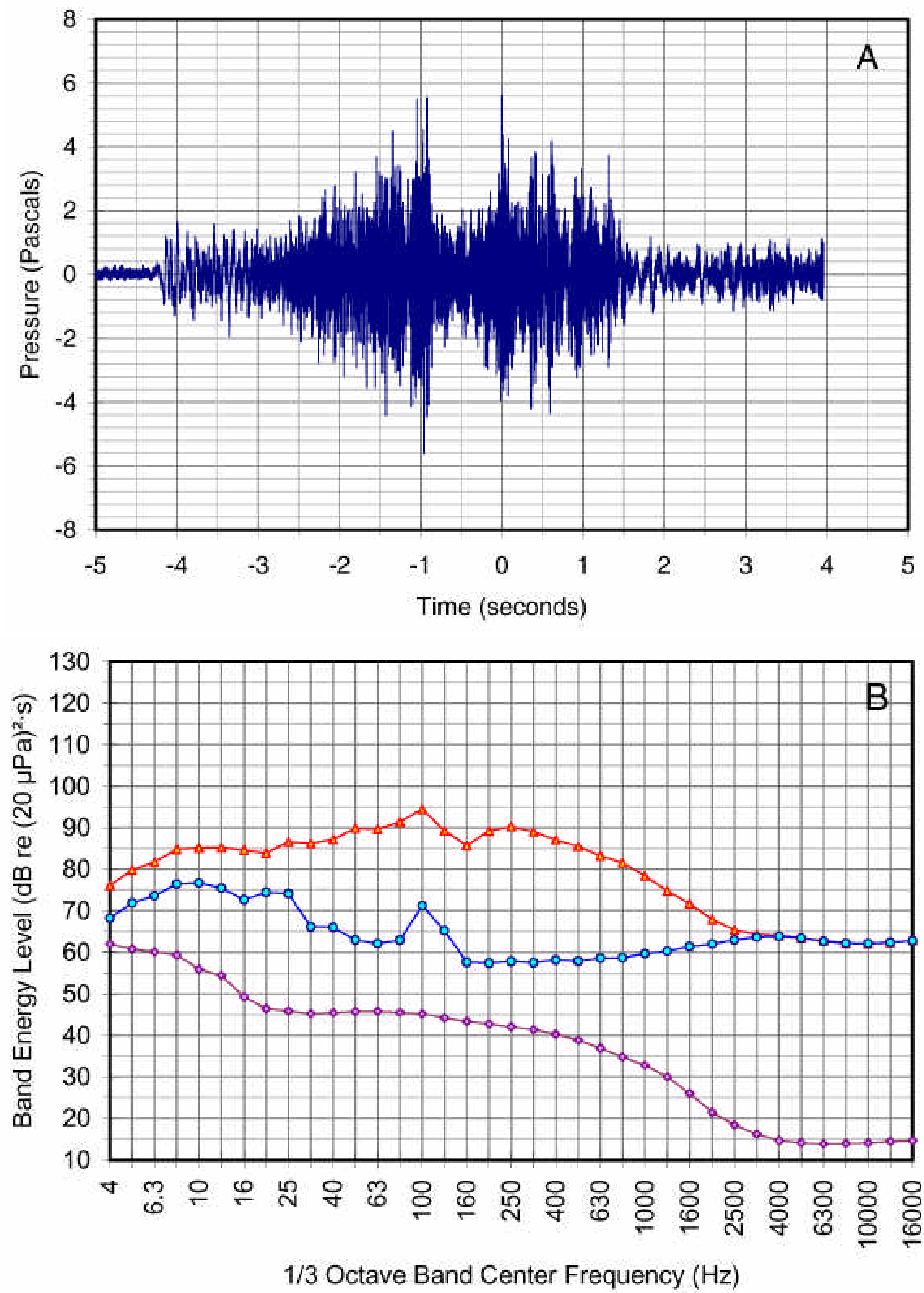


FIGURE 2.3. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 12:55 on 15 August 2001 recorded at site "End of Redeye Road". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

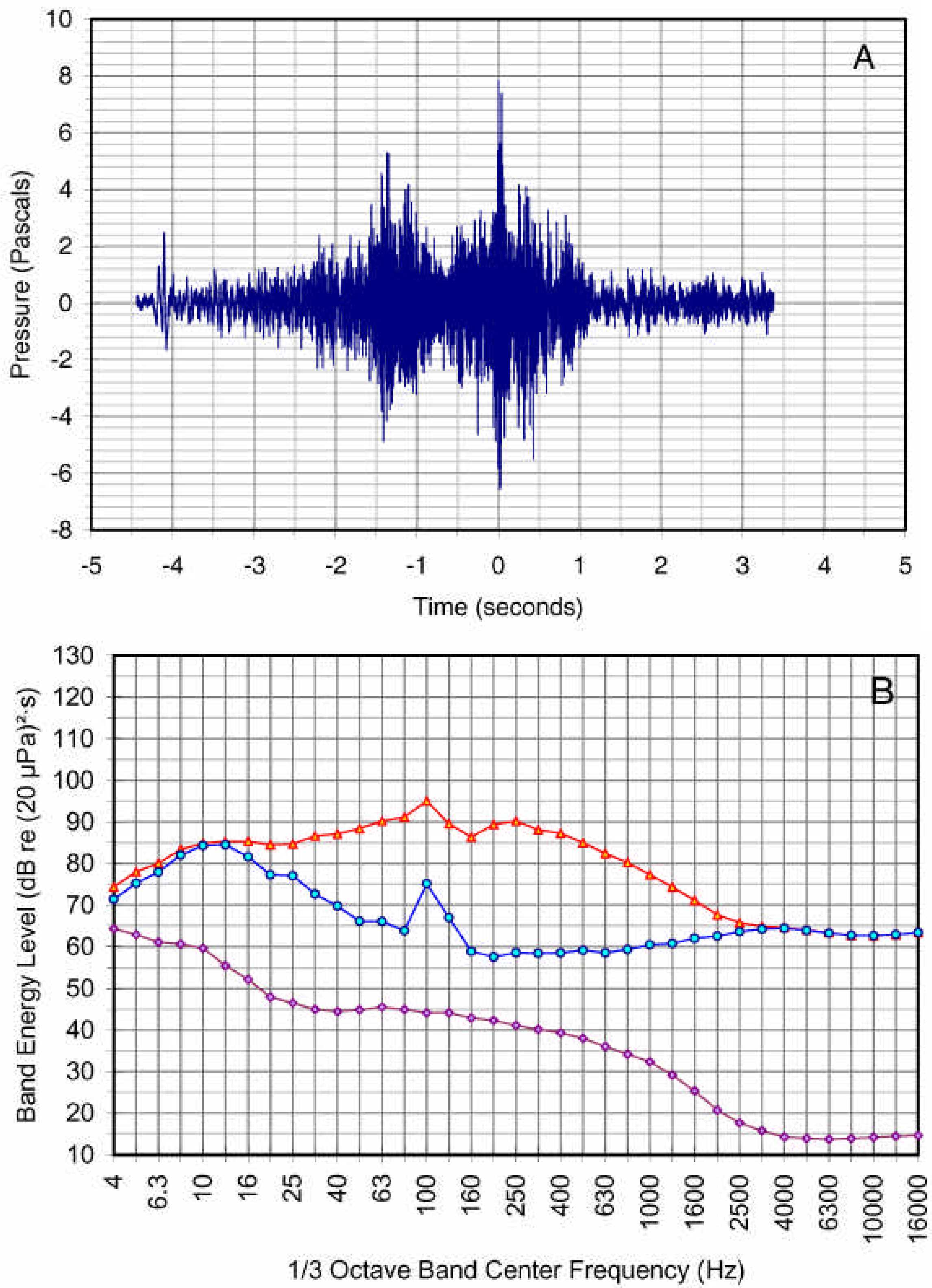


FIGURE 2.4. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 13:16 on 15 August 2001 recorded at site "End of Redeye Road". In (**B**), Δ = missile sound; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

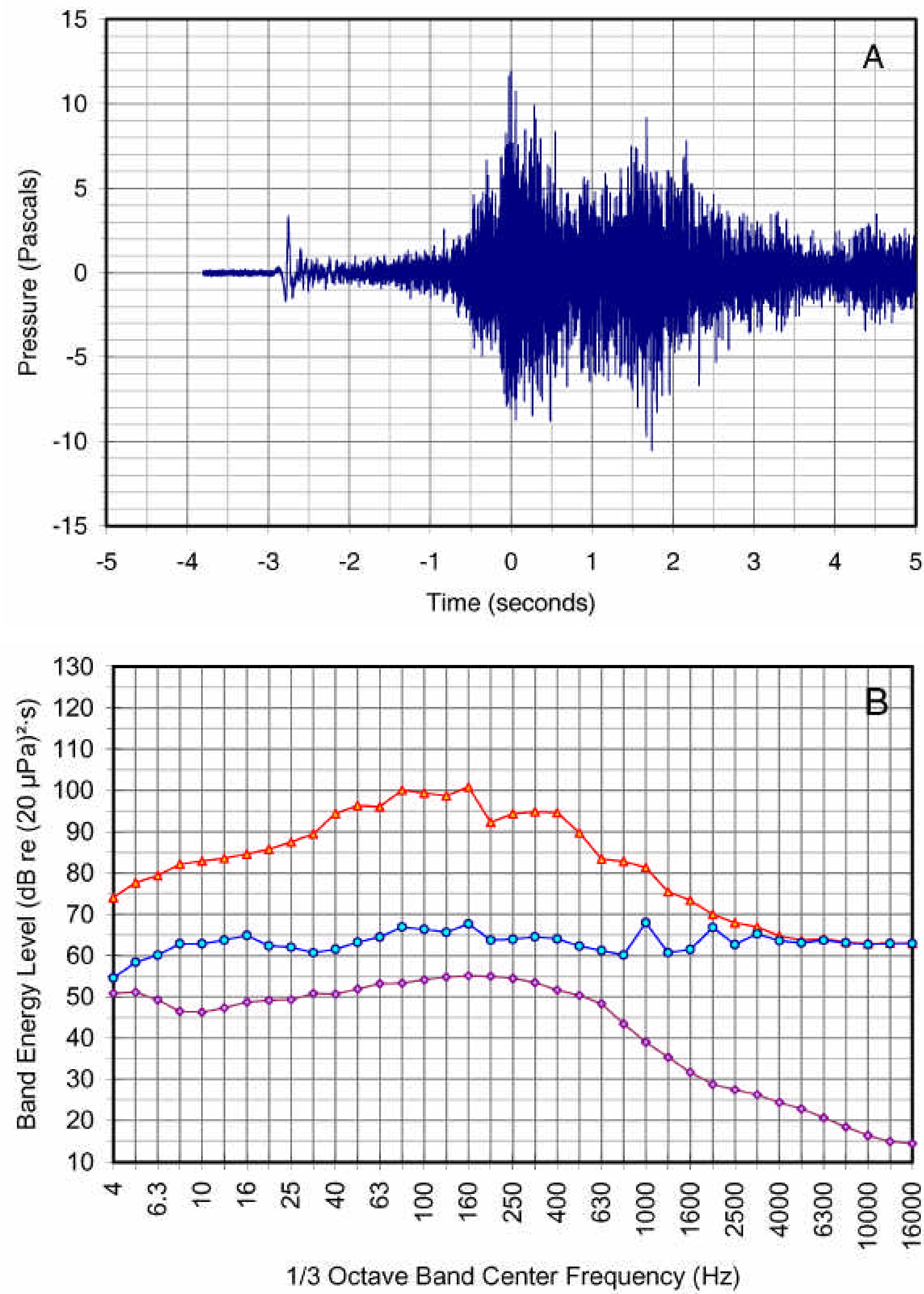


FIGURE 2.5. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 08:29 on 20 September 2001 recorded at site "Tender Beach". In (**B**), Δ = missile sound; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

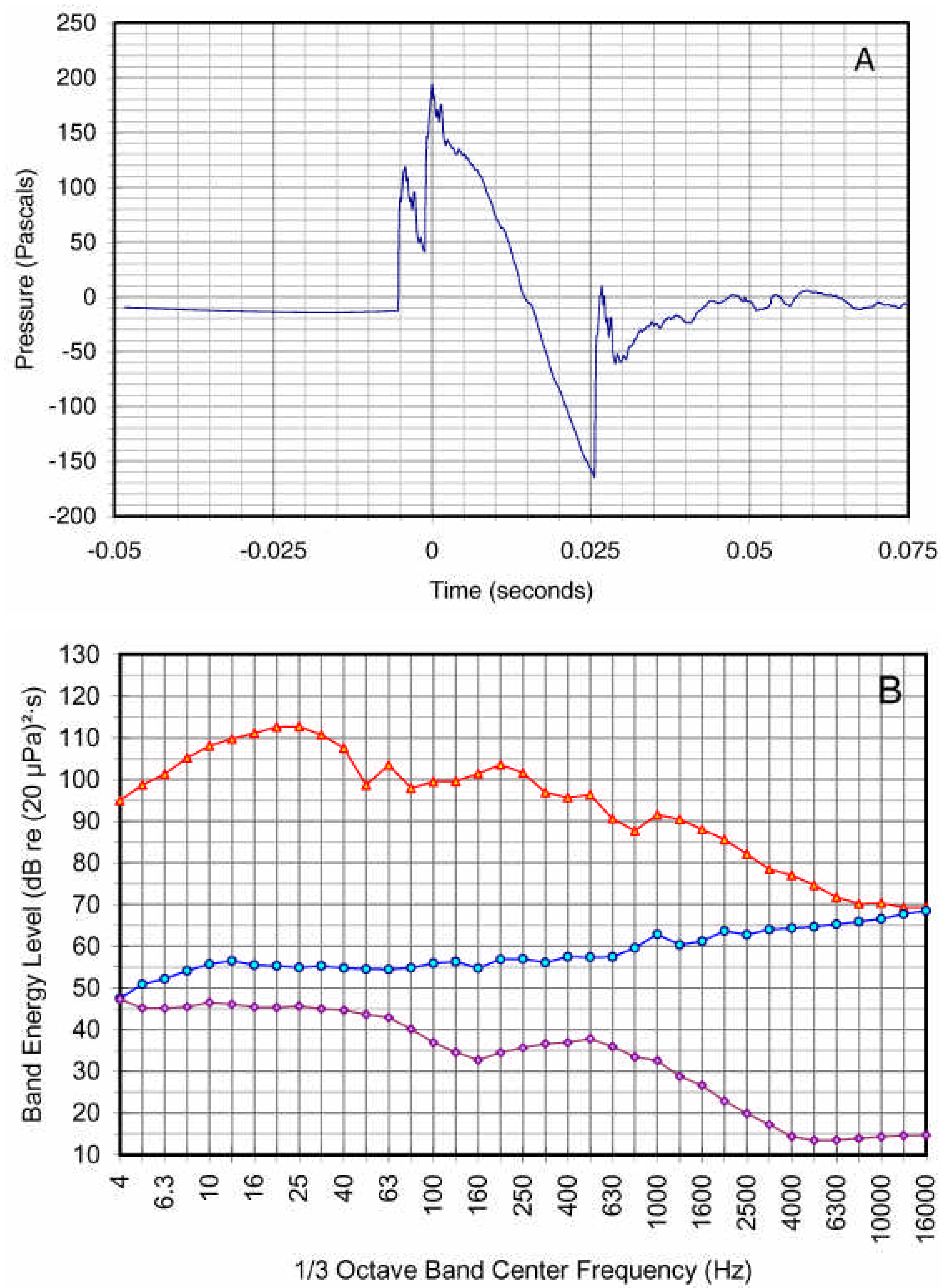


FIGURE 2.6. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 08:29 on 20 September 2001 recorded at site "809 Camera". In (**B**), Δ = missile sound; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

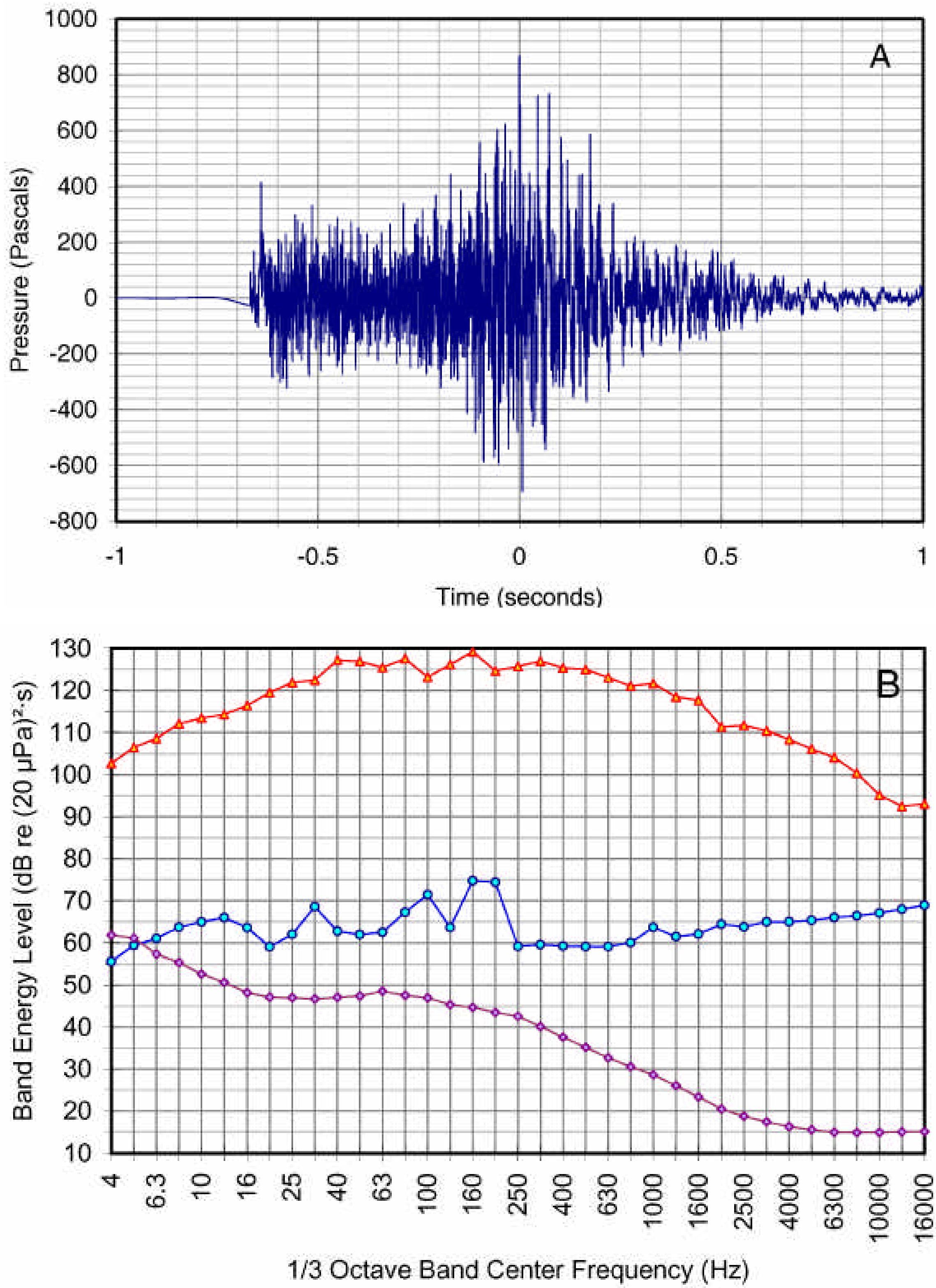


FIGURE 2.7. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Terrier Orion flight at 17:00 on 20 September 2001 recorded at site "Building 807". In (**B**), Δ = missile sound; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

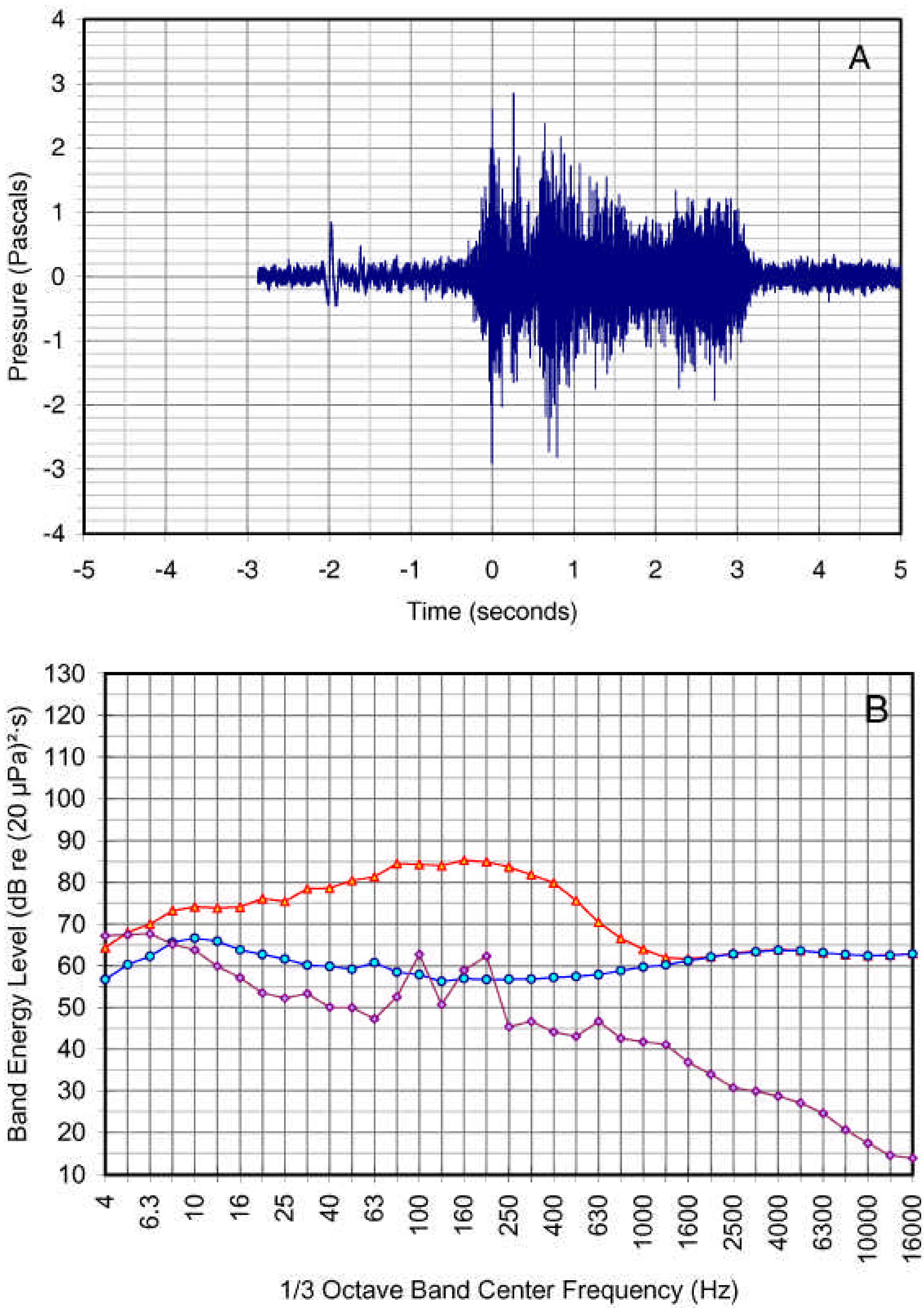


FIGURE 2.8. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Terrier Orion flight at 17:00 on 20 September 2001 recorded at site “100 ft from Launcher”. In (**B**), Δ = missile sound; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

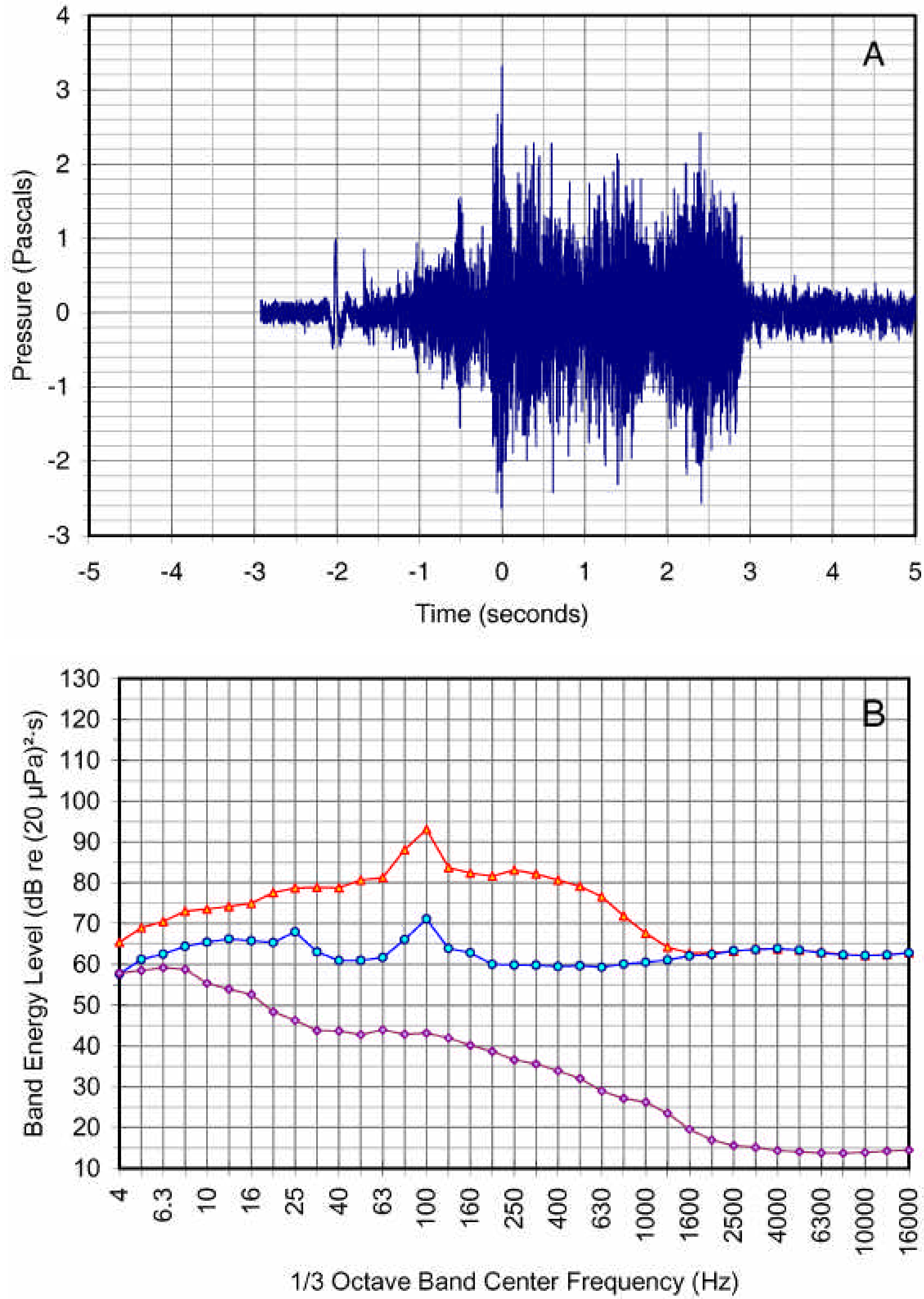


FIGURE 2.9. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Terrier Orion flight at 17:00 on 20 September 2001 recorded at site "Cormorant Rock Blind". In (**B**), Δ = missile sound; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

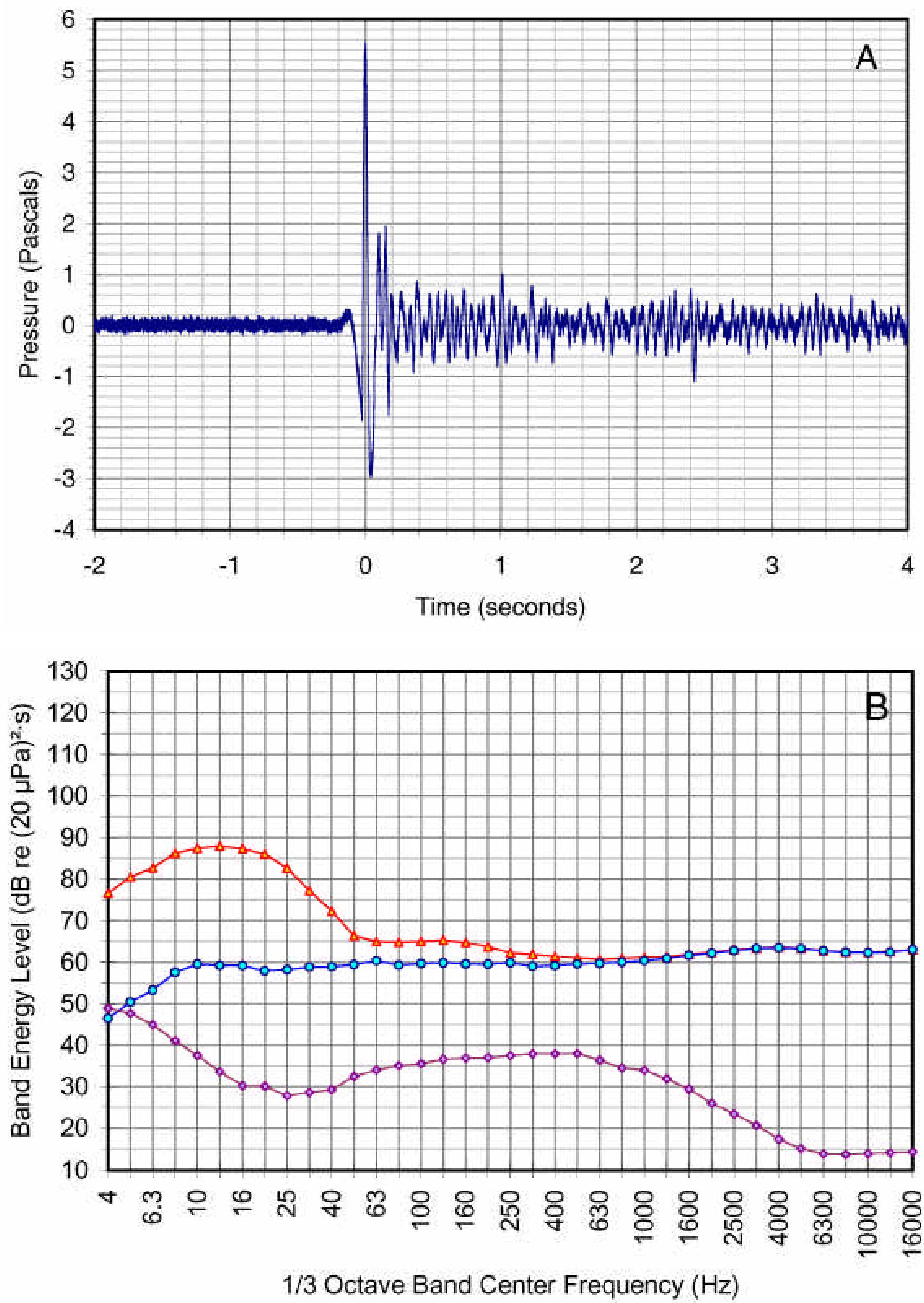


FIGURE 2.10. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 13:36 on 5 October 2001 recorded at site "Phoca Reef". In (**B**), Δ = missile sound; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

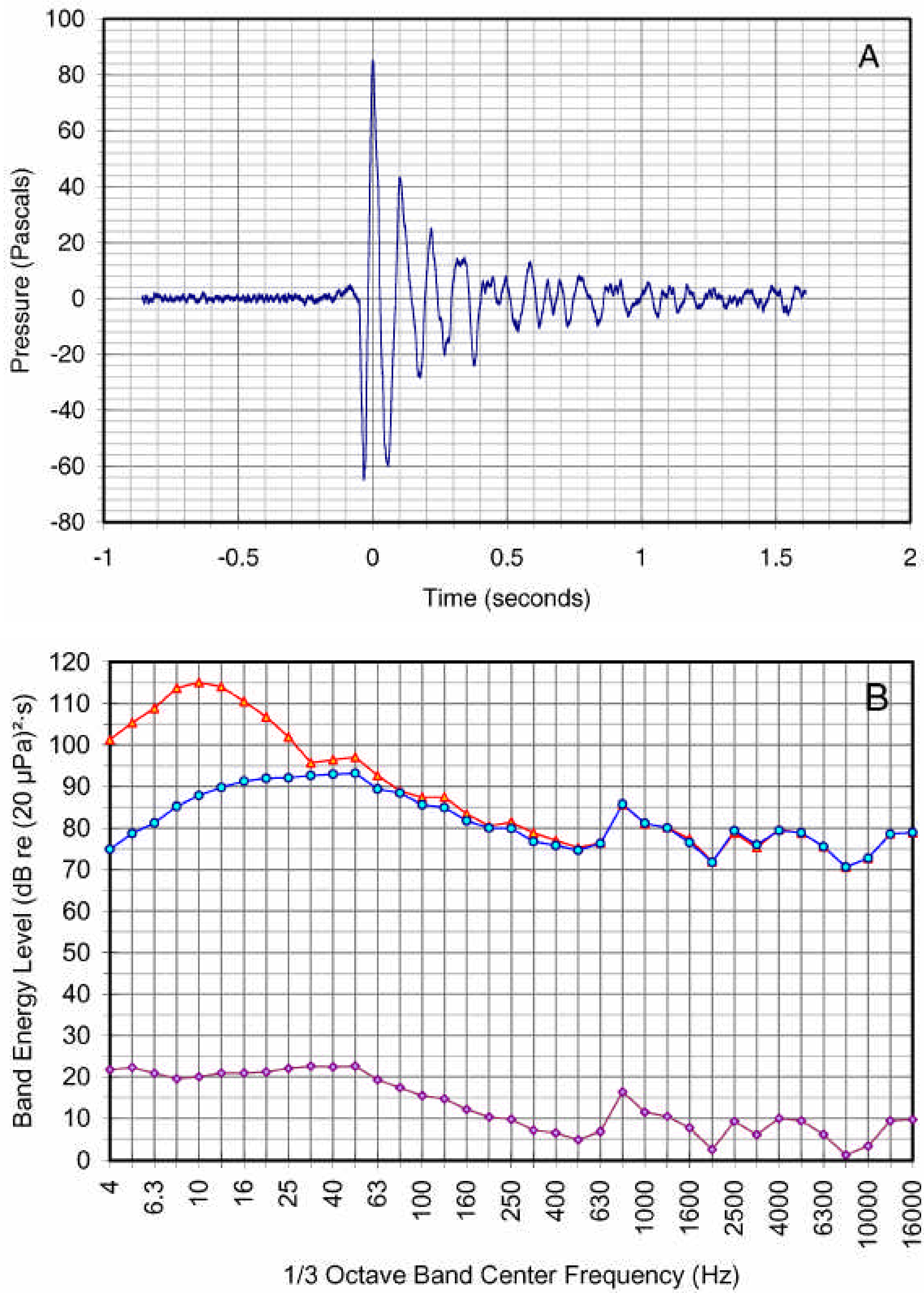


FIGURE 2.11. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 08:59 on 19 October 2001 recorded at site "NAVFAC Beach". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

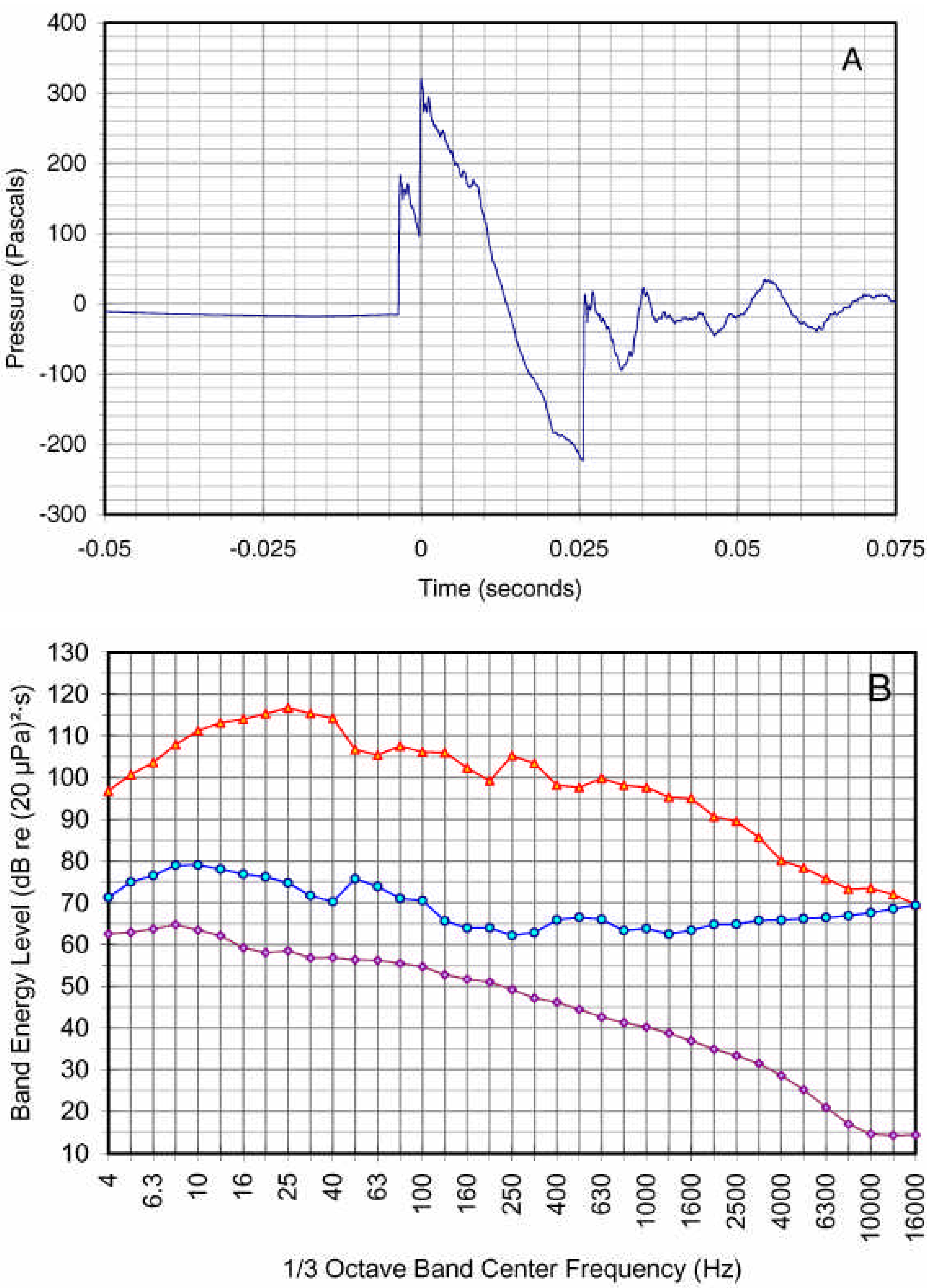


FIGURE 2.12. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 15:20 on 19 December 2001 recorded at site "Building 807". In (**B**), Δ = missile sound; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

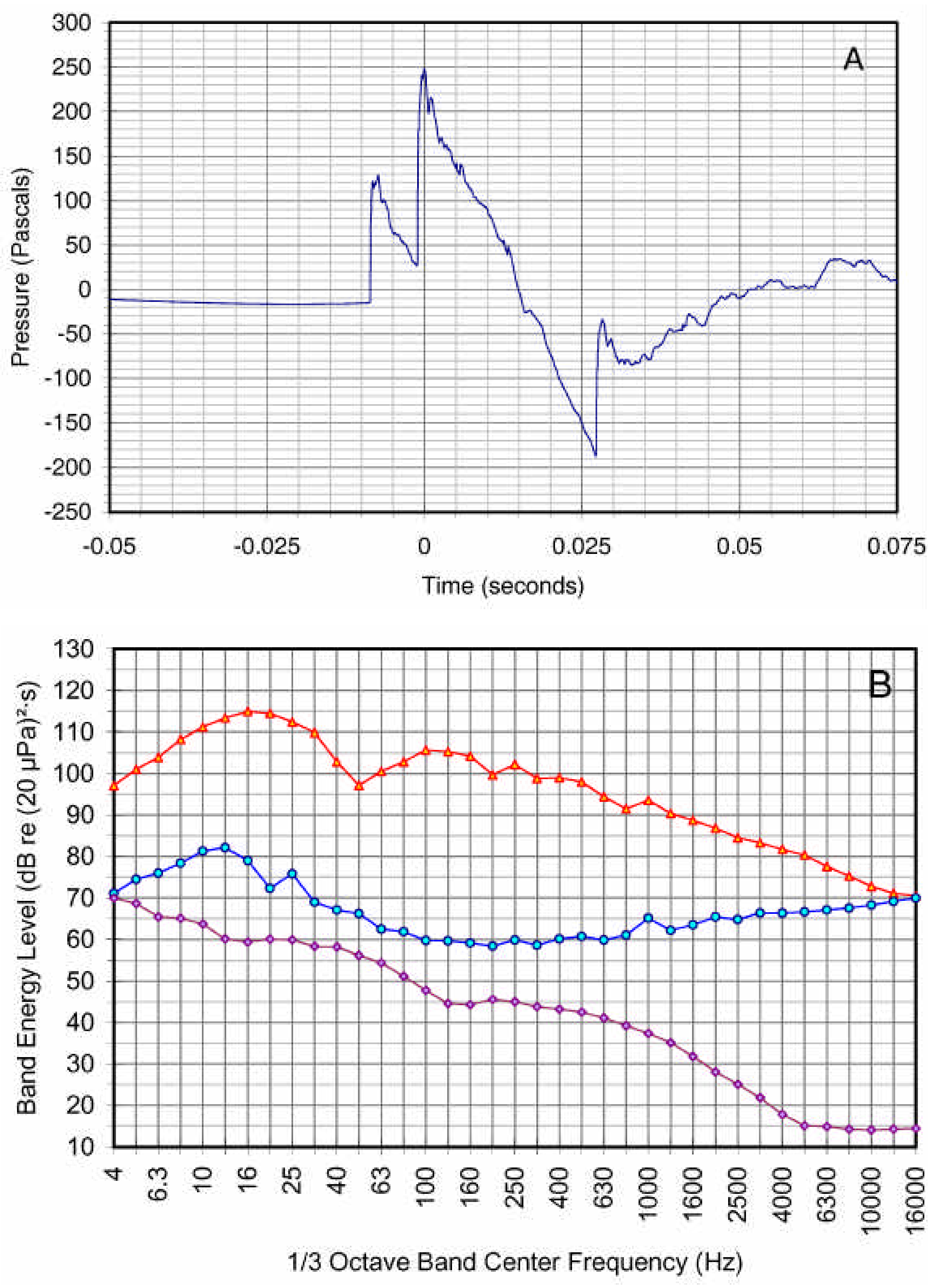


FIGURE 2.13. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 15:20 on 19 December 2001 recorded at site "809 Camera". In (**B**), Δ = missile sound; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

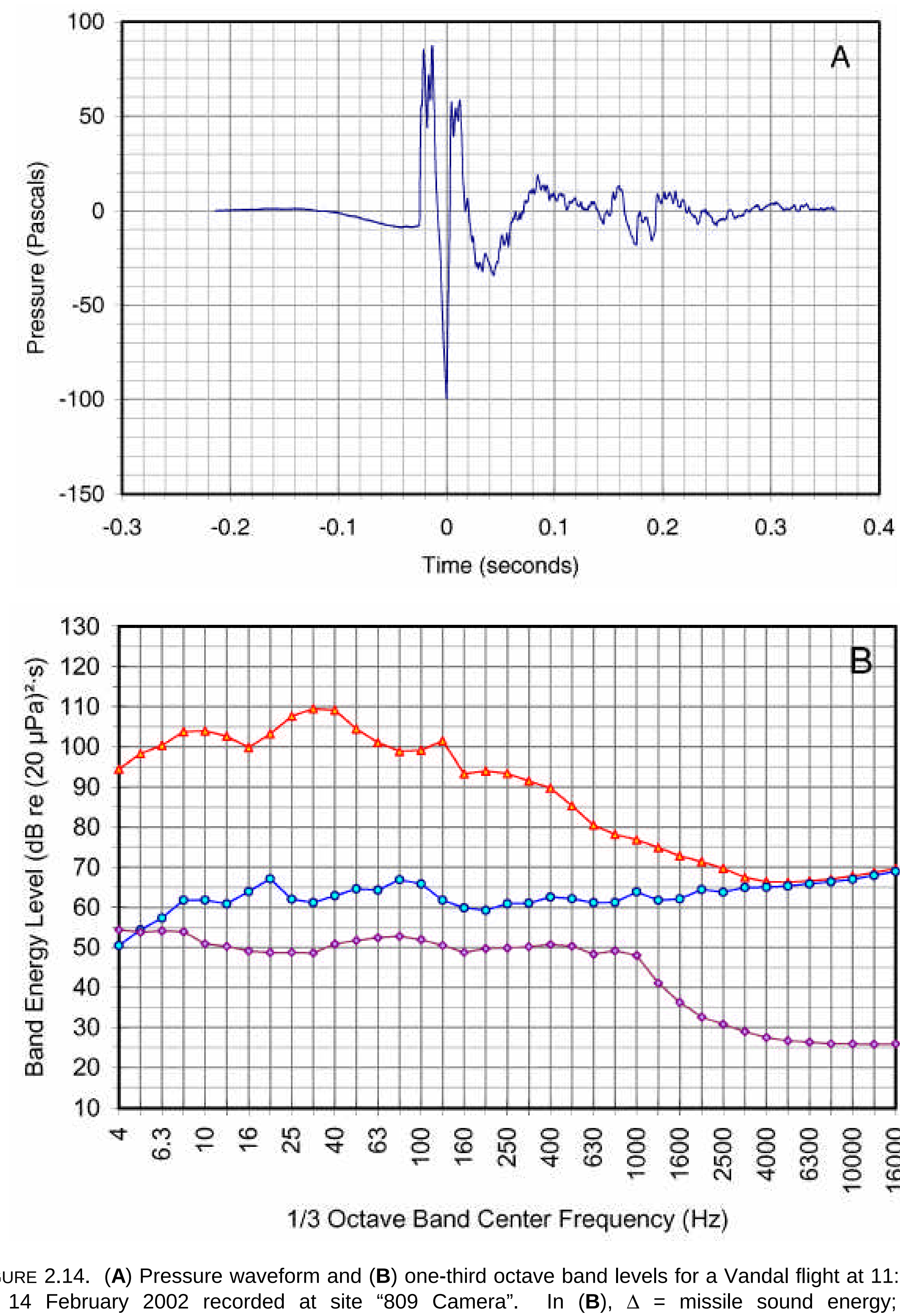


FIGURE 2.14. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 11:33:00 on 14 February 2002 recorded at site "809 Camera". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

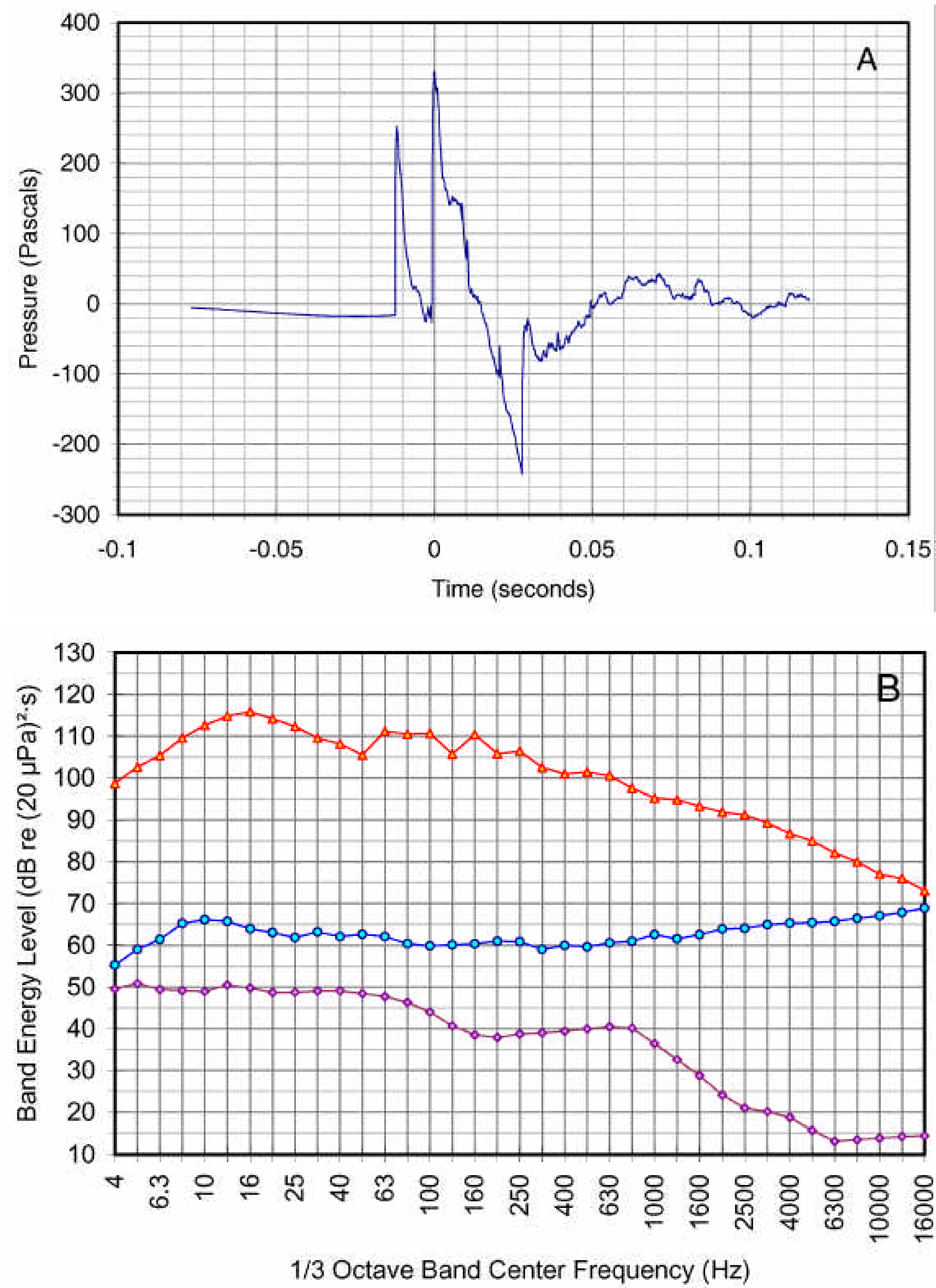


FIGURE 2.15. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 11:33:00 on 14 February 2002 recorded at site "Bachelor Beach North". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

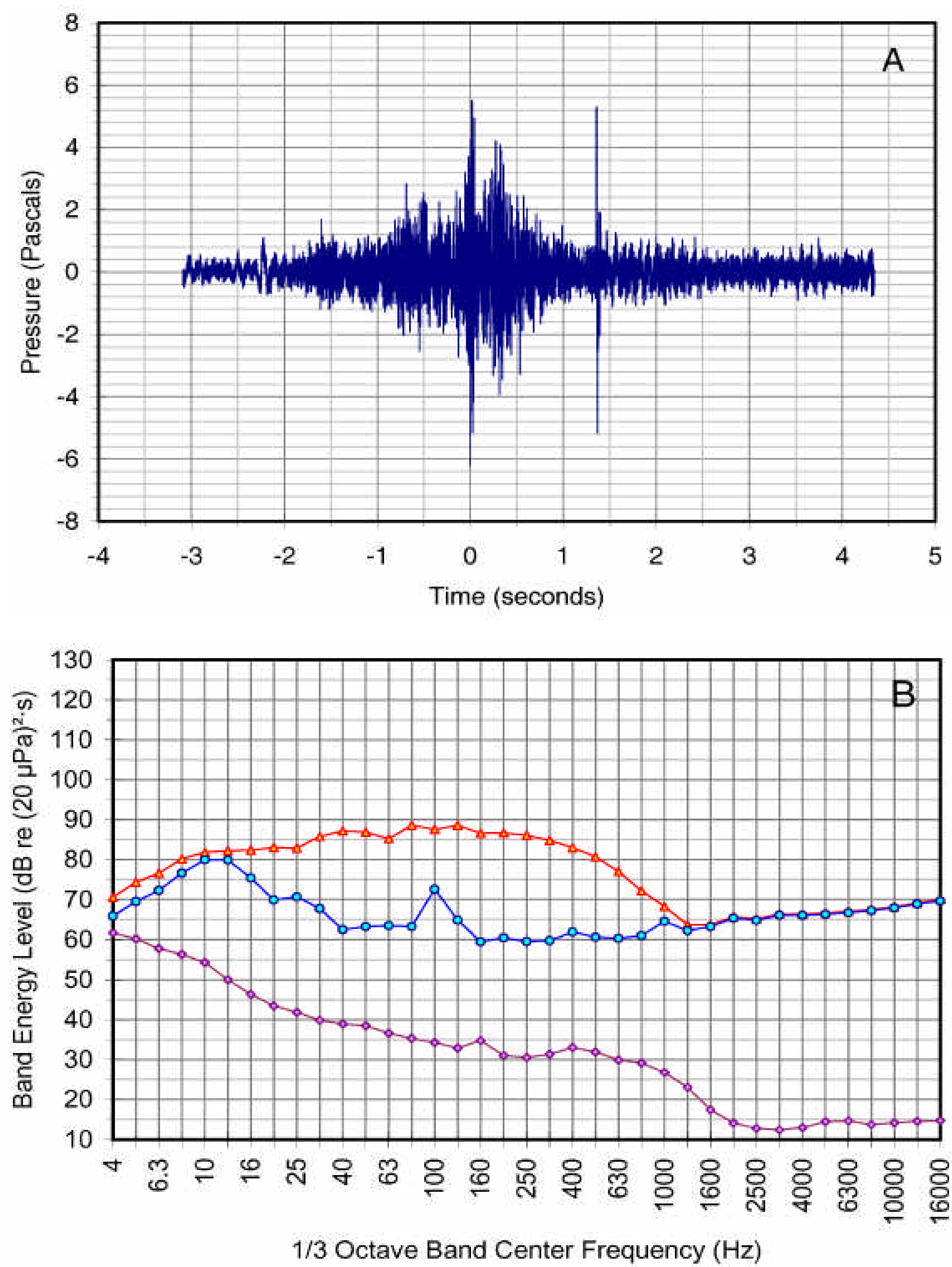


FIGURE 2.16. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 12:13:04 on 22 February 2002 recorded at site "809 Camera". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

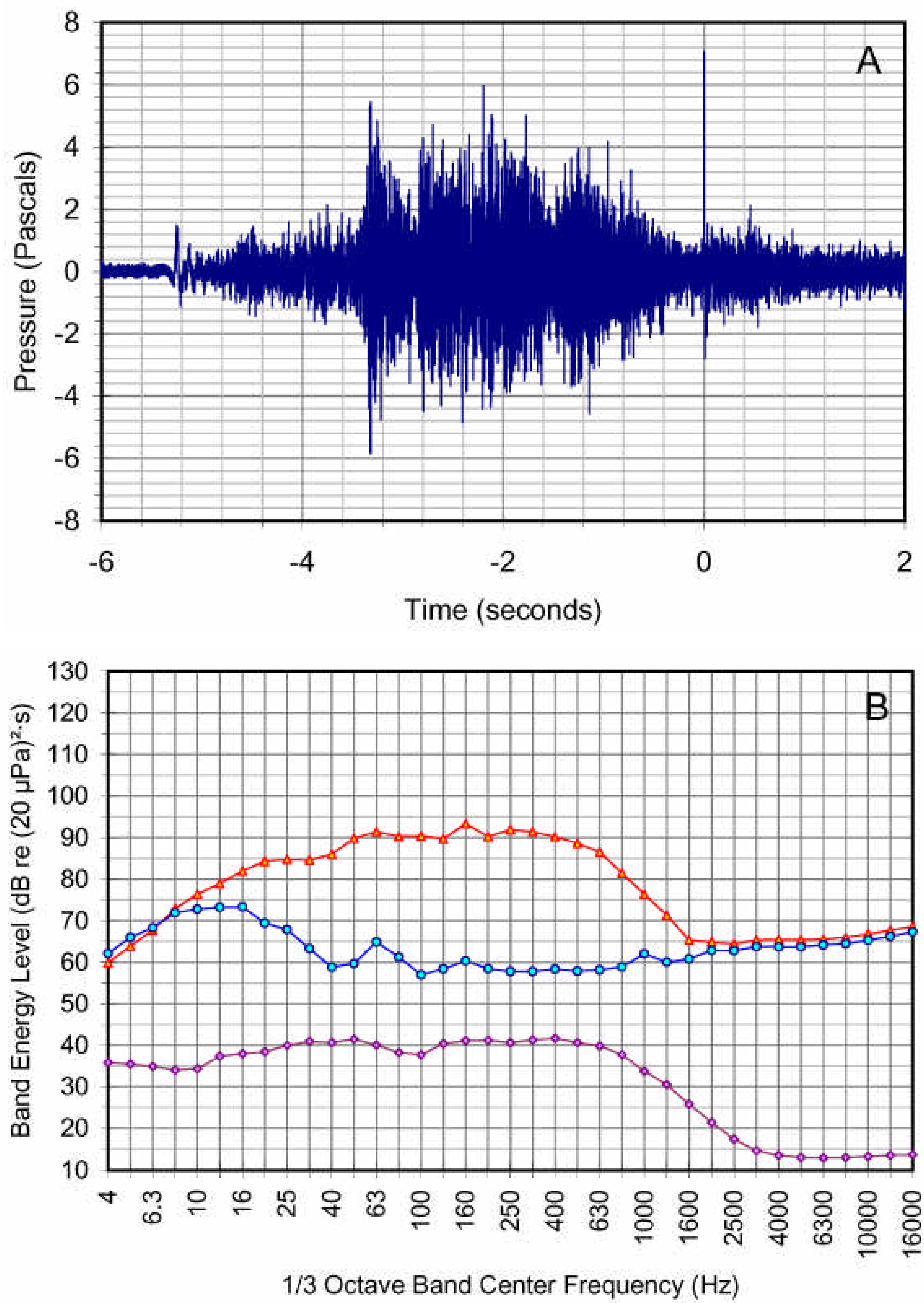


FIGURE 2.17. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 12:13:04 on 22 February 2002 recorded at site "Redeye Beach". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

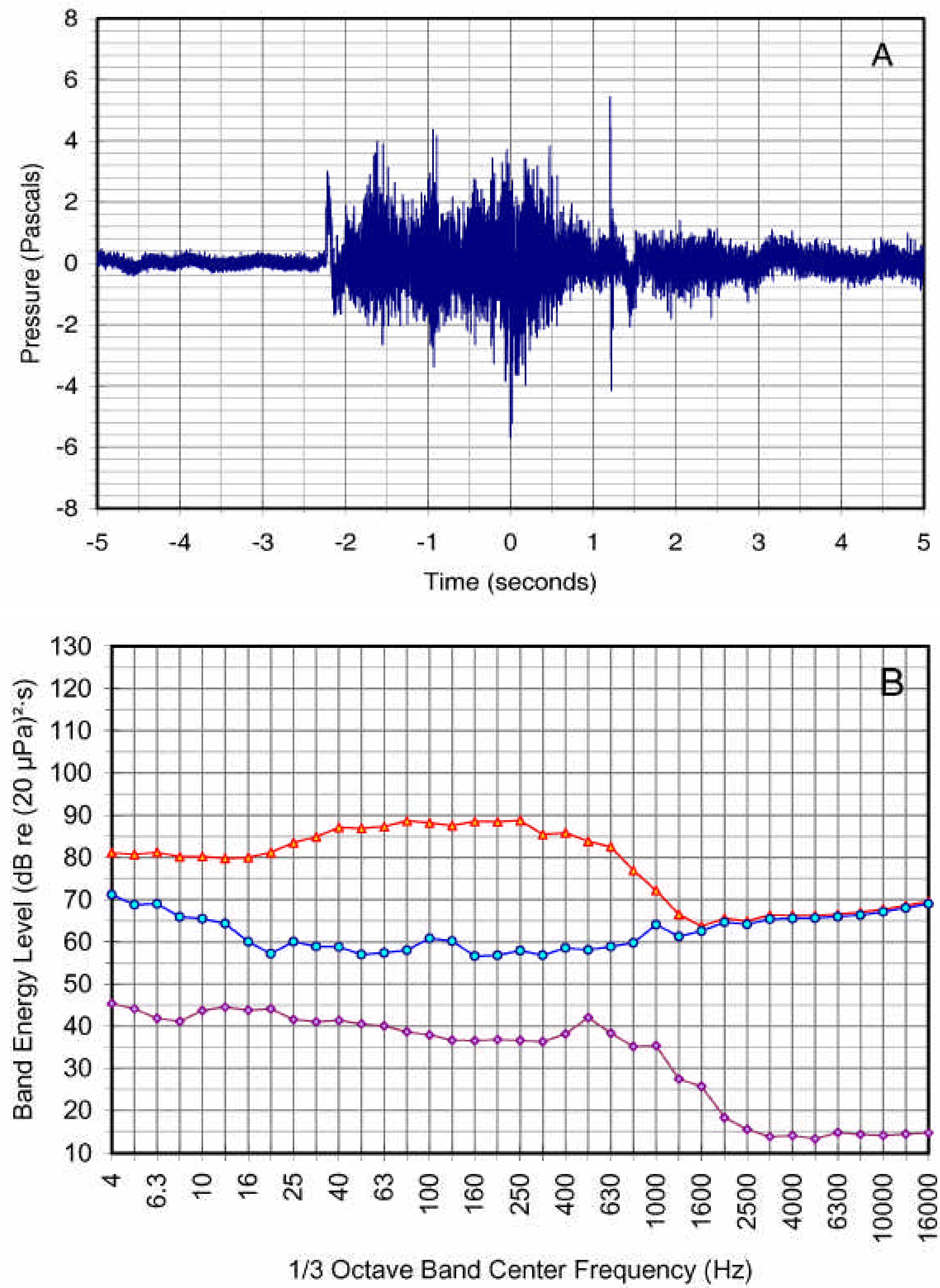


FIGURE 2.18. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 14:56:22 on 22 February 2002 recorded at site "809 Camera". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

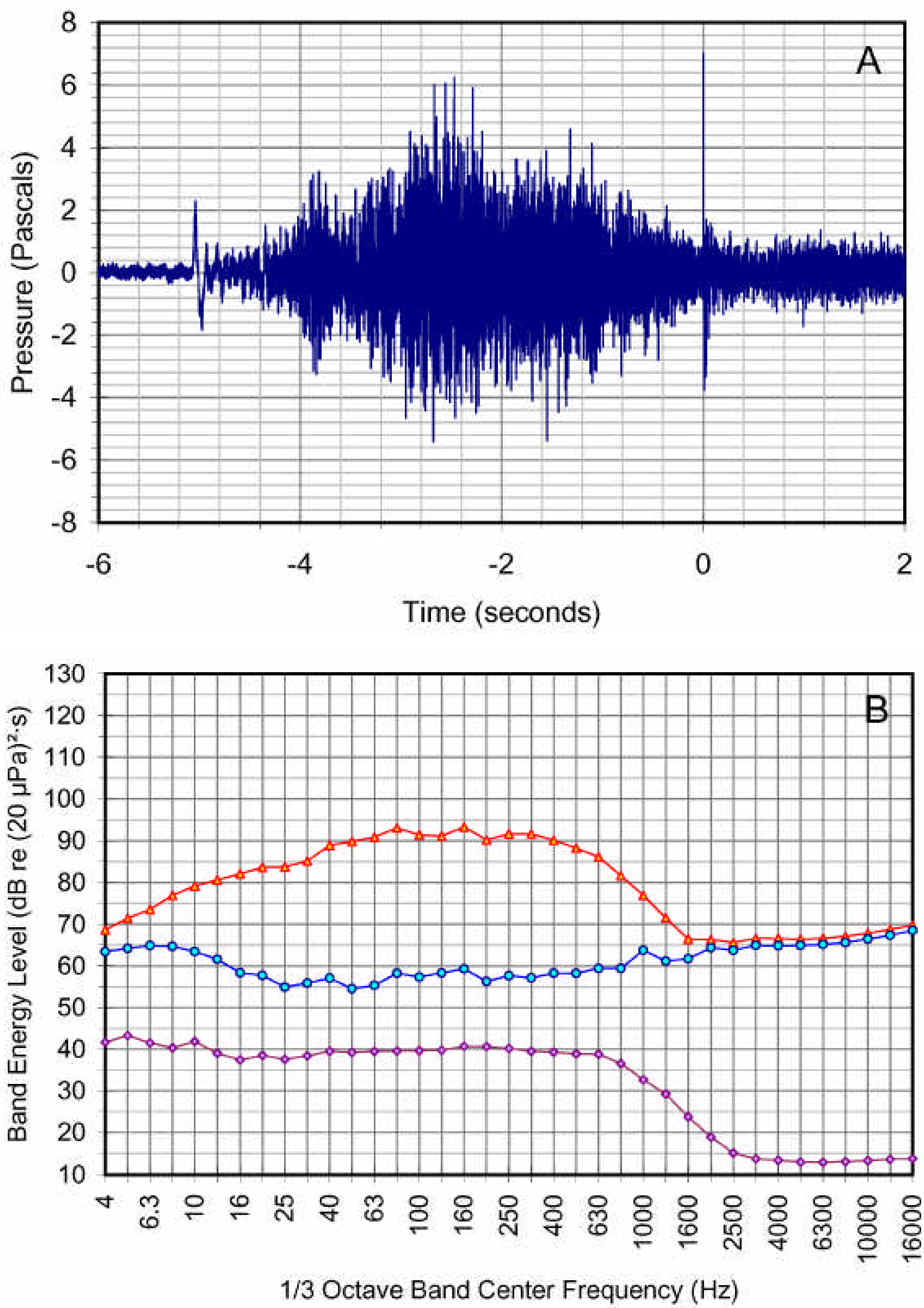


FIGURE 2.19. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 14:56:22 on 22 February 2002 recorded at site "Redeye Beach". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

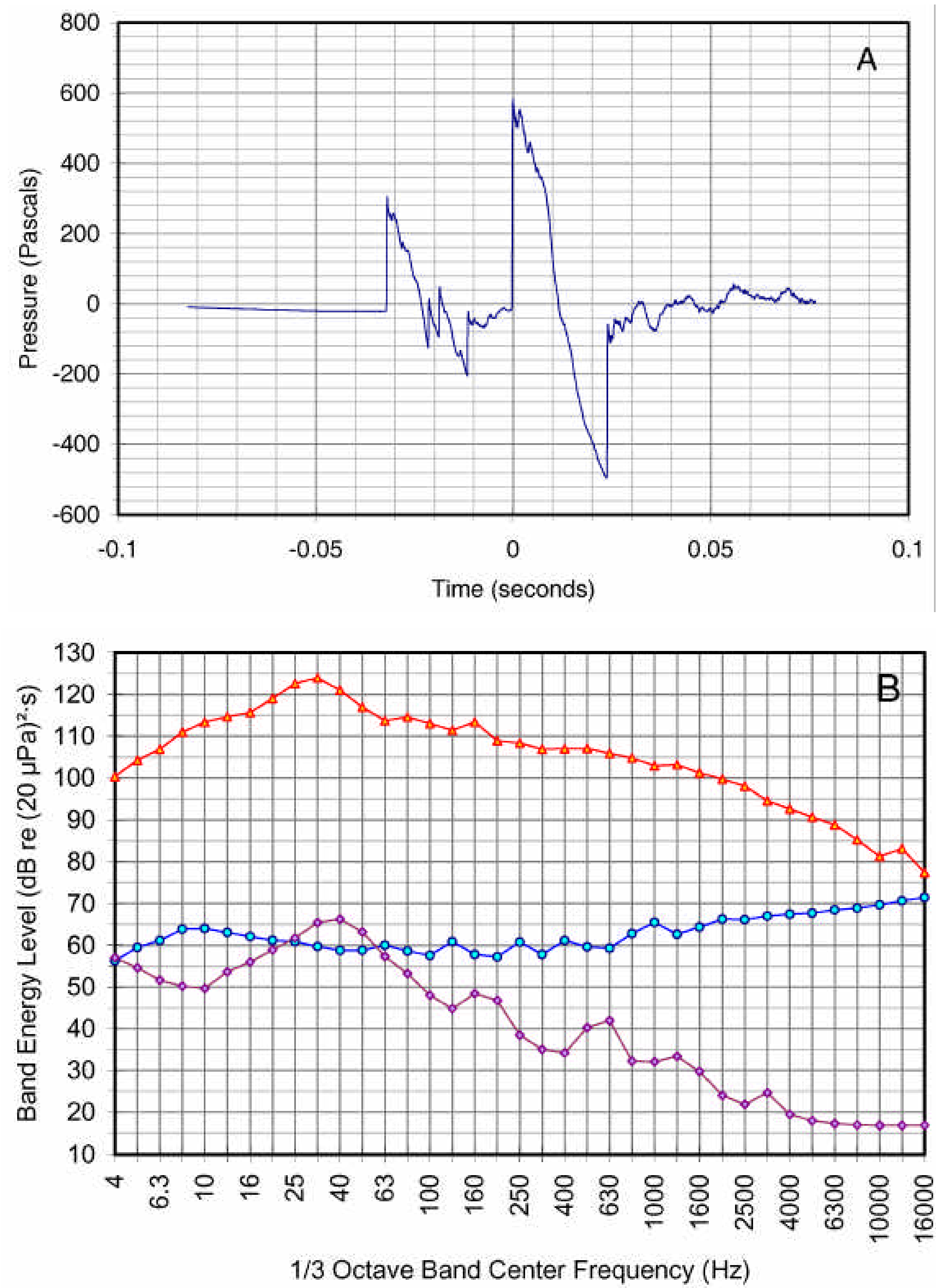


FIGURE 2.20. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 11:20:38 on 6 March 2002 recorded at site "Dos Coves". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

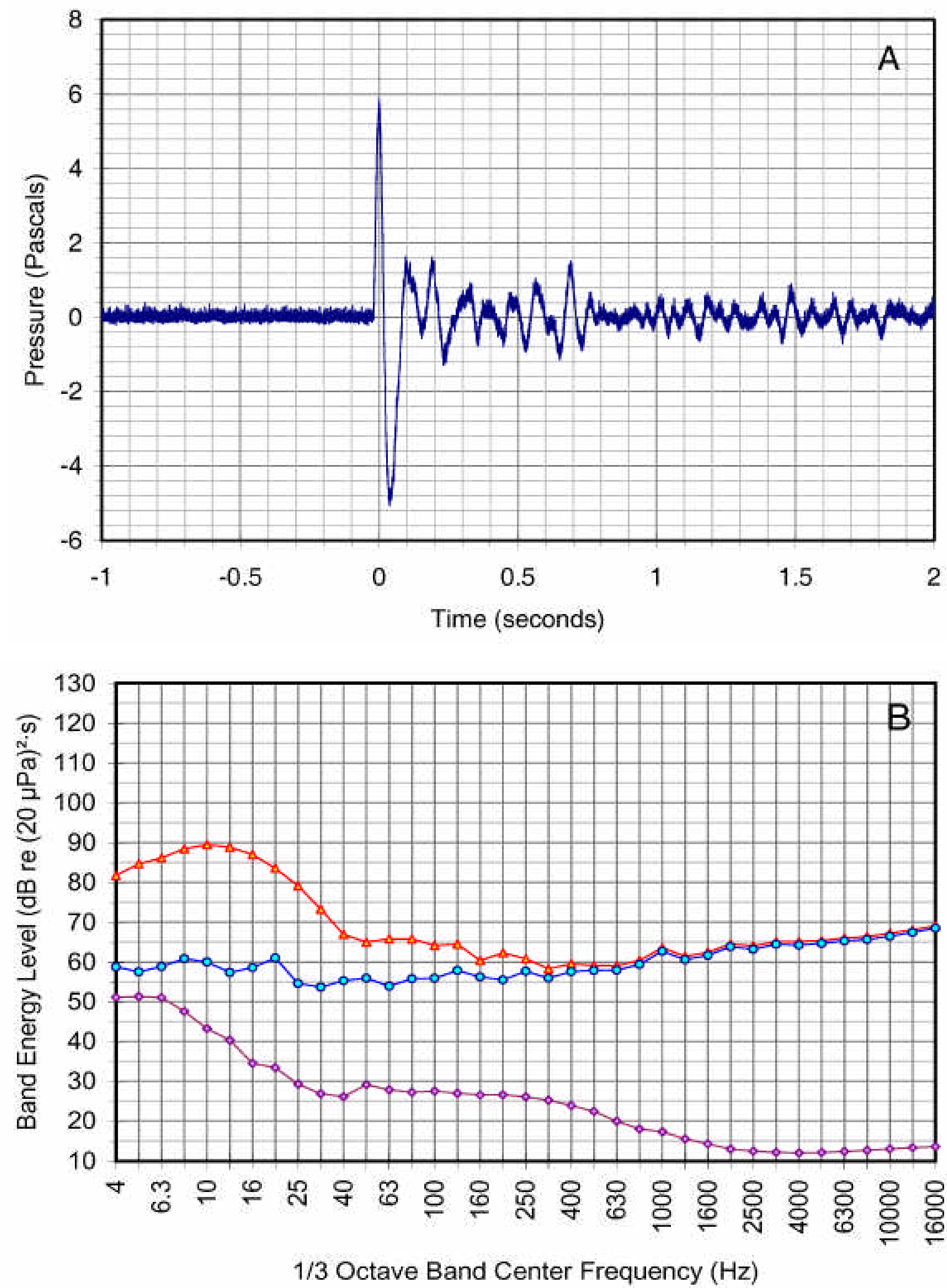


FIGURE 2.21. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 11:20:38 on 6 March 2002 recorded at site "Sheephead Ranch". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

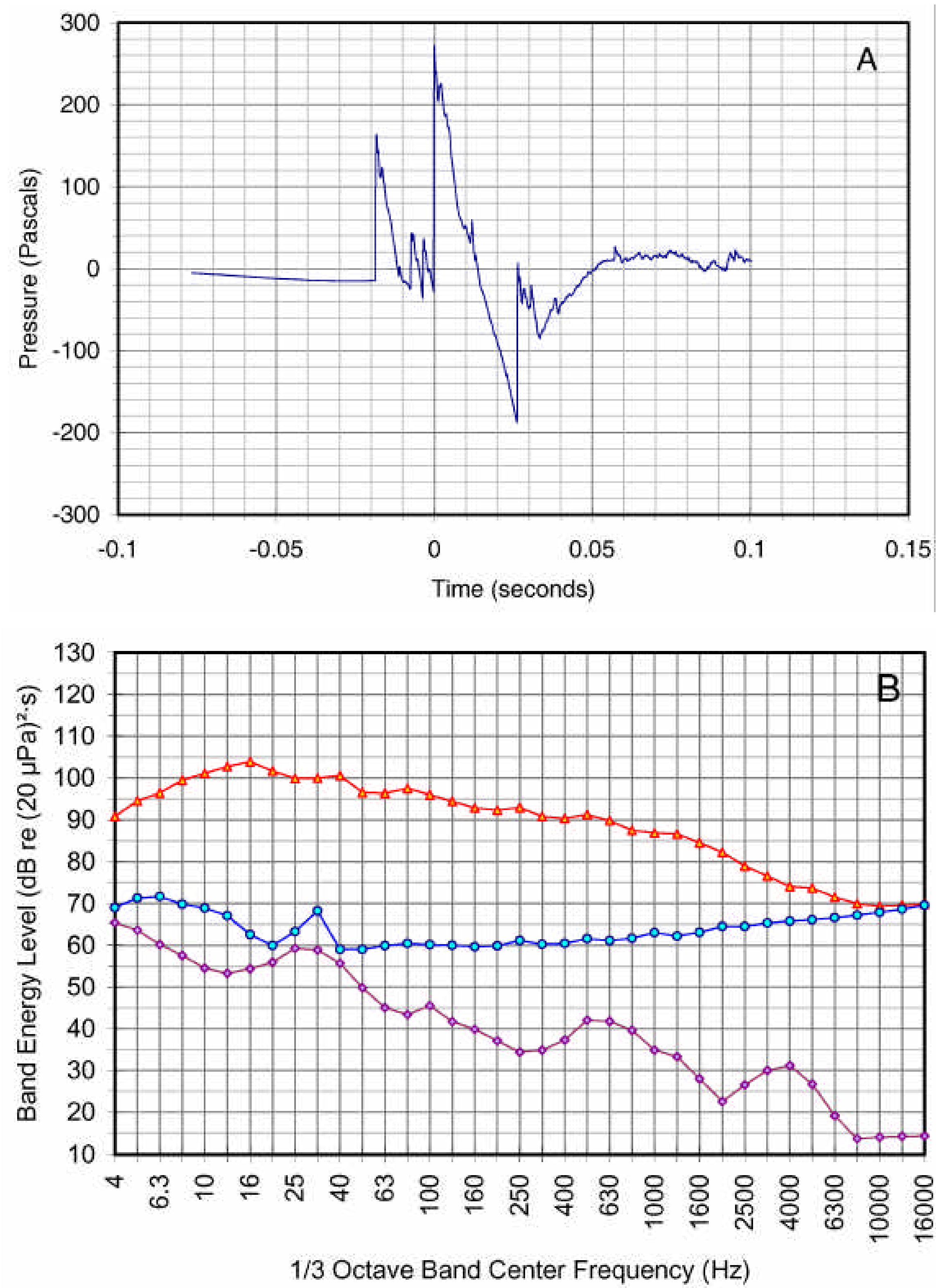


FIGURE 2.22. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 11:20:38 on 6 March 2002 recorded at site "809 Camera". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

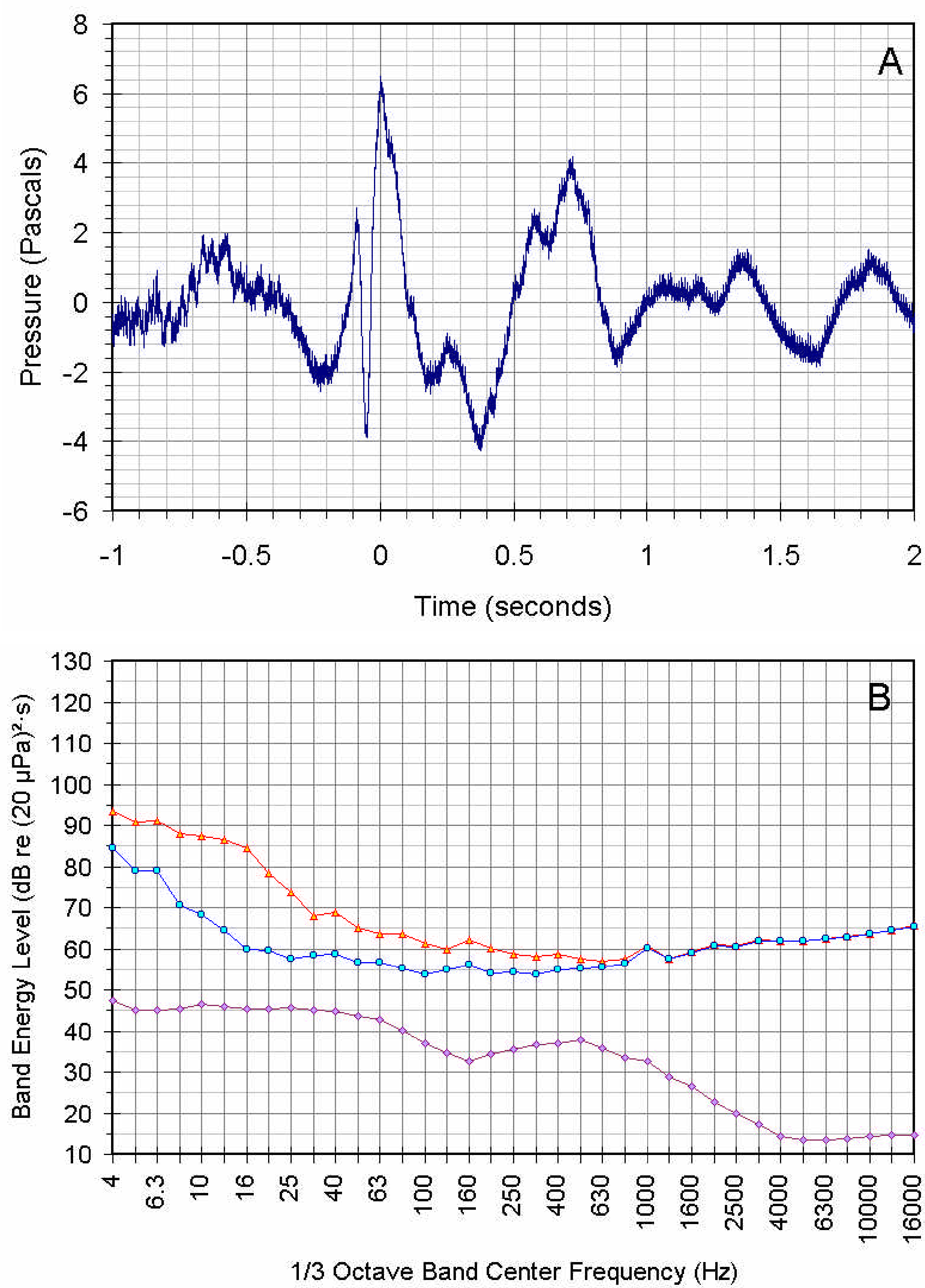


FIGURE 2.23. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 15:53:20 on 1 May 2002 recorded at site "Bachelor Beach South". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

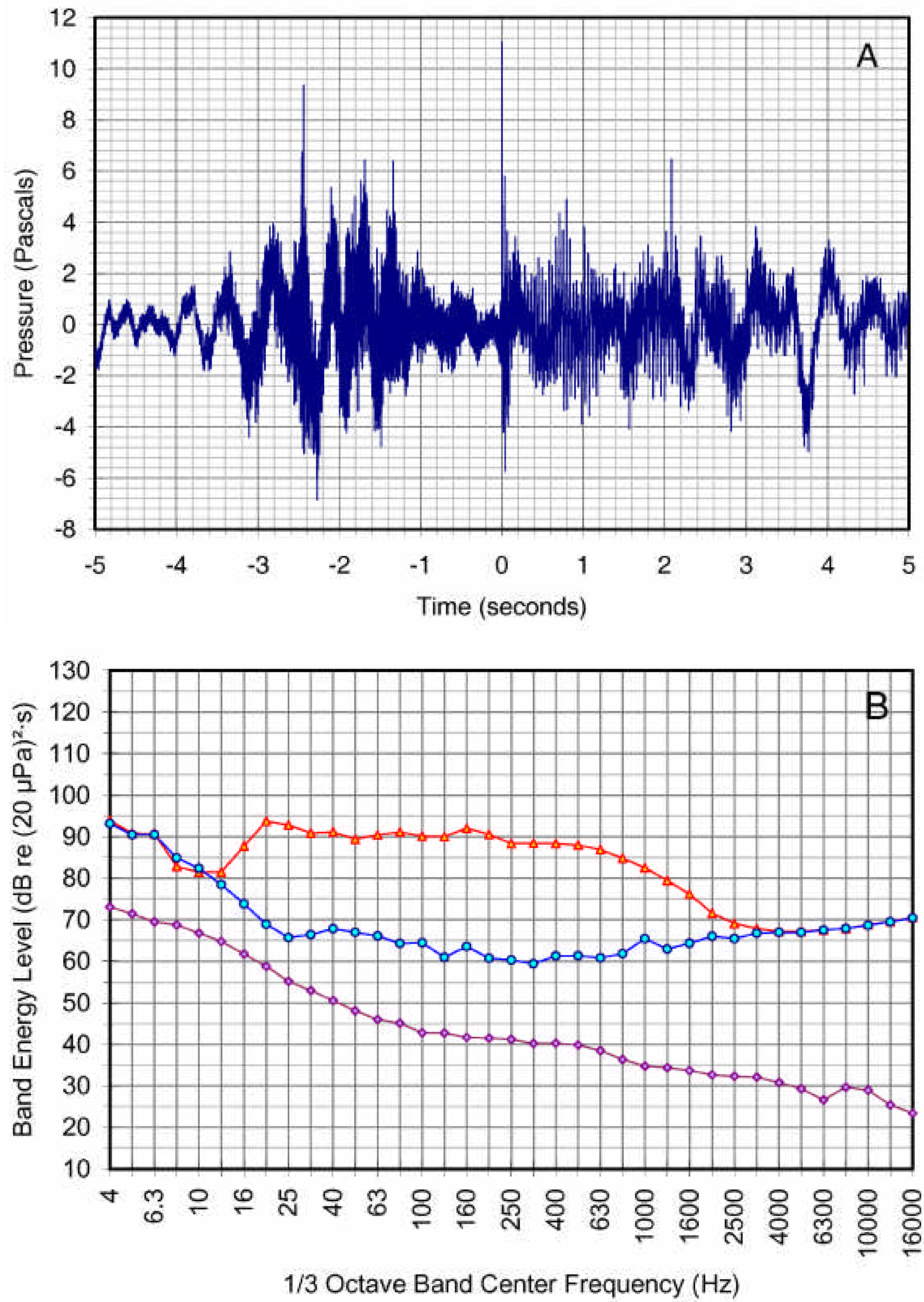


FIGURE 2.24. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 17:00:23 on 1 May 2002 recorded at site "Bachelor Beach South". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

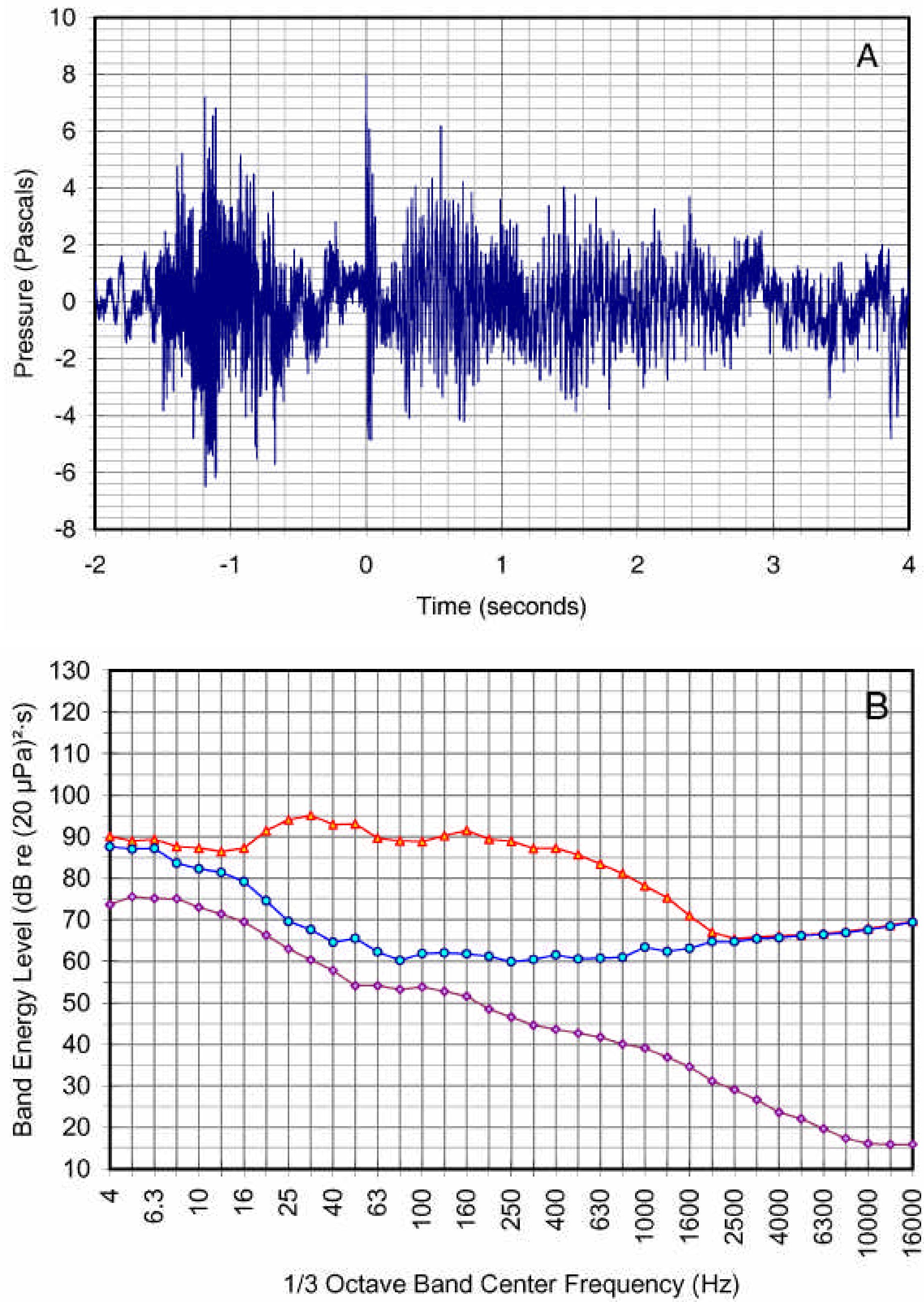


FIGURE 2.25. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 17:00:23 on 1 May 2002 recorded at site "809 Camera". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

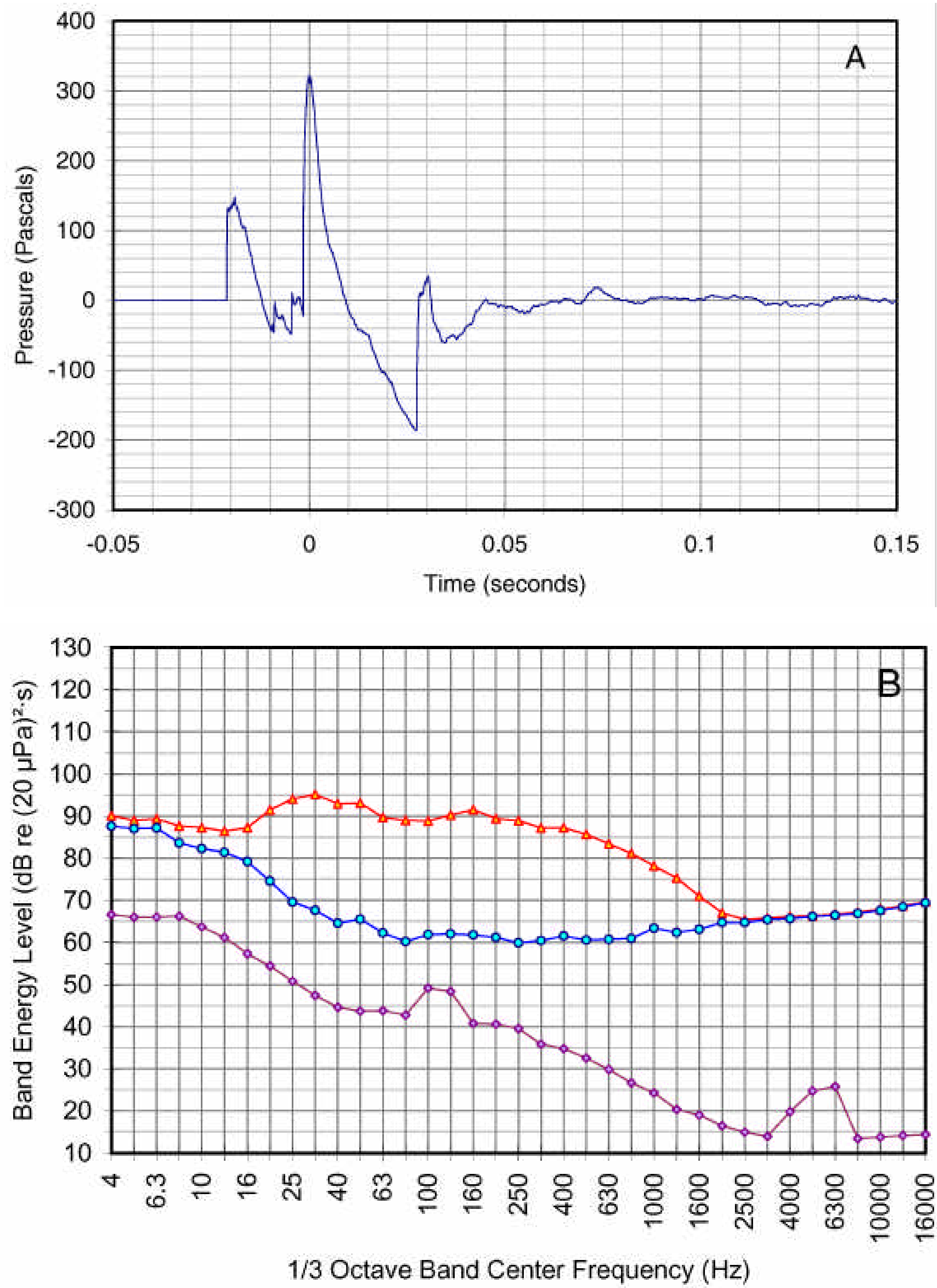


FIGURE 2.26. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 14:54:02 on 8 May 2002 recorded at site “Vizcaino Point”. In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

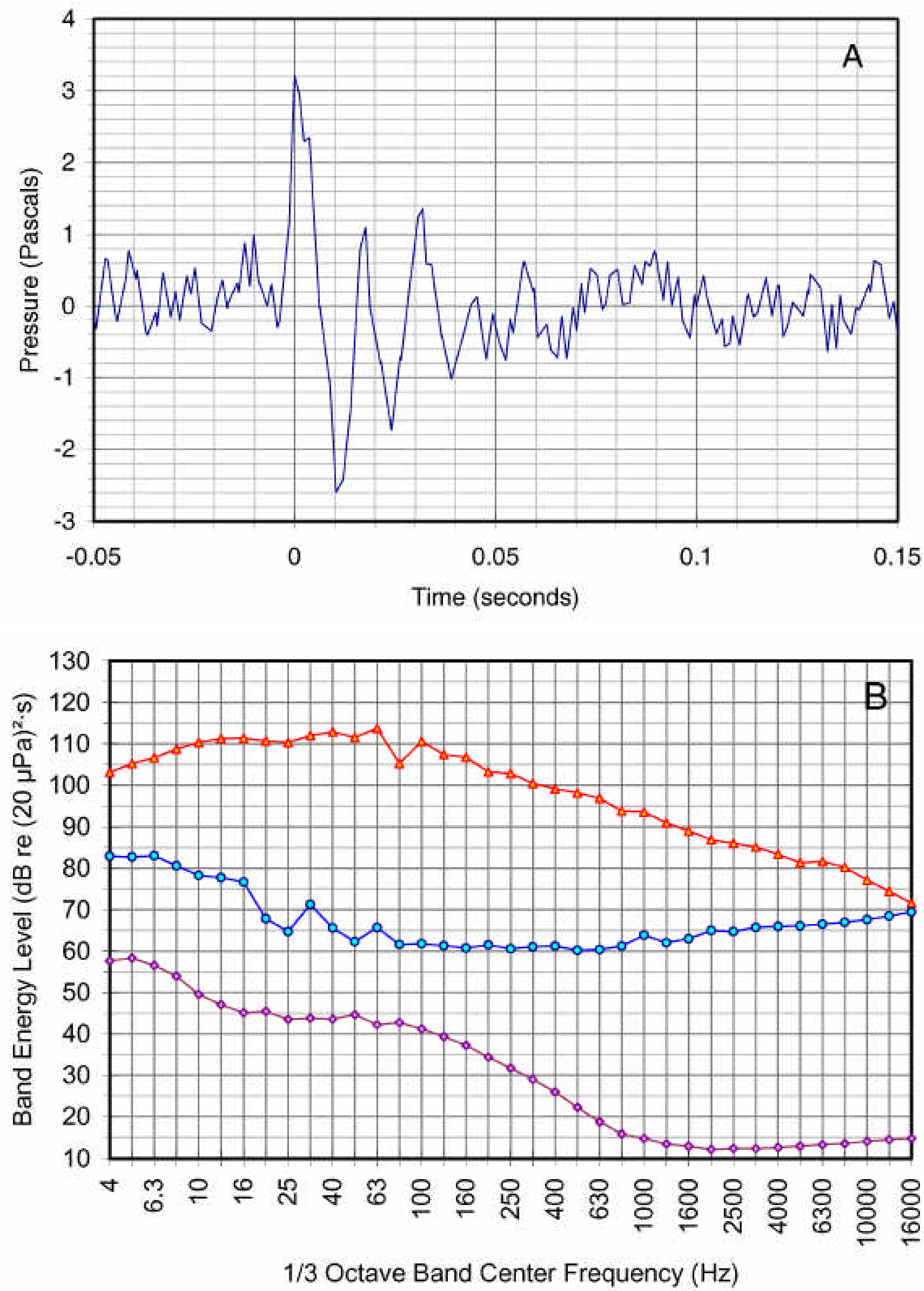


FIGURE 2.27. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 14:54:02 on 8 May 2002 recorded at site "Sea Lion Cove". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

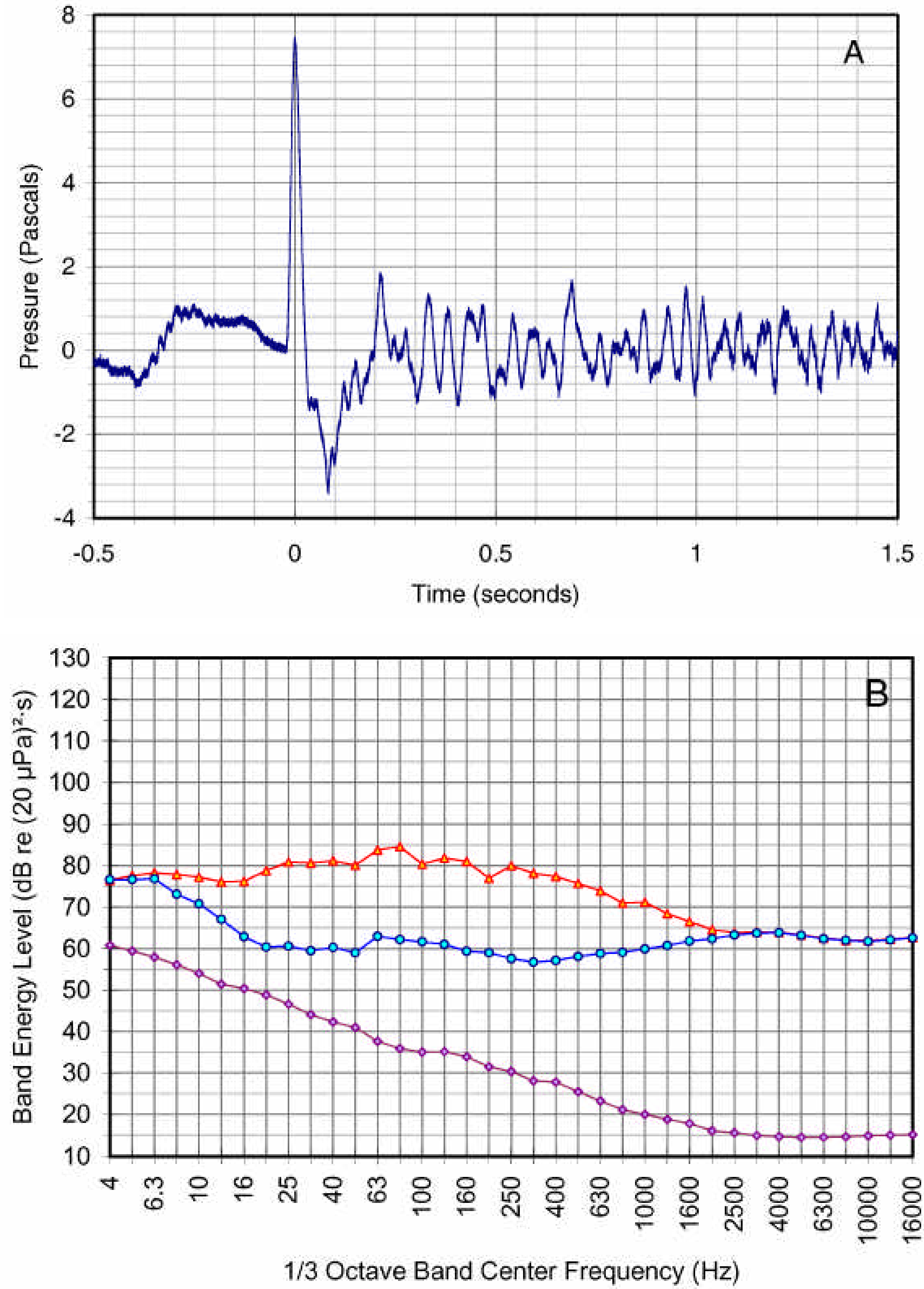
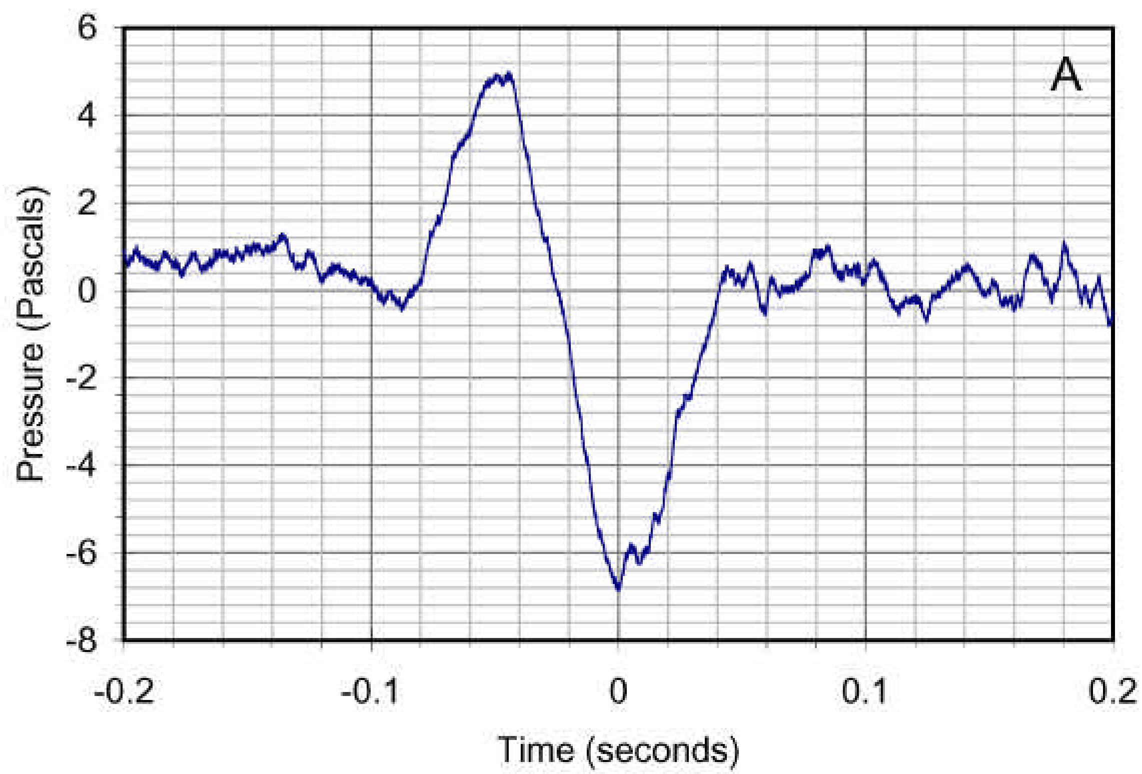


FIGURE 2.28. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 14:54:02 on 8 May 2002 recorded at site "Pirates Cove". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).



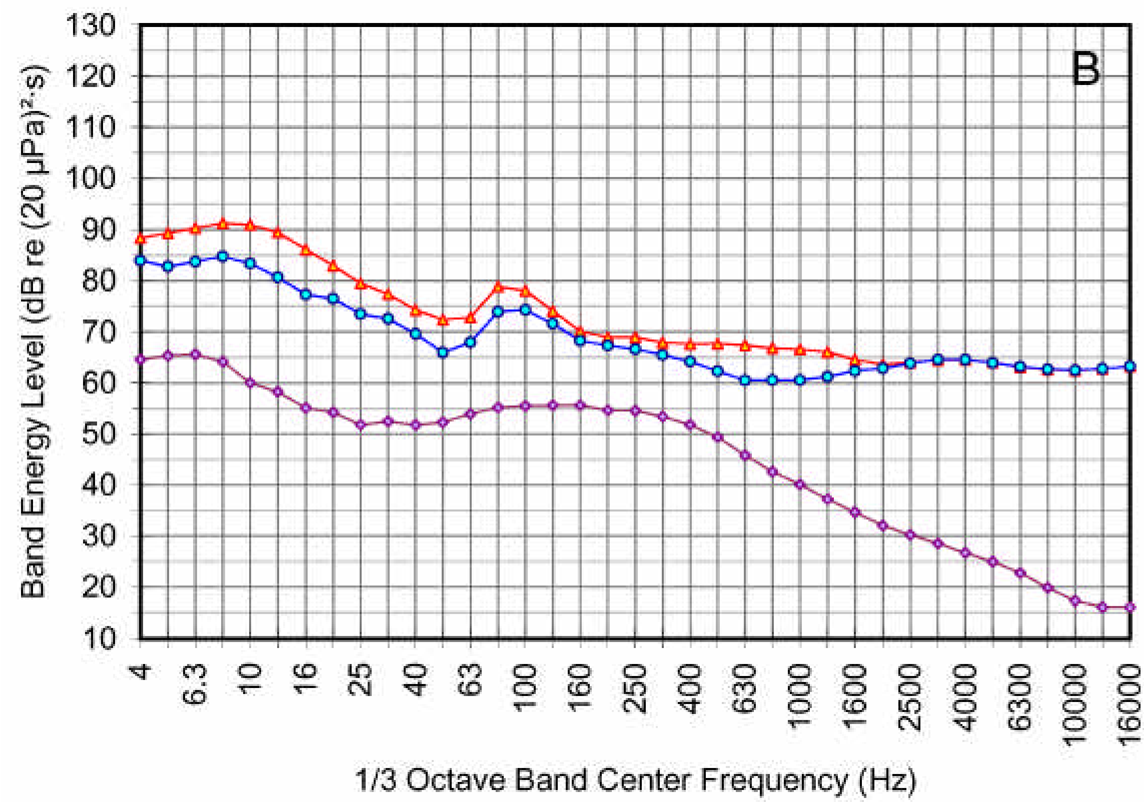


FIGURE 2.29. (**A**) Pressure waveform and (**B**) one-third octave band levels for an Advanced Gun System firing at 15:07:00 on 19 June 2002 recorded at site "Redeye II". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

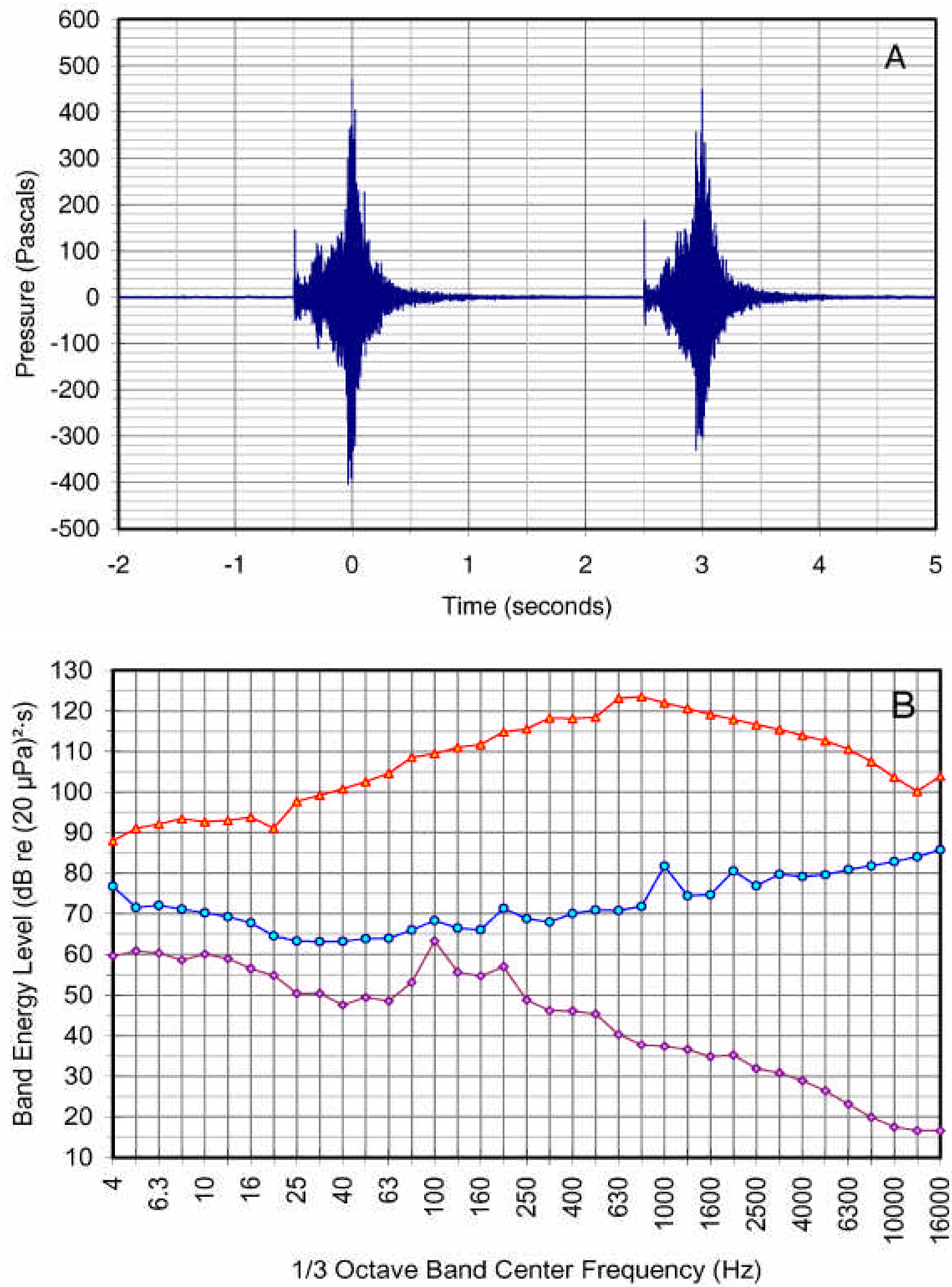


FIGURE 2.30. (**A**) Pressure waveform and (**B**) one-third octave band levels for two RAM firings at 12:53:12 and 12:53:15 on 21 June 2002 recorded at site "Launcher". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

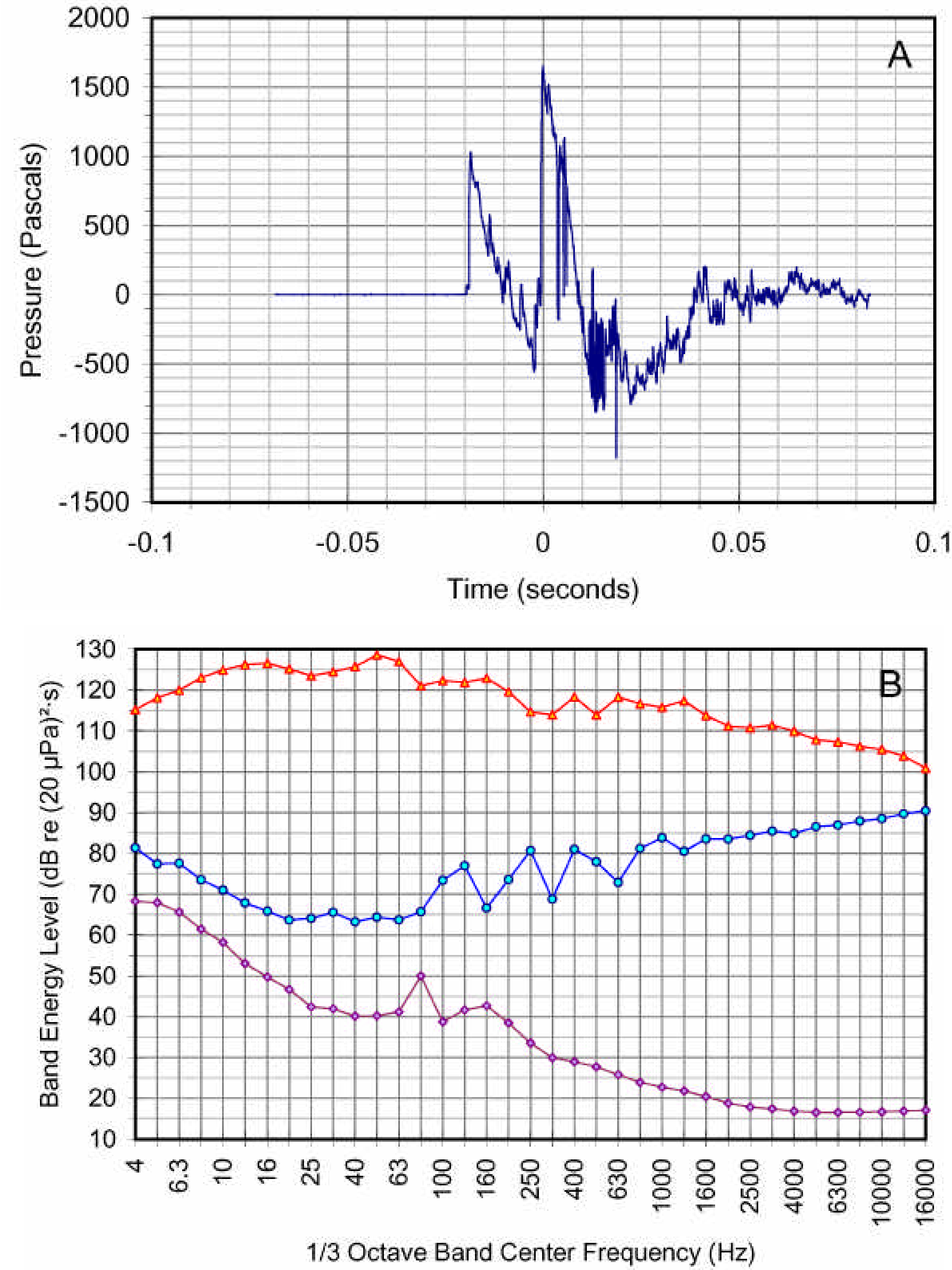


FIGURE 2.31. (**A**) Pressure waveform and (**B**) one-third octave band levels for an Advanced Gun System firing at 11:20:00 on 26 June 2002 recorded at site "Launcher". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

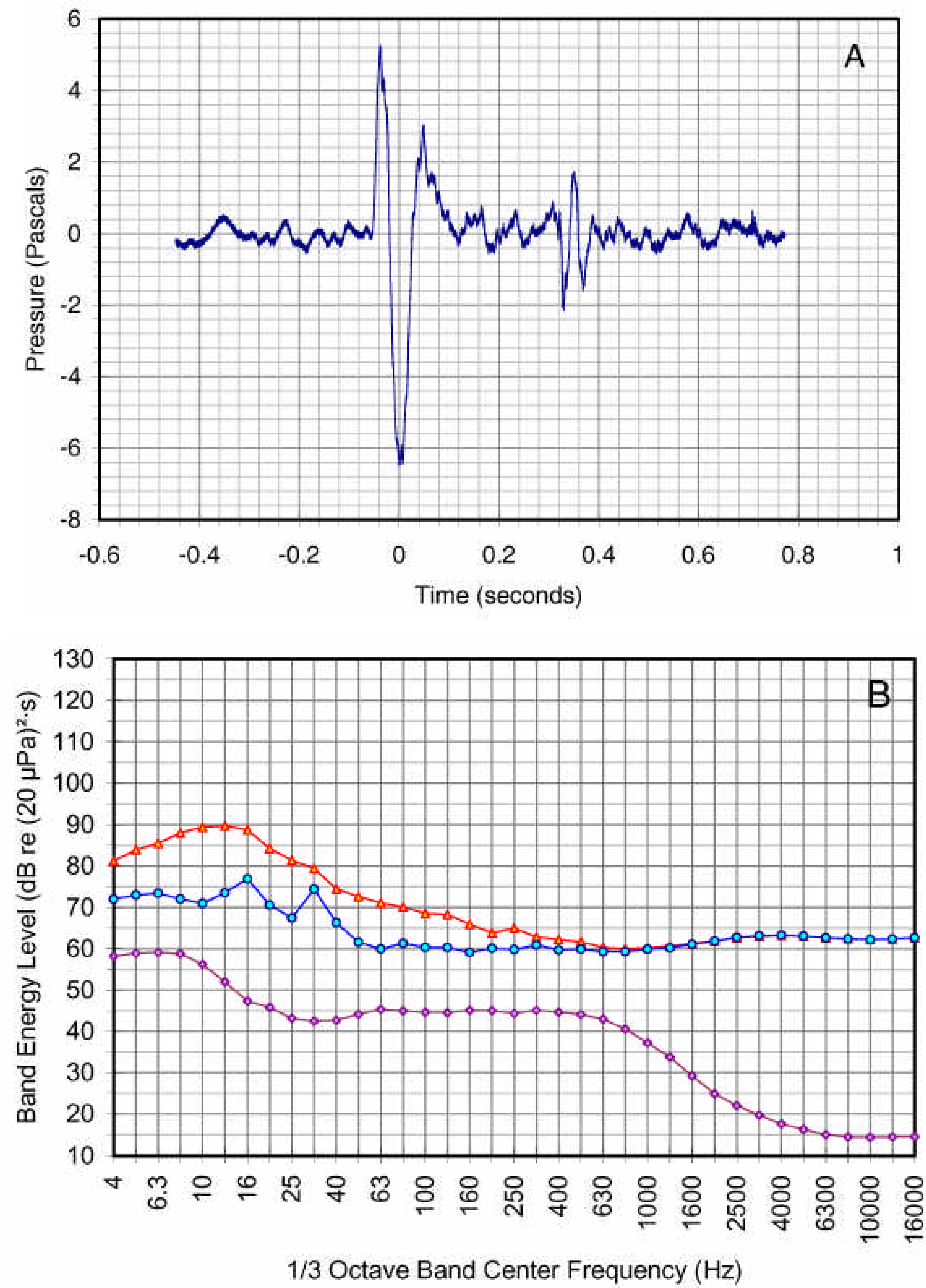


FIGURE 2.32. (**A**) Pressure waveform and (**B**) one-third octave band levels for an Advanced Gun System firing at 11:20:00 on 26 June 2002 recorded at site "Redeye Beach". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

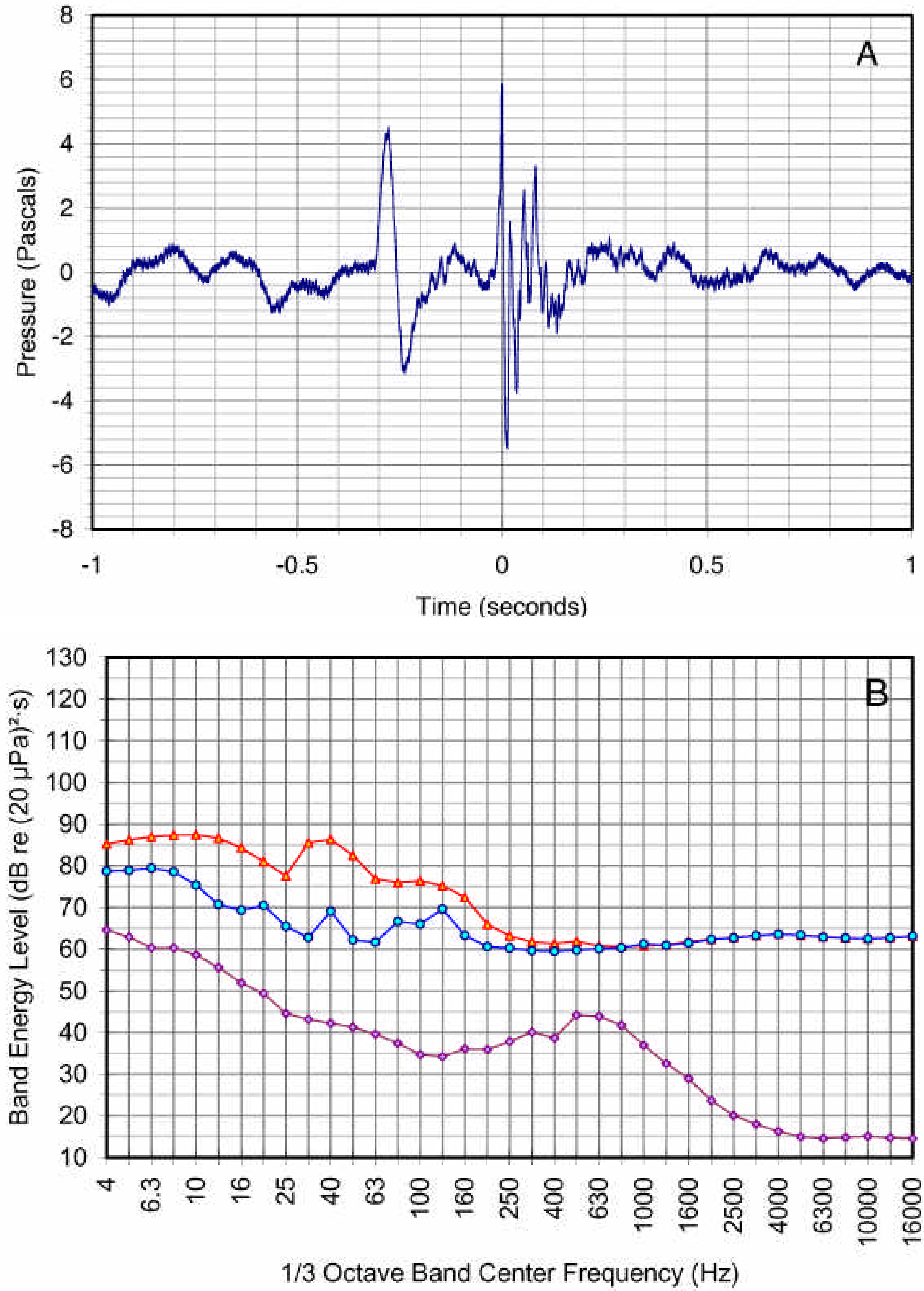


FIGURE 2.33. (**A**) Pressure waveform and (**B**) one-third octave band levels for an Advanced Gun System firing at 11:20:00 on 26 June 2002 recorded at site "809 Camera". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

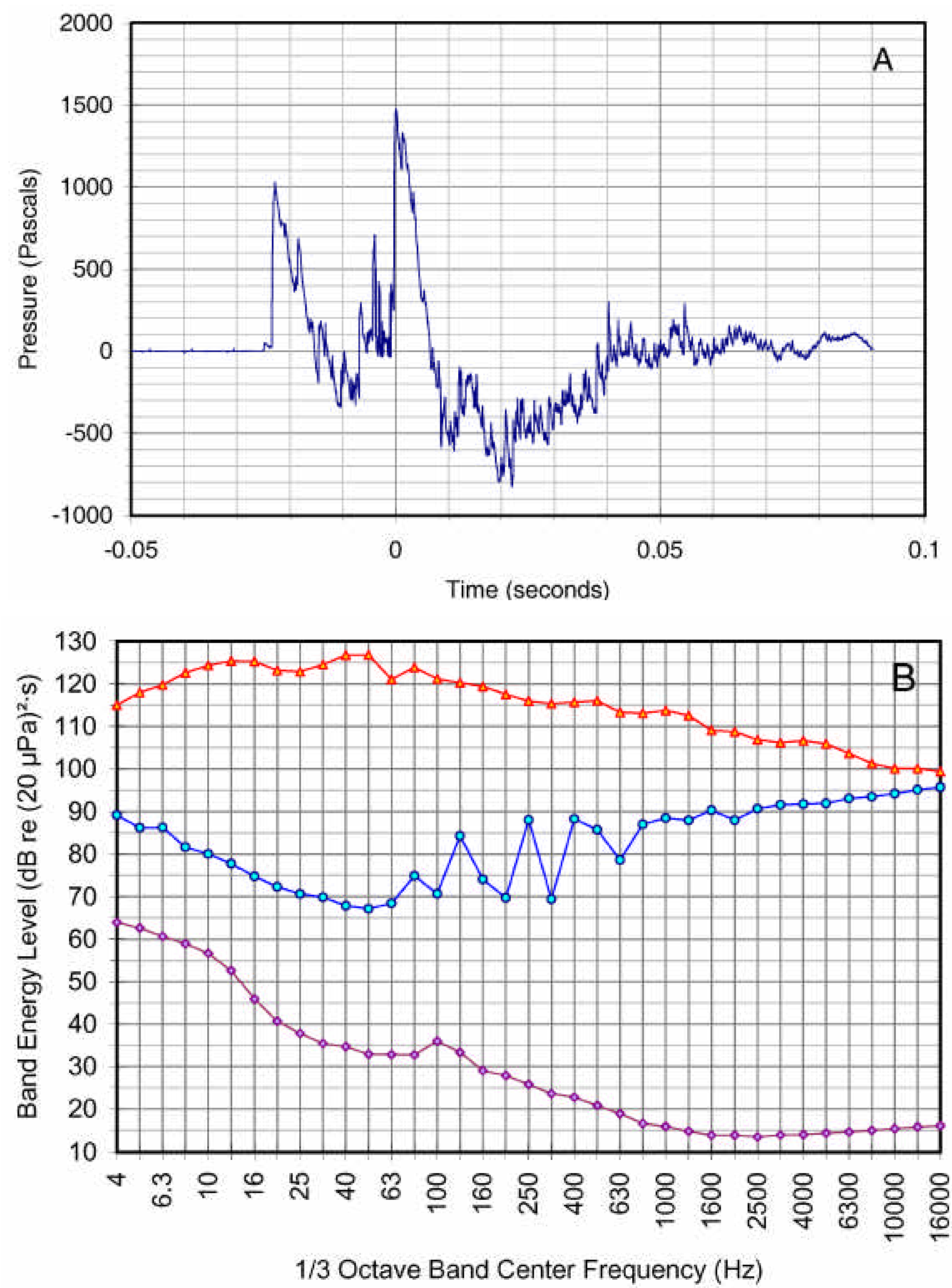


FIGURE 2.34. (**A**) Pressure waveform and (**B**) one-third octave band levels for an Advanced Gun System firing at 12:51:00 on 26 June 2002 recorded at site "Launcher". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

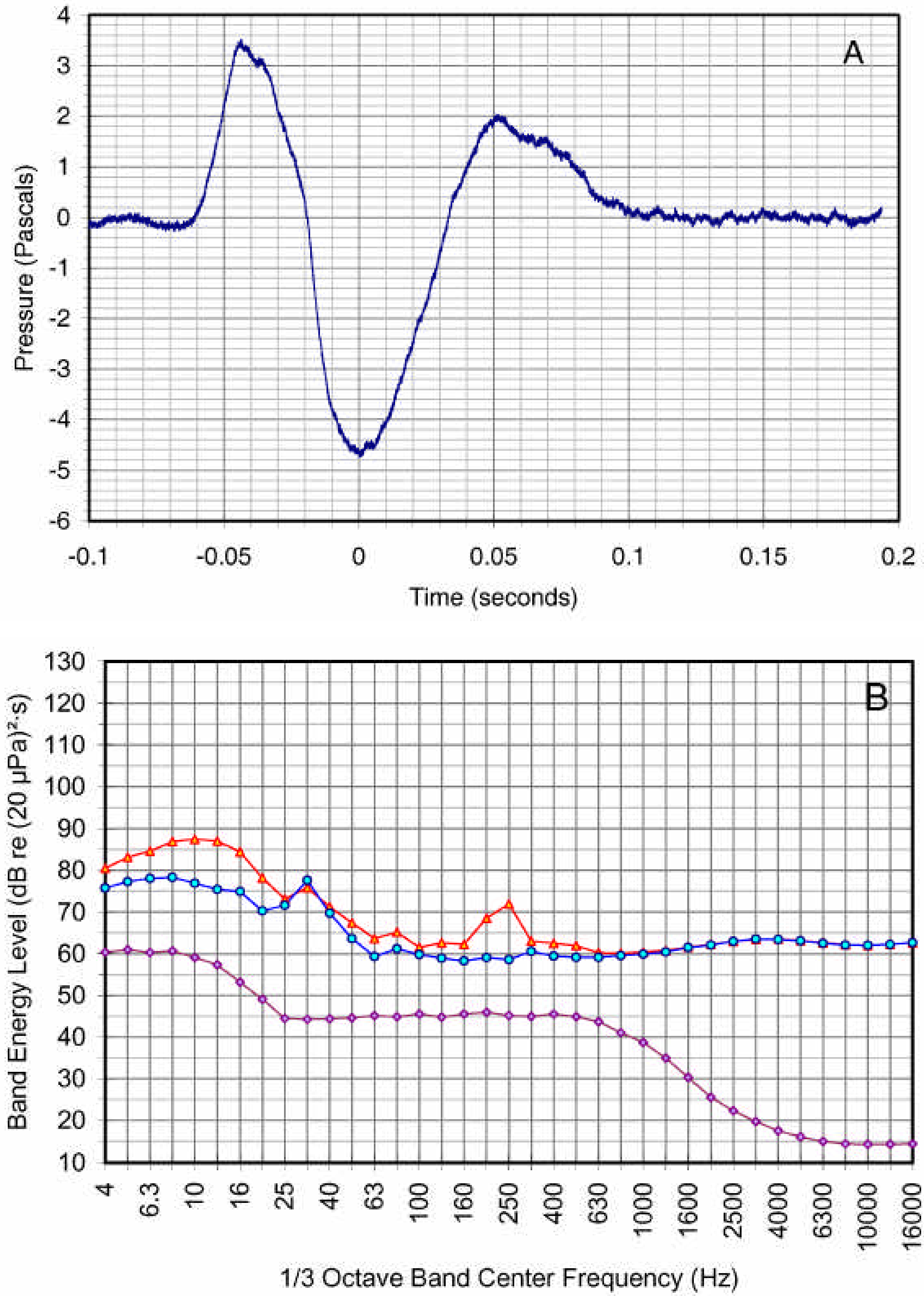


FIGURE 2.35. (**A**) Pressure waveform and (**B**) one-third octave band levels for an Advanced Gun System firing at 12:51:00 on 26 June 2002 recorded at site "Redeye Beach". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

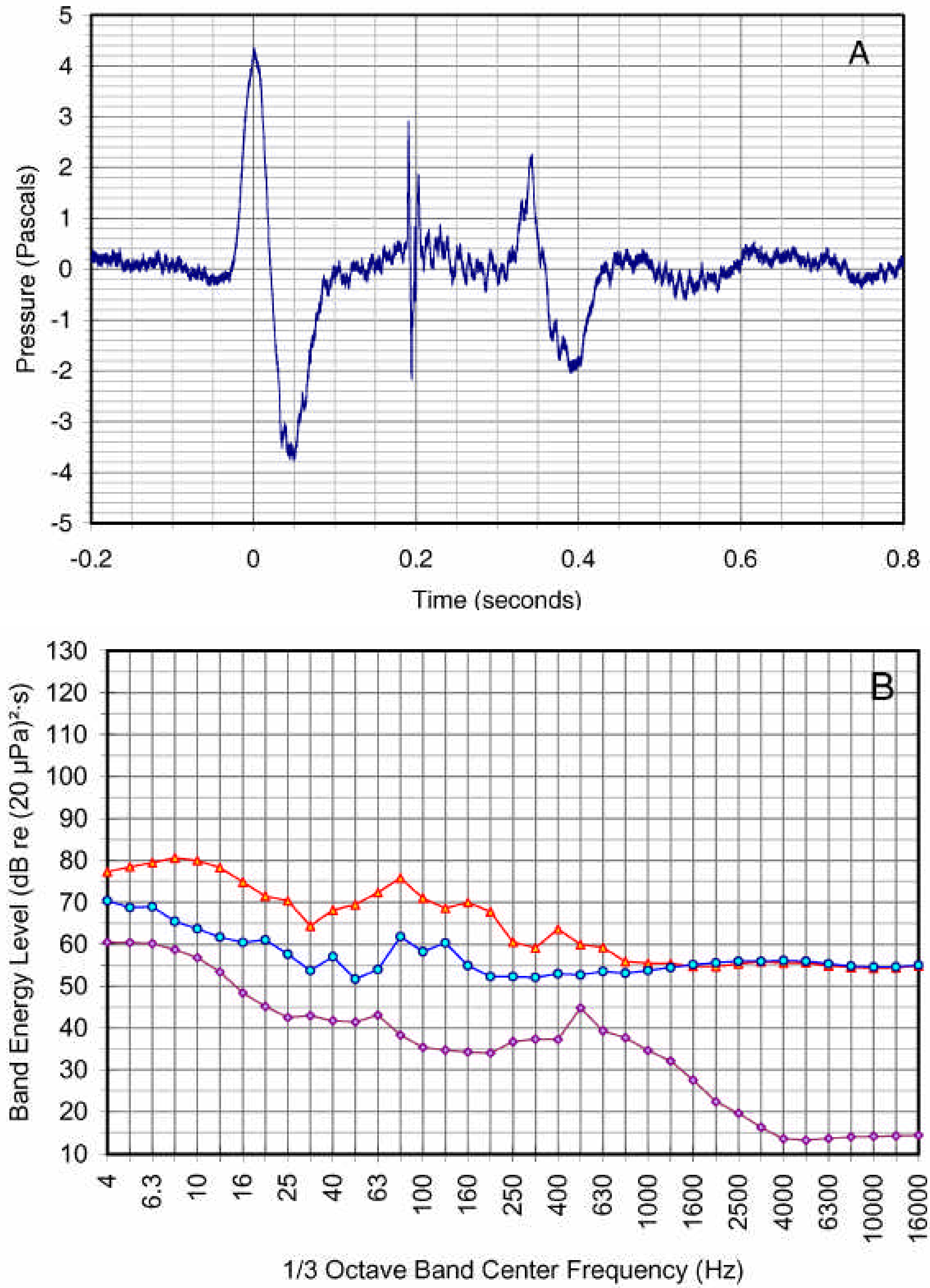


FIGURE 2.36. (**A**) Pressure waveform and (**B**) one-third octave band levels for an Advanced Gun System firing at 12:51:00 on 26 June 2002 recorded at site "809 Camera". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

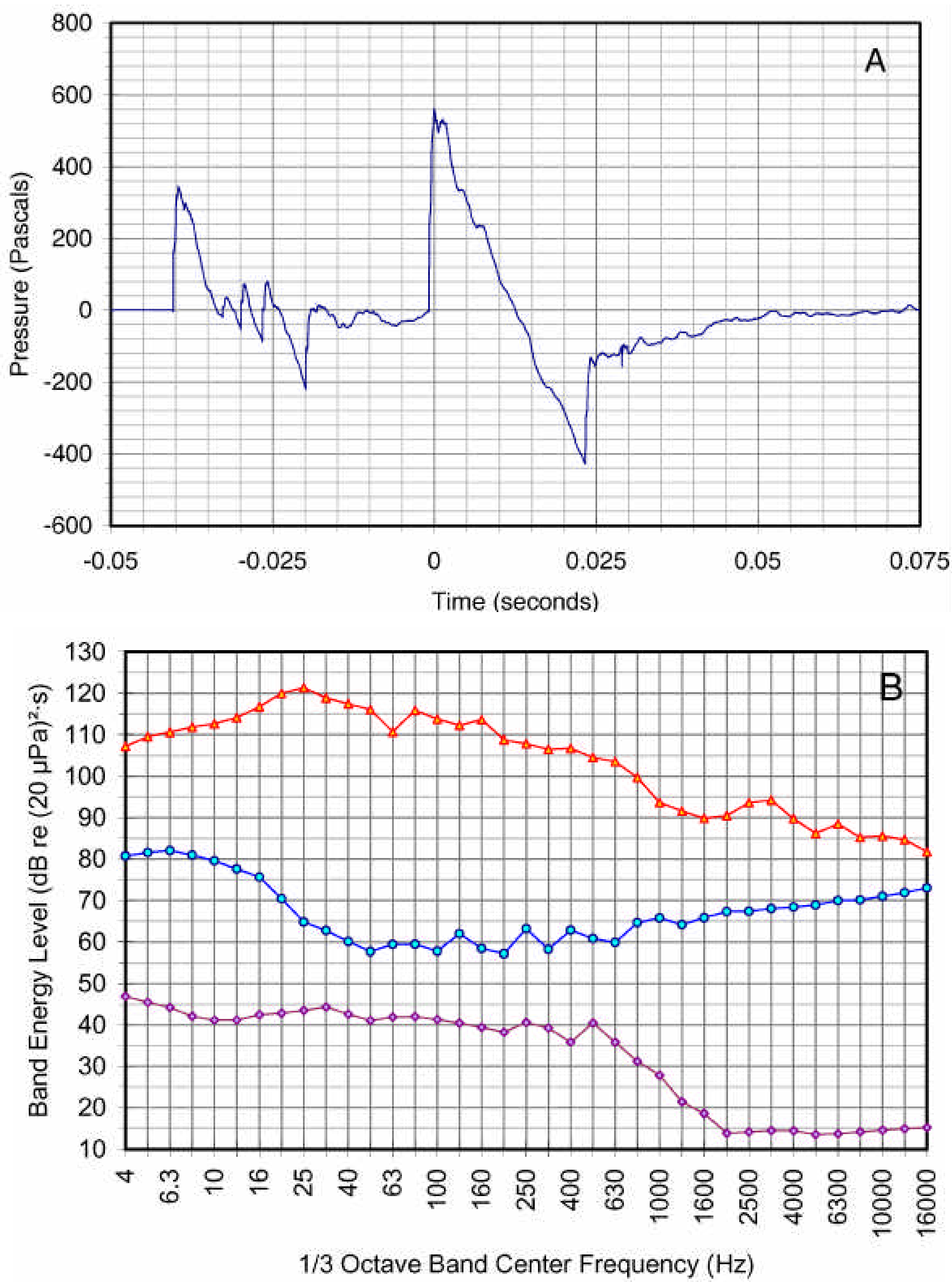


FIGURE 2.37. (**A**) Pressure waveform and (**B**) one-third octave band levels for a Vandal flight at 11:54:42 on 18 July 2002 recorded at site "Dos Coves". In (**B**), Δ = missile sound energy; O = instrumentation noise energy (low-gain channel); ◊ = ambient noise power (high-gain channel).

TABLE 2.5. Broadband (10-20,000 Hz) sound levels for each site as recorded by the high-sensitivity sensor designed to measure ambient sounds. See Figure 1.6 for maps of monitoring locations.

Date	Time	Vehicle	Site	Flat-Weighting (dB re 20 μPa)	A-Weighting (dBA re 20 μPa)
15 Aug. 01	12:55	Vandal	End of Redeye Road	60	44
"	12:55	Vandal	Dos Coves	52	35
"	12:55	Vandal	809 Camera	62	40
15 Aug. 01	13:16	Vandal	End of Redeye Road	61	43
"	13:16	Vandal	Dos Coves	53	36
"	13:16	Vandal	809 Camera	74	48
20 Sept. 01	08:29	Vandal	Tender Beach	65	55
"	08:29	Vandal	809 Camera	55	41
20 Sept. 01	17:00	Terrier	Building 807	59	42
"	17:00	Terrier	100 ft from Launcher‡	69	55
"	17:00	Terrier	Cormorant Rock Blind	59	38
5 Oct. 01	13:36	Vandal	Phoca Reef	48	43
19 Oct. 01	08:59	Vandal	Bachelor Beach South	51	41
"	08:59	Vandal	809 Camera	48	39
"	08:59	Vandal	NAVFAC Beach	32	21
19 Dec. 01	15:20	Vandal	Building 807	69	51
"	15:20	Vandal	809 Camera	69	48
14 Feb. 01	11:33:00	Vandal	150 ft from Launcher‡	34	29
"	11:33:00	Vandal	809 Camera	63	55
"	11:33:00	Vandal	Bachelor Beach North	59	45
22 Feb. 02	12:13:04	Vandal	809 Camera	55	36
"	12:13:04	Vandal	Redeye Beach	53	45
22 Feb. 02	14:56:22	Vandal	809 Camera	54	44
"	14:56:22	Vandal	Redeye Beach	52	44
6 Mar. 02	11:20:38	Vandal	Dos Coves	71	46
"	11:20:38	Vandal	Sheephead Ranch	45	29
"	11:20:38	Vandal	809 Camera	65	46
1 May 02	15:53:20	Vandal	Bachelor Beach South	80	68
1 May 02	17:00:23	Vandal	Bachelor Beach South	69	46
"	17:00:23	Vandal	809 Camera	76	49
8 May 02	14:54:02	Vandal	Vizcaino Point	66	40
"	14:54:02	Vandal	Sea Lion Cove	55	33
"	14:54:02	Vandal	Pirates Cove	57	33
19 June 02	15:07:00	AGS Test Slug	Redeye II	67	55
21 June 02	12:53:12	RAM	RAM Launcher at	68	52
26 June 02	11:20:00	AGS Test Slug	50 ft from Launcher‡	59	37
"	11:20:00	AGS Test Slug	Redeye Beach	59	48
"	11:20:00	AGS Test Slug	809 Camera	61	47
"	12:51:00	AGS Missile	50 ft from Launcher‡	57	29
"	12:51:00	AGS Missile	Redeye Beach	62	49
"	12:51:00	AGS Missile	809 Camera	59	45
18 July 02	11:54:42	Vandal	Dos Coves	54	42

‡ launcher at Alpha Launch Complex

in April 2002. As there were only two comparable (low-elevation) Vandal launches in the April-July 2002 period, there are too few recent data to warrant updating these estimates at the present time. The following discussion explains the procedure used and provides documentation for interpreting the results. The primary components of the analysis involved

- normalizing the data recorded at various sites around the island to estimate a standardized, average source spectrum for the sounds, and
- developing a spreadsheet-implemented transmission loss matrix that included both spreading loss and atmospheric absorption components.

The standardized missile noise source was characterized by a spectrum of 1/3-octave band levels referred to an acoustic pressure reference of 20 μPa, 1000 ft altitude, and USAF Standard Day meteorological conditions (15°C or 59°F, 70% rel. hum.). The procedure used to derive this source spectrum from the measured data is described in the next subsection.

The procedure used to estimate the received level contours involved several steps. The time durations (sec) of the pulses of launch sound received by the ATARs were analyzed to obtain a linear regression line relating 10 Log (Duration) to the estimated "closest distance" of the Vandal to the ATAR. The "closest distance" was the distance from the closest point of approach (CPA) on the flight trajectory along the sound transmission path to the ATAR, including allowance for the altitude of the Vandal above the beaches where ATARs and pinnipeds were located (Figure 2.38). The contour development process then consisted of combining a transmission loss matrix for various combinations of frequency vs. distance with the source level spectrum to obtain a series of received level spectra versus range. Each received level spectrum was then adjusted by applying an A-weighting function to account, in part, for the frequency response function (sensitivity) of pinniped hearing. The resulting A-weighted 1/3-octave values were then power-summed to obtain the overall level for a given range, and converted to the A-weighted sound exposure level (ASEL) by adding 10 Log10 T, where T is the typical pulse time duration (sec) for that range. The resulting table provided a convenient method of finding the ranges where ASEL levels were 120, 110, 100, and 90 dB re 20 μPa^2-sec (see Table 2.6).

To map the typical isopleths for 120, 110, 100 and 90 dB ASEL, the geometry of the missile flight path during a launch at 8º elevation and azimuth 270º was incorporated into a plotting program to produce the required results (Figure 2.39). The contours produced by the program take account of the changing altitude of the missile relative to sea level as the missile flies along the representative flight profile shown in Figure 2.38. The calculated isopleths have ***not*** been corrected for terrain shadowing or for terrain elevation. Thus, the contours are expected to underestimate received levels at terrestrial locations that are well above sea level, but are realistic for beach locations used by pinnipeds. Shadowing effects are expected to result in somewhat lower average ASEL levels at some pinniped locations than are estimated in Figure 2.39. Also, it is emphasized that these are estimates of ***typical*** received levels at sea level for various locations on the western part of the island based on the available measurements from August 2001 – March 2002. As expected given the day-to-day variations in weather, the measurements show considerable day-to-day variability in received levels at any given location.

The following subsections provide additional details concerning the procedures used.

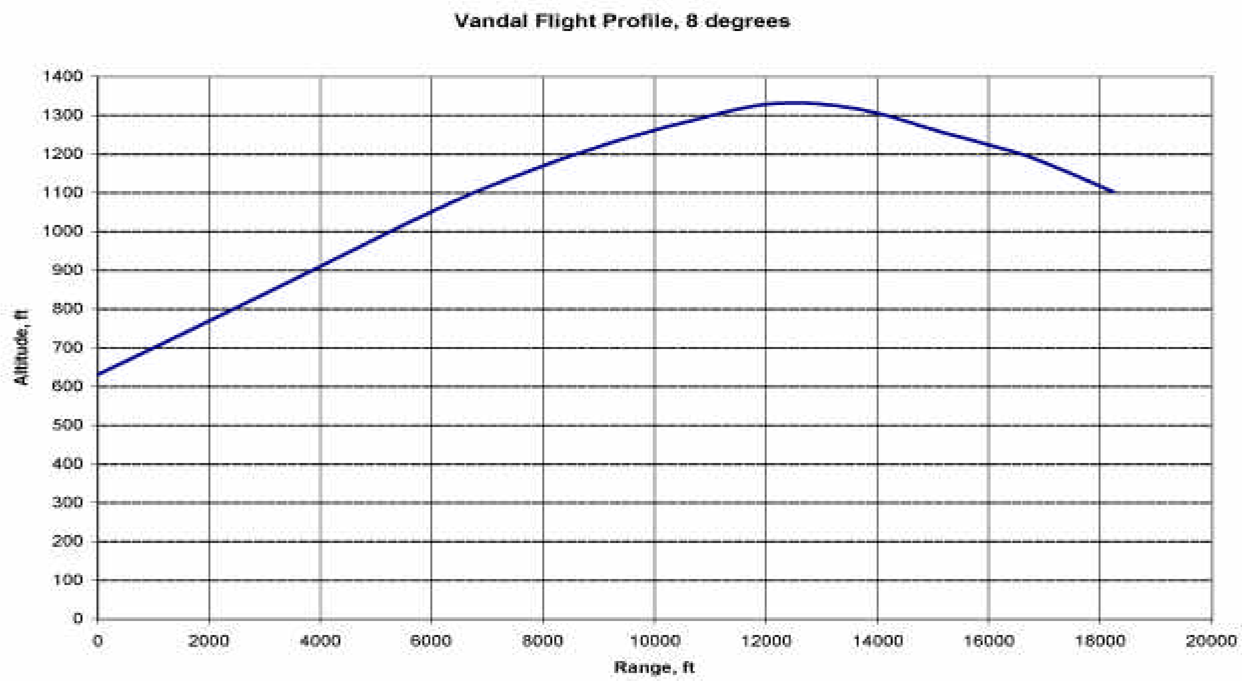


FIGURE 2.38. Vandal flight profile for 8° launch angle from Alpha Launch Complex (625 ft above sea level) on San Nicolas Island.

TABLE 2.6. Estimated slant range (in feet) to locations with various ASEL values, as estimated from the present measurements and earlier (1998) results.

ASEL (dB re 20 µPa^2-sec)	2002 Results (ft)	1998 Results (ft)
120	800	890
110	1,800	4,000
100	4,500	14,000
90	12,500	40,000

2.5.2 Analysis to Derive a Standardized Source Spectrum

The received level spectra were obtained at various ranges from the missile launch pad and missile flight path as described in Section 2.4. Figure 2.40 shows representative spectra from the measurements, normalized to values expected at a standard distance. In order to normalize these received level spectra to a reference range to permit comparison and averaging, the 1000-ft reference range used by the USAF was selected as more appropriate than the 1-m reference used in underwater acoustics. This also minimizes absorption loss errors that occur when spectra are range-adjusted with imprecise information about humidity and temperature at the times and locations of the measurements. The temperature and humidity data reported for the island were generally similar to the "Standard Day" conditions used by the USAF in reporting aircraft radiated noise spectra, so these values of 15°C (59°F) and 70% relative humidity were used.

The source location was assumed to lie along the missile path at the CPA point relative to a given receiver site. The actual source point along the path would be at the Mach angle with the path to the receiving site if a shock wave were the dominant source. Data on missile speed versus distance along the track were not available; moreover, the missile may have been subsonic for some of the sites. Hence, the CPA assumption was used as a standard for all data. Any resulting range error caused by the difference between a right angle and the correct sound radiation angle for a sonic boom is expected to not greatly affect the analysis results.

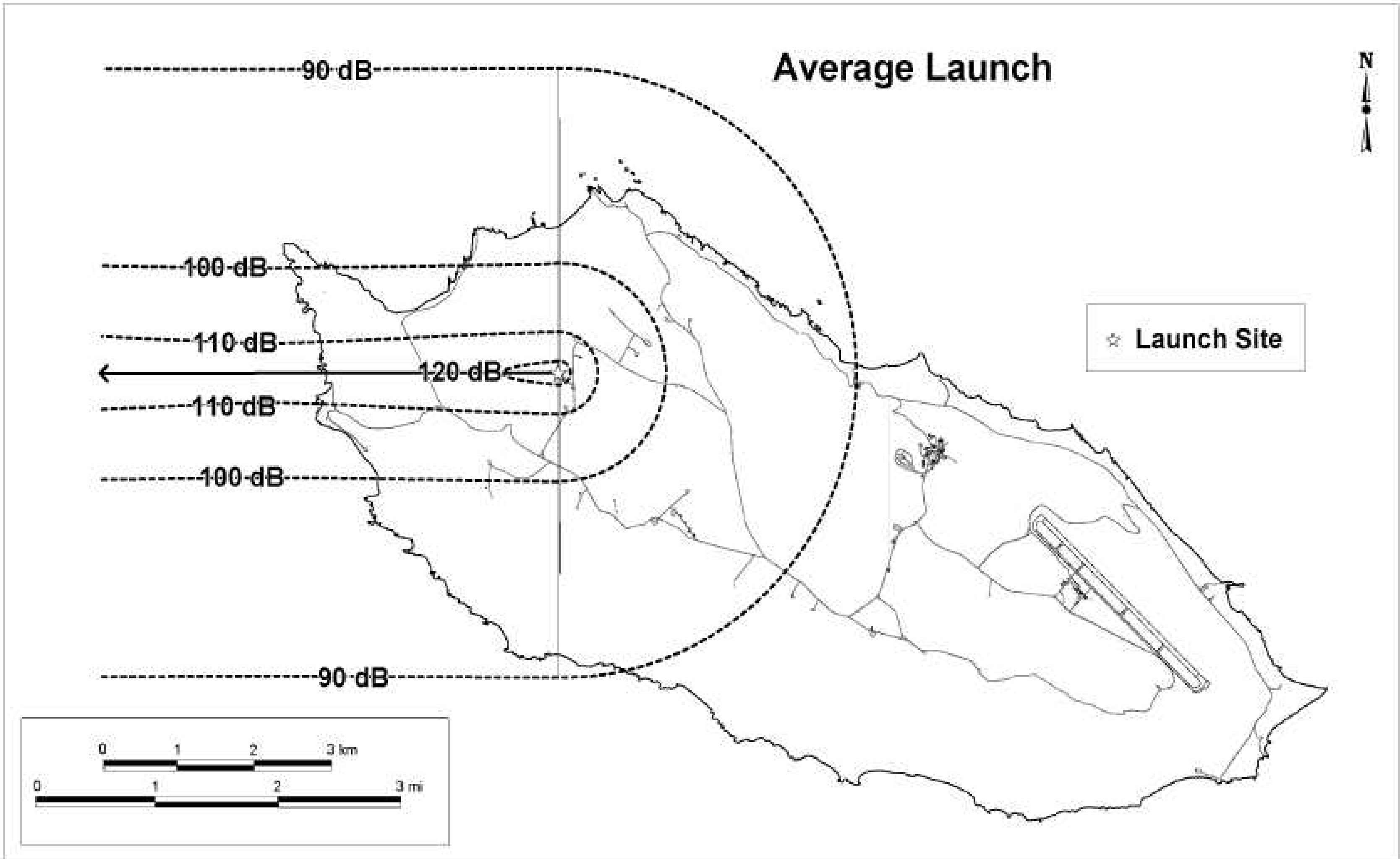


FIGURE 2.39. ASEL noise level contours at sea level for average Vandal launch conditions at 8° launch angle and azimuth 270°, August 2001 – March 2002.

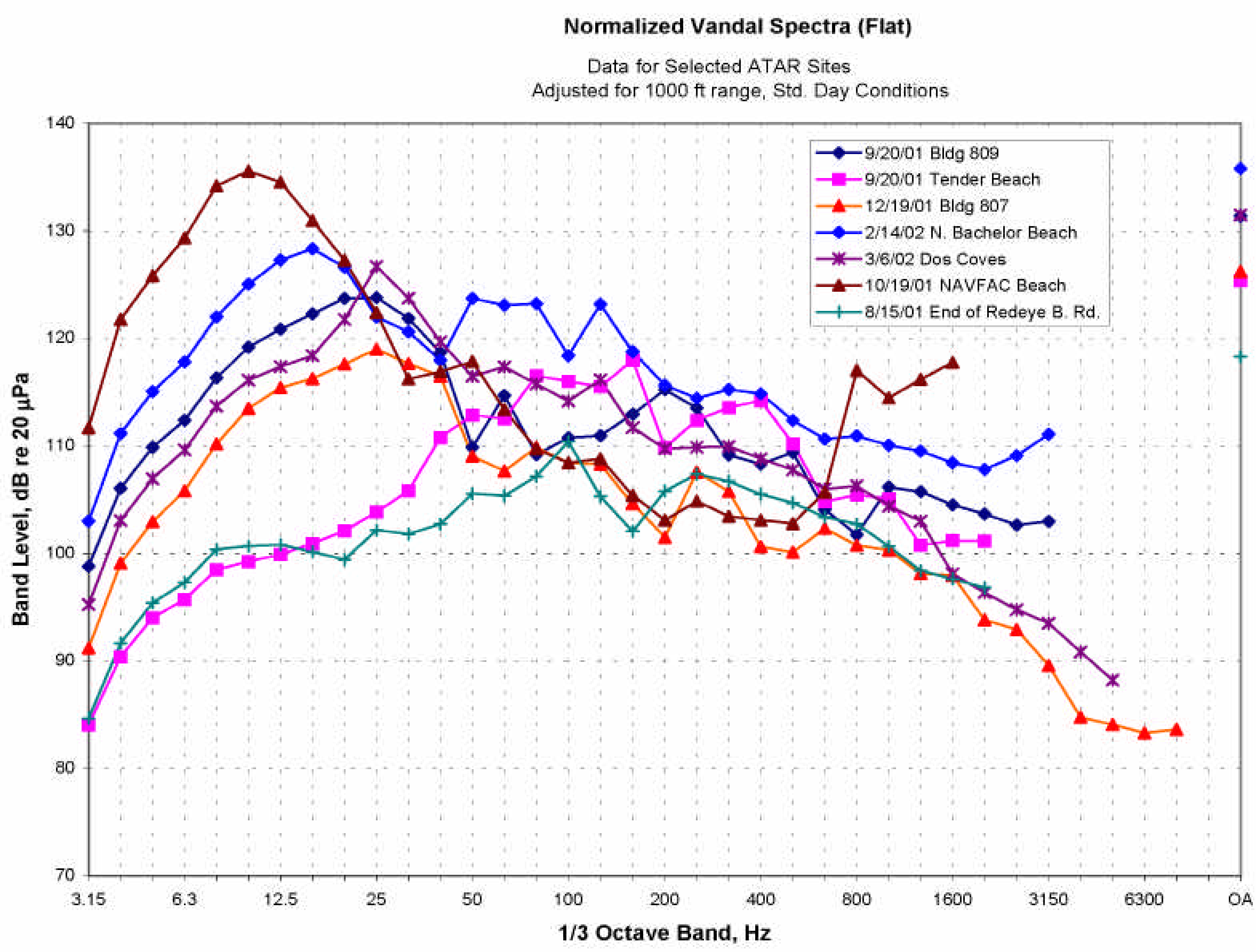


FIGURE 2.40. Representative Vandal launch noise spectra, August 2001 – March 2002. OA means overall level, all frequencies.

The Vandal is initially launched by a rocket booster that brings it up to supersonic speed, at which time the ram jet engine can take over. The missile launches thus involve three types of noise, which are concurrent during the early stages of supersonic flight moments after launch: booster noise, ram jet noise, and sonic boom (shock wave). The recorded data show both shock wave and subsonic rocket noise components in the missile acoustic signature, depending on the range and aspect to the measurement site. Detailed data on the noise contribution from the two stages of the propulsion system versus distance from the launch point were not available. As a result, the radiated noise spectra derived by the Greeneridge analysis (Section 2.4) included all components of the missile noise signature. Since it was likely that the source characteristics were changing as the missile flew over the island, an attempt was made to minimize this effect by separating the data according to the measurement site relative to the missile track geometry. Six sites near the west end of the island were selected as probably receiving noise from both rocket and ramjet engines as well as any sonic boom component that may have been produced. Statistical analyses of the overall A-weighted levels for these sites were compared with analyses of the overall levels for all of the sites to insure that no significant bias resulted from this selection. The results showed that the mean value for the selected group was the same as the mean for the entire dataset, but the total data range and variability had been reduced by a factor of 2 for the selected set. The standard error for the entire data set was 2.1 dB and the standard error for the group of six sites was 2.3 dB[4].

2.5.3 Analysis of Pulse Time Duration

Another source of variability in the ASEL values is the variability of the noise pulse duration. This is significantly affected by the interaction between the sonic boom (N wave) and rocket noise, which may persist for a much longer period. Analysis of the time duration data showed instances of less than 0.1 sec duration at some sites but durations >1 sec at other sites at comparable ranges. Normal shock wave propagation results in the pulses increasing in duration as they travel through the atmosphere, since their high frequencies are absorbed more rapidly. It was necessary to neglect some of the short duration data to obtain a linear prediction of duration increase with range as shown in Figure 2.41.[5] The alternative of using the measured data would have resulted in multiple contour predictions for the same ASEL value. Moreover, it would not permit spreadsheet analysis for the required ASEL values. The standard error that resulted from the regression fit of the selected data was 2.2 dB. Since the standard error of the mean of the overall A-weighted sound level spectra is independent of the mean of the duration estimate, the resulting standard error of the ASEL estimate is the sum of the two or 4.5 dB.

2.5.4 Vandal Noise Measurement Variability

The six selected 1/3-octave spectra were power averaged to obtain a composite source spectrum. For each of the individual 1/3 octave bands, the six estimates of signal power at range 1000 ft were averaged; this resulted an estimated average source spectrum for that distance. This source spectrum was compared with the source spectrum used in a previous (1998) contour analysis (Figure 2.42). The overall

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[4] The standard error is a measure of the error that may occur if the mean of a sample is used as an estimate of the mean of the entire population. In this application it is used as an estimate of the bias that may occur by using the mean of the sample of 6 spectra to represent the mean of the entire dataset that is in itself a sample of all possible observations. 2.1 dB for the overall dataset compared with 2.3 dB for the sample of six sites seems acceptable.

[5] Linear relationship was derived by least-squares regression. This is a method of fitting a straight line to a set of data points so that the sum of the squares of the differences between the data points and the points predicted by the line is a minimum.

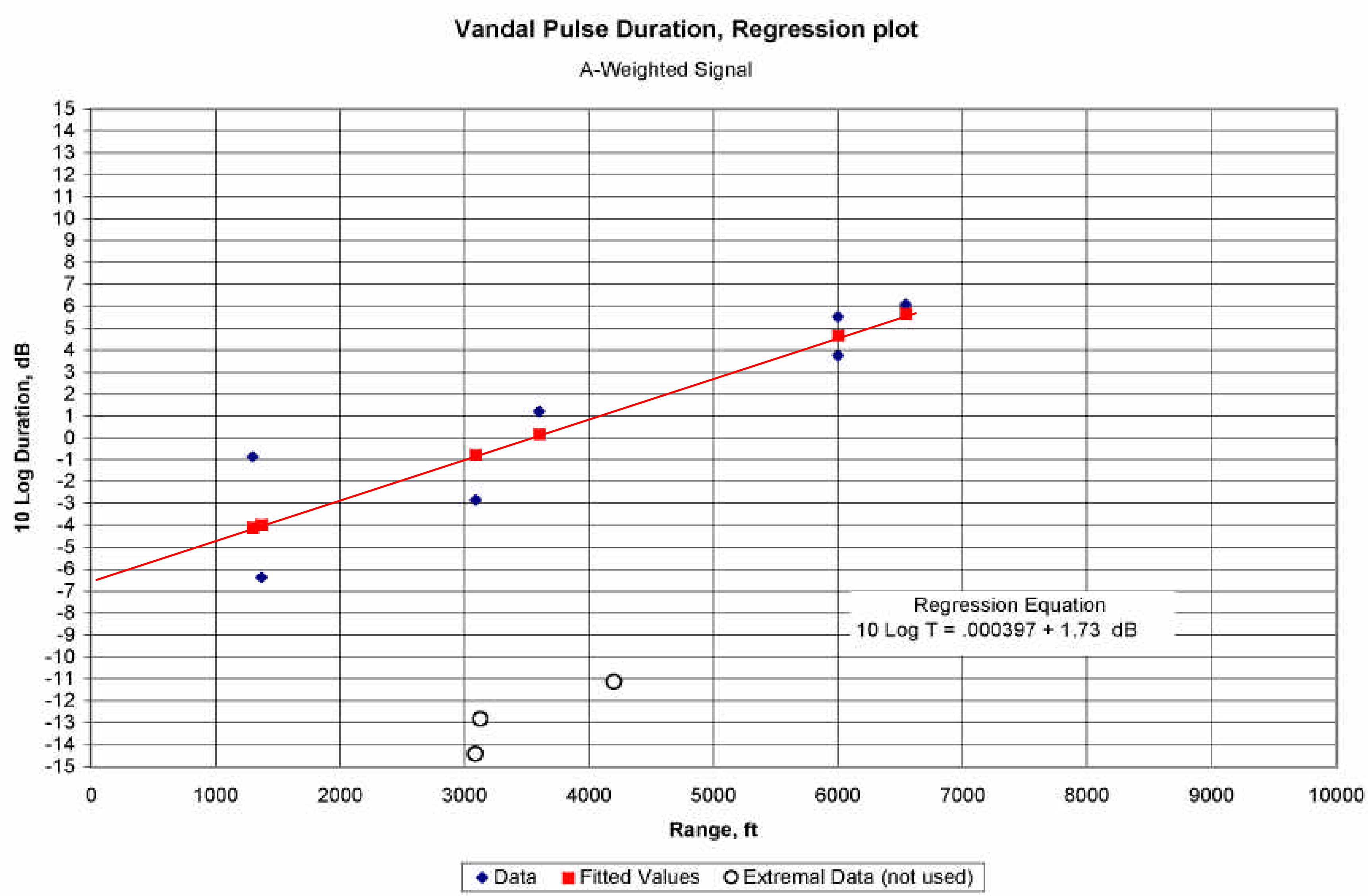

FIGURE 2.41. Pulse duration analysis for Vandal launch noise, with best-fit values for 10 Log (T), A-weighted signal.

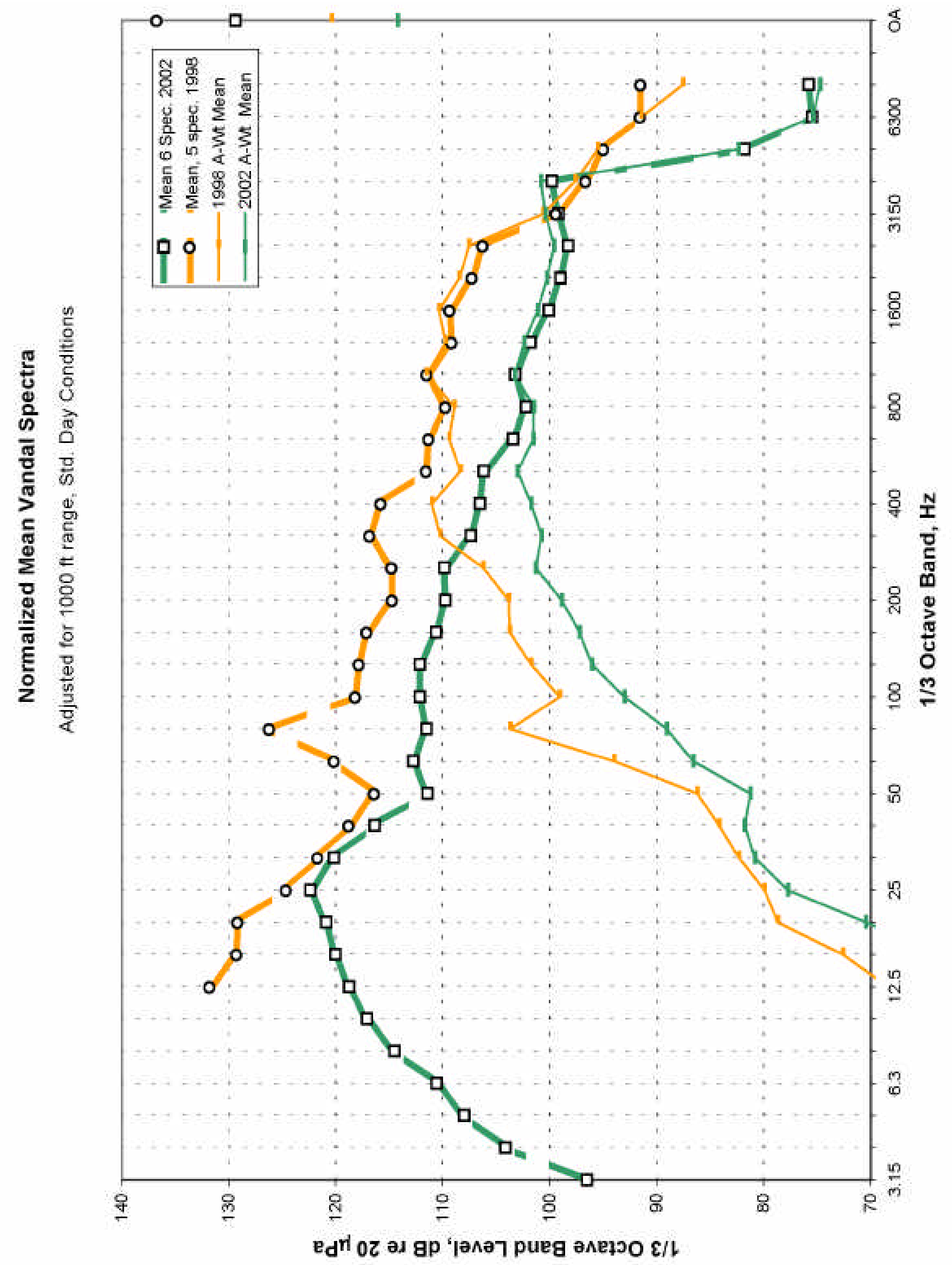

FIGURE 2.42. Mean Vandal launch noise spectra used for contour calculation, 1998 and 2002. Both the unweighted spectra and the A-weighted spectra are shown. OA means overall level, all frequencies.

A-weighted average levels, based on the 2001-2002 data, were found to be about 6 dB lower than those estimated in 1998 (114 dB vs. 120 dB). This lower level is probably the result of variability in the measured data. The propagation conditions are the main suspect since outdoor sound propagation is highly dependent on wind and temperature gradients. These can easily produce fluctuations of 10 to 20 dB over ranges shorter than those involved in the measurements reported here.

Two of the reported measurements demonstrate that repeatable received level data can be obtained when propagation conditions are stable. On 15 August 2001, two Vandals were launched 20 min apart at noon. The noise from these launches, as recorded at a site at the end of Redeye Road, gave overall A-weighted levels of 110.0 and 110.5 dB. These data may be compared with data for the 809 Camera site (near Redeye Beach) obtained on different days (20 Sept. 2001, 19 Dec. 2001, 14 February 2002) with likely different propagation conditions. The overall A-weighted levels for these measurements were 116.7, 118.6, and 104.6 dB, respectively. For the seemingly-anomalous 14 February 2002 case, wind speed was quoted as 4-7 mph from the northwest. An adverse wind gradient may have caused the low level seen on that day.

2.6 Discussion and Summary

The measured sound levels compare well with the range of sound levels reported in 1998 (Burgess and Greene 1998) for Vandal flights at San Nicolas Island. Two Vandal launches in 1997 resulted in flat-weighted SPLs ranging from 96 to 141 dB re 20 µPa at five sites. That range compares with 90 to 142 dB for the Vandal SPLs for 2001-02 (Table 2.3). The Terrier Orion SPLs in Table 2.3 ranged from 89 to 138 dB, although the latter high pressure appears anomalous. A number of the ATARs overloaded during launches due to incorrect gain settings. However, there is no reason to believe that the average received level at overloaded ATARs was greater than that for non-overloaded ATARs, as the problem was an incorrect gain setting rather than the level of the received signals.

The sonic booms recorded during some Vandal flights were very short, on the order of 0.05 sec. However, the definition of duration as encompassing the time interval associated with receipt of 5 to 95% of cumulative energy effectively extends the duration because of the propulsion noise following the sonic boom. These longer times result in lower SPLs, because of the longer averaging of comparatively low-level sounds. There are actually two sound sources involved, the sonic boom and the rocket noise, and it is correct to separate them. The sonic boom durations have been selected to avoid extending them for rocket noise.

None of the sound pressures recorded at coastal locations approached 164 dB re 20 µPa on a pressure basis, or 145 dB re 20 µPa SEL. Those are the levels that have been assumed to be the lowest received levels at which a pinniped might experience TTS upon exposure to a single launch – see Table 1.2 of this report and Section 4.7.1.4 of Lawson et al. (1998). Some of the highest measured levels were obtained 50 ft from the Advanced Gun 'Test' System. However, this was located well inland, and levels of AGS sound received at coastal sites were quite low.

The measurements of Vandal launch noise obtained from August 2001 – March 2002 were used to estimate isopleths (contours) of A-weighted sound exposure level (ASEL) during Vandal launches from San Nicolas Island. The mapped isopleths are for the common launch condition of 8º elevation angle and 270º launch azimuth. Areas that would, on average, receive launch sounds at ASEL levels of 120, 110, 100, and 90 dB re 20 μPa^2-sec during such a launch were mapped. The resulting estimates differ somewhat from those predicted in an earlier (1998) analysis. Distances to a given ASEL value are generally lower than previously estimated.

3. BEHAVIOR OF PINNIPEDS DURING MISSILE LAUNCHES[1]

3.1 Introduction

A total of 18 missiles and two slugs were launched by the U.S. Navy from the west end of San Nicolas Island, California, from 15 August 2001 to 18 July 2002. There were a total of 19 distinct launches on 14 different dates; one of the 19 launches was a dual launch of two small RAM missiles within 3 sec of one another. On five additional occasions, two separate launches occurred on the same day at longer intervals. Specific information about each of the launches is given in Chapter 1, and Chapter 2 documents the sounds measured at various sites on western San Nicolas Island during each launch. This chapter documents the behavioral reactions of pinnipeds exposed to the launch sounds.

Three species of pinnipeds are common on the beaches of San Nicolas Island: the California sea lion *Zalophus californianus*, the harbor seal *Phoca vitulina*, and the northern elephant seal *Mirounga angustirostris*. No other species were recorded during the present monitoring work. There were relatively few pinnipeds ashore during launches in August–December 2001. All missiles flew high over haul-out sites occupied by non-breeding California sea lions and harbor seals. A small number of northern elephant seals were also observed at a haul-out site monitored during these launches. In February–March 2002, missiles flew high over haul-out sites occupied by breeding/pupping harbor seals and northern elephant seals. Non-breeding California sea lions were also observed at haul-out sites during these launches. From May–July 2002, missiles flew high over haul-out sites occupied by molting harbor and elephant seals, as well as breeding/pupping California sea lions.

No evidence of injury or mortality was observed on the day of any launch. However, one or two dead pups (elephant seal pups and sea lion pups) were sometimes seen during follow-up monitoring the day after missiles were launched. However, these pups appeared to have died several days before the launches. Thus, the death of these pups was not attributed to missile launches.

In most cases, sea lion and elephant seal behavior returned to pre-launch states within minutes following the launches. In fact, northern elephant seals demonstrated little or no reaction to the missile launches. Harbor seals commonly left the haul-out sites during launches, and these seals generally did not return prior to the end of the videotaping periods. However, numbers on the haul-out sites usually had returned to pre-launch values by the time these sites were checked the following day.

Behavior as well as numbers of pinnipeds hauled-out the day following launches appeared similar to the behavior and numbers observed the day of the launch.

3.2 Field Methods

The launch monitoring program included remote video recordings. Observations were obtained before, during, and after each missile launch. Remote cameras were essential because, during missile 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 allowed observations of up to three pinniped species during the same launch, depending on how many species were hauled out within the presumed area of influence.

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[1] By **Meike Holst** and **John W. Lawson,** LGL Ltd., environmental research associates.

For this first year of combined pinniped and acoustic monitoring, the Navy attempted to obtain video and audio records from three locations at different distances from the flight path of the missile during each launch from San Nicolas Island. Video data were generally acquired via a permanent ("fixed") camera installation near Building 809 plus two additional cameras that could be set up temporarily at any site. During most launches, one monitoring location was near the planned launch azimuth or the launcher itself; other monitoring sites were some distance to the size of the launch azimuth. Figure 1.7 in Chapter 1 shows the monitoring locations relative to the launch azimuths. Although monitoring was limited to three locations during any one launches, the locations varied from launch to launch. Thus, over the year of monitoring work, the results provide data from a considerable variety of locations relative to the launch azimuth. This was important to ascertain the lateral extent of the disturbance effects and the "dose-response" relationship between sound levels and pinniped behavioral reactions. Due to problems with the acoustical equipment, and because audio and video equipment was not always deployed in a paired manner, paired video and audio data were obtained from less than three sites during most launches in the August 2001 to July 2002 period. Also, the species present at the various monitoring sites varied from launch to launch. Thus, for each species, the total number of observations of responses to launches was considerably less than three times the number of launches, especially when only the cases with simultaneous acoustic data are considered (Table 3.1).

Fixed Camera.—A permanent, fixed camera was installed in an elevated position near Building 809 at the west end of San Nicolas Island (Figure 1.7 in Chapter 1). This camera, designated "809 Camera", was situated on a wooden post overlooking a haul-out site (Figure 3.1). The camera could be remotely zoomed, tilted, and panned by an observer stationed in a remote blockhouse (Building 127). Digital video data from this camera were sent back to the blockhouse where they were viewed on a large video monitor and recorded on large-format digital videotape. Data from this camera could be recorded for any desired duration. This camera did not include a built-in microphone. However, an ATAR was deployed near the base of the camera pole during most of the launches (Figure 1.7 in Chapter 1).

Mobile Cameras.—During the day of each launch, Navy personnel placed up to two portable Sony Hi-8 digital video cameras on tripods that overlooked haul-out sites (Figure 1.7 in Chapter 1). Placement of the camera 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 the mobile cameras. The entire haul-out aggregation at a given site was not recorded, as the wide-angle view necessary to encompass an entire beach would not allow detailed behavioral analyses. It was more effective to obtain a higher-magnification view of a sample of the animals at the site. Missile and other sounds detected by the microphone built into these cameras were also recorded.

A ***Wagoncam*** (or ***Camera Cart***) was also used on several occasions (Figure 3.2). Wagoncams, unlike other portable video cameras, can transmit their 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 did not include a built-in microphone. During the day of each launch, Navy personnel placed up to two wagoncams that overlooked haul-out sites (Figure 1.7 in Chapter 1). 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 did not allow detailed behavioral analyses.

Visual Observations.—Navy personnel from the Environmental Project Office, Point Mugu, made direct visual observations of the pinniped groups prior to deployment of the cameras and ATARs.

TABLE 3.1. Video data collected for harbor seals, California Sea Lions, and northern elephant seals during missile launches at San Nicolas Island, August 2001 – July 2002. The five dates when two launches occurred minutes or hours apart are indicated by “´2”. A dual launch, consisting of two missiles launched within seconds of each other, occurred on 21 June 2002.

Video Recording Location	Launch Date													
	15 Aug (´2)	20 Sep (´2)	5 Oct	19 Oct	19 Dec	14 Feb	22 Feb (´2)	6 Mar	1 May (´2)	8 May	19 June	21 June “x2”	26 June (x2)	18 July
California Sea Lion														
809 Camera	×	×	×	×	×			×	×	×	×		×	
Bachelor Beach North												×		
Dos Coves North	×	×												×
Dos Coves South	×	×										×		
Redeye Beach													×	
Sea Lion Cove		×								×				
Vizcaino Point			×	×										
Harbor Seal														
809 Camera	×	×	×					×						
Phoca Reef			×											
Pirates Cove								×	×	×				
Redeye Beach								×		×			×	
Sea Lion Cove										×				
Northern Elephant Seal														
Bachelor Beach North		×				×	×					×		
Bachelor Beach South		×		×										
Pirates Cove									×	×				
Redeye Beach						×								
Redeye I											×			
Sea Lion Cove										×				

Note: Some video data were lost or could not be analyzed due to technical problems. 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 three occasions (19 Dec. 2001, 22 Feb. 2002, and 1 May 2002), cameras were set up at harbor seal haul-out sites, but no seals were seen during the launch.

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 observers returned to the monitoring sites during the hours following launches and the following day, to note the status of pinnipeds at the haul-out site (e.g., were there similar numbers of pinnipeds? Was there obvious evidence of recent injury or mortality?).

FIGURE 3.1. View of permanent fixed video camera atop a wooden post at 809 Camera. This camera can be remotely zoomed, tilted, and panned. Digital data from this camera were sent back to a distant blockhouse where they were recorded on large-format digital videotape. An ATAR was deployed near the base of the camera pole during most launches. (Photograph by J. Lawson, LGL.)

FIGURE 3.2. 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)

3.3 Video and Data Analysis

Digital video data were copied to DVD-ROMs to facilitate transport and playback. Video records were then transferred from the Navy to LGL Ltd., environmental research associates, for analysis.

Subsequent to the launch, experienced biologists 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.

Observations of pinnipeds were made based on two 1-min samples of each video recording from the day of each launch. Data were recorded for the 1-min interval immediately preceding the launch and for a 1-min duration starting 10 min after the launch (i.e., from 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. Observations of pinnipeds were also made during a 1-min sample of each video recording the day after each launch (during follow-up monitoring). As the "follow-up" videos were not recorded at the same time as the launches on the previous day, the 1-min "follow-up" samples were taken as close as possible to the actual time of the launch on the previous day.

The variables transcribed from the videotapes include

1. composition of the focal subgroup of pinnipeds (numbers by sex and age class),
2. description and timing of disruptive event (missile 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.

In addition, the following variables concerning the circumstances of the observations were also recorded from the videotape or from direct observations at the site:

6. study location,
7. local time,
8. 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]),
9. substratum slope (0-15º, >15º, or irregular), estimated from the video records,
10. weather (including an estimate of wind strength and direction, and presence of precipitation; these data were made available by the Navy meteorological unit),

11. 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 furthest visible object was relative to the interacting pinnipeds, as evident from the known positions of local objects and accounting for obstructing terrain), and

12. tide state (the number of hours before or after peak flood tide; exact time for local high tide was determined from relevant tide tables).

3.4 Descriptions of Pinniped Behavior During Specific Launches

The following subsections provide overall descriptions of pinniped responses during each launch, descriptions of any notable reactions, and quantitative comparisons of pinniped behavior and distribution prior to and following the launches.

Video recordings of pinniped behavior during launches were collected for California sea lions on 12 dates, for harbor seals on seven dates, and for northern elephant seals on eight dates (Table 3.1). During each of these dates, sea lions were monitored at 1-3 different sites (total of 22 site–date combinations); incidental observations at a fourth site were made on one occasion. Harbor seals were monitored at 1-3 different sites (12 site–date combinations), and elephant seals were observed at 1 or 2 sites (11 site–date combinations); incidental observations of elephant seals at a third site were made on one occasion. 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 Double Vandal Launches, 15 August 2001

Two Vandals were launched within approximately 21 min of each other from the Alpha Launch Complex (Table 2.1 in Chapter 2). Both vehicles were launched with an azimuth of 270º and an elevation angle of 8º. The Vandals passed near Dos Coves, where recordings of California sea lions were made, and to the south of 809 Camera, where recordings of sea lions as well as harbor seals were made (Table 3.1; Figure 1.7A). In the case of the two mobile cameras that were used, concurrent recordings of audio data (such as pup calls and adult vocalizations) were also made using the cameras' microphones. For this and subsequent launches, these audio data were used during behavioral analyses, but were not of sufficient quality to provide launch sound information. Launch sound was recorded at the end of Redeye Road (Table 2.2 in Chapter 2; Figure 1.7A).

***Harbor Seals*.—**Prior to the launches (both the first and second), adult harbor seals were observed, via 809 Camera, resting on a rocky ledge just offshore of the beach on which the California sea lions were aggregated. Immediately following the launch, 66% of the adult harbor seals resting on an offshore rocky ledge fled into the water inshore of the haul-out group; they then went out into deeper waters. A number of the animals that left the ledge appeared to do so in response to other harbor seals swimming vigorously past their location, rather than to the sound or sight of the missile itself. In addition, the gulls and cormorants present in the water and on the haul-out sites in this area startled and fled their resting places just prior to the seals reacting – perhaps providing one of the stimuli that elicited the reactions by the pinnipeds. Within 5-7 min, most harbor seals that had remained at the haul-out site had settled back to their pre-launch activities (Table 3.2).

TABLE 3.2. Details of missile 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 of these missiles were launched from the Alpha Launch Complex. Times are local time. Sound was not recorded at all monitoring sites.

Launch Date	Launch Time	Missile Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	Sound Exposure Levels [dB re (20 µPa)^2·s] flat-weighted/A-weighted	Behavioral Reaction
15 Aug. 01	12:56	Vandal	270°	8° / 1,280 ft	809 Camera[n]	N/A	Most seals (66%) fled into the water; seals that had remained on beach settled within 5 min after the launch.
"	13:17	Vandal	270°	8° / 1,280 ft	"	N/A	Less reaction to second launch; only 40% fled into water.
20 Sep. 01	08:30	Vandal	270°	8° / 1,280 ft	809 Camera[n]	119/101	Most seals (75%) entered the water; the remaining seals settled a few minutes after the launch.
"	17:02	Terrier Orion	232.3°	64.6° / 13,000 ft	"	N/A	All seals entered water.
5 Oct. 01	13:37	Vandal	273.3°	8° / 1,300 ft	809 Camera[n]	N/A	Most seals (70%) entered water in response to launch; 10 min after launch, no seals were left on beach.
					Phoca Reef[e]	94/*	Less than 10% of seals entered water; most looked up but did not move in response to launch.
6 Mar. 02	11:20	Vandal	273.1°	8° / 1,300 ft	809 Camera[n]	121/106	Seals looked up or moved in response to launch but did not enter water; settled within minutes.
					Pirates Cove[e]	N/A	All seals entered water; seals started to return to beach 16 min after launch.
					Redeye Beach[n]	N/A	Most seals (98%) entered the water in response to launch, but some individuals took as long as 6 min to do so. Seals started to return to beach 13 min after launch.

TABLE 3.2. Continued.

Launch Date	Launch Time	Missile Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	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	Most of the seals were startled and looked up, but did not enter the water. Very few moved (14%) in reaction to the launch sound; those that did were pups.
"	17:00	Vandal	273°	42° / 9,600 ft	Pirates Cove[e]	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° / 1,300 ft	Pirates Cove[e]	96/67	All seals looked up and some moved slightly; 7% entered the water
					Redeye Beach[n]	N/A	All seals rushed into the water; they started hauling out again 13 min after the launch.
					Sea Lion Cove[s]	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]	96/62	Seals looked up, but did not move.
"	12:51	AGS Missile	300°	62.5° / 5,300 ft	Redeye Beach[n]	93/ 64	Seals looked up, but did not move.

Note: N/A means that sound exposure levels are not available for that location.
[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.

During the second launch on 15 August, only 40% of seals entered the water. Overall, there was seemingly less reaction to the vehicle overflight by the harbor seals, with most of those remaining after the first launch merely altering their positions on the rocks slightly. This may have been attributable either to their habituation to launch sounds that day, or to the fact that those adult harbor seals remaining after the first launch were less responsive to such stimuli than those that had departed the haul-out area earlier (or both).

***California Sea Lions*.**—Several California sea lions near 809 Camera (north of the launch track) left the beach to enter the water; two of these were pups. Prior to the first launch, many pups were playing near the water, or were playing in the shallow water near the beach. Approximately 30 of these pups in the water moved up onto the beach in response to the launch sounds. The adults lifted their heads and displayed increased vigilance at the time of the launch, and in response to the younger animals' vigorous movements along the beach margin. Within 5-7 min of both launches most of the sea lions, including the younger animals, had appeared to settle back to their pre-launch activities. Those that remained active were usually younger sea lions involved in group-play activity in the shallow waters near the shoreline; this type of activity had been occurring prior to the launches (Table 3.3).

During the second launch on 15 August, there was seemingly similar or less reaction to the vehicle overflight by sea lions near 809 Camera. Less than 5% of the adult and juvenile California sea lions flushed into the water. This may have been attributable to habituation to launch sounds that day, or to lower responsiveness by animals that remained relative to those that departed the haul-out area earlier.

Prior to both launches, sea lion pups at Dos Coves South were moving around on the beach. During the launches, adults lifted their heads but most did not move, whereas pups moved around on the beach. Only a few individuals (<10%) entered the water. Pups remained active for some time after the launch. Adults settled back to their pre-launch activities within a few minutes after the launch. Pups appeared more active prior to the second launch compared to the first launch.

Most individuals in the focal subgroup of animals at Dos Coves North startled during the launch and looked around. Few animals left the area right away, although groups of sea lions from other locations on that beach moved into the area. During the second launch, only four sea lions remained at the location; they sat up in response to the launch, but did not leave the area.

There was more vocal activity by sea lion mothers and pups immediately following the launches at each location, but this subsided within approximately 10 min.

***Follow-up Monitoring*.**—During follow-up monitoring the next day, harbor seals and California sea lions were once again hauled out at the same locations as on the previous day. There seemed to be a more harbor seals in the area than on the day of the launches. The distribution, numbers, and behavior patterns of California sea lions were similar to those during the pre-launch period. No injury or mortality attributable to the missile launches was observed.

3.4.2 Vandal and Terrier Orion Launches, 20 September 2001

A Vandal and a Terrier Orion were launched approximately 10.5 hr apart from the Alpha Launch Complex. The Vandal departed westward (azimuth 270º), passing near monitoring sites at Dos

TABLE 3.3. Details of missile 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 missiles 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	Missile Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	Sound Exposure Levels [dB re (20 μPa)^2·s] flat-weighted/A-weighted	Behavioral Reaction
15 Aug. 01	12:56	Vandal	270°	8° / 1,280 ft	809 Camera[n]	N/A	Most adults lifted their heads and were more vigilant; only a few animals entered the water. Pups in water rushed on shore. Animals settled within 5 min after launch.
					Dos Coves North and South[d]	N/A	Most adults lifted their heads, but did not move; only a few animals entered the water. Adults settled within minutes; pups stayed active longer.
"	13:17	Vandal	270°	8° / 1,280 ft	809 Camera[n]	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]	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° / 1,280 ft	Dos Coves North and South[d]	N/A	Adults looked up, some moved, but did not leave area; settled within minutes. Pups reacted vigorously by running around.
					809 Camera[n]	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]	96/83[#]	Little reaction by pups and adults in response to launch; animals settled within minutes.
					809 Camera[n]	N/A	Sea lion pups in water swam vigorously and came ashore.*

TABLE 3.3. Continued.

Launch Date	Launch Time	Missile Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	Sound Exposure Levels [dB re (20 μPa)^2·s] flat-weighted/A-weighted	Behavioral Reaction
5 Oct. 01	13:37	Vandal	273.3°	8° / 1,300 ft	809 Camera[n]	N/A	Pups on shore moved around, but did not enter water. Some pups that were in water came ashore. Animals settled within a few minutes and resumed previous activities.
					Vizcaino Pt.[n]	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° / 1,280 ft	809 Camera[n]	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]	N/A	Most sea lions were startled and scattered, but only some animals (10 %) left the area; they were mostly pups. Within 5 min animals resumed pre-launch activities.
19 Dec. 01	15:22	Vandal	273°	8° / 1,300 ft	809 Camera[n]	121/103	Most animals (60%) left the location were they had rested but did not enter the water. Within 5 minutes all animals had settled back to their pre-launch activities.
6 Mar. 02	11:20	Vandal	273.1°	8° / 1,300 ft	809 Camera[n]	121/106	Most animals looked up and some moved. . Only 16% of animals entered water; they were mostly juveniles. Within 5 min after launch animals had settled.
1 May 02	15:53	Vandal	273°	6.5° / malfunctioned & hit land	809 Camera[n]	N/A	Sea lions showed no distinct reaction to the first launch.
"	17:00	Vandal	273°	42° / 9,600 ft	809 Camera[n]	103/90	Most of the sea lions looked up, and several moved in response to the launch sound (mostly younger animals).

TABLE 3.3. Continued.

Launch Date	Launch Time	Missile Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	Sound Exposure Levels [dB re (20 μPa)^2·s] flat-weighted/A-weighted	Behavioral Reaction
8 May 02	14:54	Vandal	273°	8° / 1,300 ft	809 Camera[n]	122/104[?]	All sea lions looked up, some got up and moved around, and 33% entered the water.
					Sea Lion Cove[s]	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	Most sea lions sat up and some moved, but none entered the water.
21 June 02	12:53:12/ 12:53:15	RAM	240°	8° / 50 ft	Bachelor Beach North[s]	N/A	During the launch, most sea lions looked up and some moved slightly, but none entered the water.
					Dos Coves South[n]	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]	96/62	The sea lions did not show much reaction; some looked up and several moved slightly.
"	12:51	AGS Missile	300°	62.5° / 5,300 ft	809 Camera[s]	94/64	The sea lions did not show much reaction; some looked up and several moved slightly.
18 July 02	11:54:42	Vandal	273°	8° / 1,300 ft	Dos Coves North[d]	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 sound exposure levels are not available for that location.

[n] monitoring site located north 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.

[?] SEL taken nearby at Vizcaino Pt.; located < 0.5 km from 809 Camera.

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

* incidental sightings of sea lions at harbor seal haul-out sites.

Coves; the Terrier Orion departed southwestward (azimuth 232º) but at a much higher elevation angle of 64.6º (Table 1.1; Figure 1.7B). Video recordings were made of California sea lions via 809 Camera and as well as at Dos Coves and Sea Lion Cove. Harbor seals were also recorded via 809 Camera, and a small focal group of juvenile northern elephant seals was recorded at Bachelor Beach (Table 3.1). For the Vandal launch, sound was recorded at 809 Camera and Tender Beach; during the Terrier launch, sound was recorded at Building 807, Cormorant Rock Blind, and the Alpha Launch Complex (Table 2.2; Figure 1.7).

***Harbor Seals*.—**As for the 15 August launches, most adult harbor seals in the focal subgroup hauled out on a rocky ledge near 809 Camera entered the water in response to both the Vandal and later the Terrier Orion. During the Vandal launch, approximately 75% of the focal subgroup entered the water. Later, during the Terrier Orion launch, all harbor seals that were hauled out entered the water (Table 3.2). Harbor seals that left the site following the first launch did not return during the recording period. The few remaining harbor seals on the beach after the Vandal launch were increasingly vigilant for several minutes following the launch, and then settled back to the behavior pattern they exhibited prior to the launch (e.g., resting).

***Northern Elephant Seals*.—**Groups of juvenile northern elephant seals were videotaped at Bachelor Beach South and North during the Terrier Orion launch. Bachelor Beach South and North were located about 500 ft (150 m) and 2,000 ft (610 m), respectively, north of the launch azimuth (Figure 1.7B). The Terrier Orion was about 13,000 ft high when it passed over the beach, so it was at a high elevation angle at its closest point of approach (CPA) to the seals at both sites. Seals were hauled out in a tightly-packed group far from the shoreline at both locations. At Bachelor Beach South, seals showed very little overt reaction to the sound or sight of the missile (Table 3.4); most seals in the group glanced up as the missile sound reached them, but they did not move. The sound was documented nearby, at Cormorant Rock (Table 2.2). All of the seals at Bachelor Beach North looked up during the launch, and several individuals shuffled their positions slightly, but they did not leave the immediate vicinity of the group. All elephant seals settled back to rest within approximately 30 sec.

***California Sea Lions*.—**During the Vandal launch, sea lions were video taped at Dos Coves North and South; these sites were located very close to the launch azimuth (Figure 1.7B). California sea lions were videotaped at Sea Lion Cove (south of the azimuth) during the Terrier launch (Figure 1.7B). At both Dos Coves sites and at Sea Lion Cove, small groups of California sea lion pups were observed racing through the shallow waters in play before, during, and after the launches. There was little response from pups and adult sea lions during the Terrier launch; most individuals looked about briefly, then settled back. At both Dos Coves sites, adult sea lions looked up and some moved in response to the Vandal launch, but most did not leave the area and settled within several minutes after the launch. In contrast, most pups reacted vigorously to the Vandal launch by running around and leaving the area.

Several sea lions were also observed at harbor seal haul-out sites videotaped via 809 Camera during both the Vandal and Terrier launches. However, these sea lions could not be observed clearly, since the camera was focused on the harbor seals. Downslope from the 809 Camera site, 14 sea lion pups that were playing in the water swam vigorously toward shore and hauled out in response to the Terrier launch. During the Vandal launch, pups in the water swam vigorously and kept moving in a group in the shallows for more than 5 min following the launch. Such movements by pups may not have been a prolonged response to launch sounds, but rather the continued stimulation provided by a group of these young animals, which appeared to be playing in the shallows rather than "stampeding" in a panicked manner (Table 3.3).

TABLE 3.4. Details of missile 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 missiles 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	Missile Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	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]	N/A	All seals glanced up, and some shuffled positions slightly, but did not move out of the area. Seals settled within 30 sec after launch.
					Bachelor Beach South[n]	96/83*	Exhibited very little overt reaction. Most seals looked up, but did not move.
19 Oct. 01	09:00	Vandal	270°	8° / 1,280 ft	Bachelor Beach South[s]	N/A	Most animals looked up briefly and then settled back. 20% of juveniles moved but did not enter water.
14 Feb. 02	11:33	Vandal	273°	8° / 1,300 ft	Bachelor Beach North[s]	123/107	Elephant seals showed little reaction to launch. Most seals looked up briefly, but no seals moved.
					Redeye Beach[n]	N/A	All seals looked up and several moved, but not into the water. Seals settled within 30 sec. after launch.
22 Feb. 02	12:13	Vandal	270°	42° / 7,150 ft	Bachelor Beach North[s]	N/A	Most seals glanced up, but hardly any seals moved or shifted position. All animals settled within seconds.
"	14:56	Vandal	270°	42° / 7,150 ft	"	N/A	Most elephant seals hardly reacted to second launch. Some animals looked up, but settled within seconds after launch.
1 May 02	15:53	Vandal	273°	6.5° / malfunctioned & hit land	Pirates Cove[e]	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° / 9,600 ft	Pirates Cove[e]	N/A	No elephant seals were seen.

TABLE 3.4. Continued.

Launch Date	Launch Time	Missile Type	Launch Azimuth	Elevation Angle / Altitude Over Beach	Pinniped Monitoring Site	Sound Exposure Levels [dB re (20 μPa)^2·s] flat-weighted/A-weighted	Behavioral Reaction
8 May 02	14:54	Vandal	273°	8° / 1,300 ft	Pirates Cove[e]	96/67	The seals looked up when the missile was launched, but settled within seconds after the launch.
					Sea Lion Cove[s]	92/80	The seals looked up when the missile was launched, but settled within seconds after the launch.
					Redeye Beach[n]	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]	97/72 [?]	Some seals looked up, but settled within seconds after the launch.
21 June 02	12:53:12/ 12:53:15	RAM	240°	8° / 50 ft	Bachelor Beach North[s]	N/A	All seals looked up during the launch, but none moved. They settled within seconds.

Note: N/A means that sound exposure levels are not available for that location.
[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.

Many of the seabirds remained on the beaches, although some cormorants and gulls did fly into the air in response to both the first and second launches. As during the 15 August launch, it appeared that the pinnipeds may have first reacted to the movements and alarm cries of the seabirds prior to hearing the missile flight noise.

***Follow-up Monitoring*.—**During follow-up monitoring the next day, harbor seals were once again observed near 809 Camera, but they were hauled-out at a slightly different location from the day before. The distribution, numbers, and behavior patterns northern elephant seals and California sea lions were similar to those during the pre-launch period. No injury or mortality attributable to the missile launches was observed.

3.4.3 Vandal Launch, 5 October 2001

A single Vandal was launched from the Alpha Launch Complex at 13:37 toward azimuth 273.3º, passing south of Vizcaino Point and 809 Camera. Video recordings were made of California sea lions and harbor seals near 809 Camera, additional sea lions at Vizcaino Point, and harbor seals at Phoca Reef (Table 3.1, Figure 1.7C). Launch sound was recorded at Phoca Reef (Table 2.2; Figure 1.7C).

***Harbor Seals*.—**Most (70%) of the adult harbor seals in the focal subgroup hauled out on a rocky ledge or on the sand near 809 Camera entered the water in response to the Vandal launch; no seals were left on the same rocky ledge 10 min after the launch. At Phoca Reef (east of the Vandal launch pad), less than 10% of harbor seals entered the water in response to the launch; most looked up but did not move. Some of the harbor seals were hauled out in locations subjected to surf action, or were in shallow water near the sites; these individuals did not move farther into the water in response to the launch. Those remaining ashore showed increased vigilance for several minutes, and then settled back to a behavior pattern such as they exhibited prior to the launch (Table 3.2).

***California Sea Lions*.—**At both Vizcaino Point and 809 Camera sites, several California sea lion pups left their position to move along the site parallel to the beach, but did not enter the water during the launch. Within 5 min, most California sea lions, including younger animals, had settled back to their pre-launch activities. Those that remained active were usually younger sea lions involved in group play activity on the sand near the shoreline; this type of activity had been occurring prior to the launch (Table 3.3).

***Follow-up Monitoring*.—**During follow-up monitoring the next day, the distribution, numbers, and behavior patterns of harbor seals and California sea lions were similar to those during the pre-launch period. No injury or mortality attributable to the missile launch was observed.

3.4.4 Vandal Launch, 19 October 2001

A single Vandal was launched from the Alpha Launch Complex at 09:00 toward azimuth 270º, and at an elevation angle of 8º (Table 1.1). Video recordings were made of California sea lions near 809 Camera and Vizcaino Point (north of the launch azimuth), and northern elephant seals at Bachelor Beach southeast of that azimuth (Table 3.1; Figure 1.7D). Launch sound was recorded at NAVFAC Beach (Table 2.2; Figure 1.7D).

***Northern Elephant Seals*.—**In contrast to other launches, 20% of 45 juvenile northern elephant seals at Bachelor Beach South moved in response to the Vandal launch sounds, but most only looked about briefly and then settled back within seconds. The 20% that moved did so by leaving the camera's field of view, rather than the beach (Table 3.4).

***California Sea Lions*.—**Sea lions (mostly pups) that were hauled out on the shore near 809 Camera remained onshore as the Vandal passed by to the south, and moved up the beach slope. Six pups that were in the water came onto shore and moved up the beach slope at a vigorous pace. Other pups in the water swam out of the lagoon rapidly. Several sea lion pups left their position to move along the site parallel to the beach, but did not enter the water. At Vizcaino Point, most sea lions scattered in response to the launch, but only 10% (mostly pups) left the area (Table 3.3). There was more vocal activity by sea lion mothers and pups immediately following the launches, and there was still substantial calling 10 min after the launch.

Within 5 min, most California sea lions, including younger animals, had settled back to their pre-launch activities. Those that remained active were usually younger sea lions involved in group play activity on the sand near the shoreline; this type of activity had been occurring prior to the launches.

***Follow-up Monitoring*.—**During follow-up monitoring the next day, the distribution, numbers, and behavior patterns of northern elephant seals and California sea lions were similar to those during the pre-launch period. No injury or mortality attributable to the missile launch was observed.

3.4.5 Vandal Launch, 19 December 2001

A single Vandal was launched from the Alpha Launch Complex at 15:22 toward azimuth 273º, with an elevation angle of 8º, and passing south of 809 Camera. Video recordings were made of California sea lions only, in the 809 Camera area (Table 3.1; Figure 1.7E). No harbor seals were present during the video monitoring at Pirates Cove, and no data were retrievable from the video recording of northern elephant seals at Bachelor Beach. Launch sounds were recorded at 809 Camera and Building 807 (Table 2.2; Figure 1.7E).

The sea lions in the focal subgroup reacted strongly to the Vandal sounds by dispersing on the beach; about 60% of those hauled out left the location where they had rested, but did not enter the water (Table 3.3). Within 5 min, most California sea lions, including younger animals, had appeared to settle back to their pre-launch activities. Received levels of Vandal sounds at 809 Camera (and also Building 807) were higher on this date than during some other launches (Table 2.3).

***Follow-up Monitoring*.—**During follow-up monitoring the next day, the distribution, numbers, and behavior patterns of harbor seals and California sea lions were similar to those during the pre-launch period. No injury or mortality attributable to the missile launch was observed.

3.4.6 Vandal Launch, 14 February 2002

A single Vandal was launched from the Alpha Launch Complex at 11:33. It was launched toward azimuth 273º, at an elevation angle of 8º (Table 1.1). Video recordings were made of northern elephant seals only, at two separate locations south (Bachelor Beach North) and north (Redeye Beach) of the launch azimuth (Table 3.1; Figure 1.7F). Sound levels were measured near Bachelor Beach and at 809 Camera (Table 2.2).

The adult northern elephant seals and pups videotaped at Bachelor and Redeye Beach showed very little overt reaction to the Vandal launch sounds. At Bachelor Beach, most seals in the focal groups looked about briefly as the missile sound reached them, but they did not move. At Redeye Beach, all animals looked during the missile launch, and several individuals shuffled their positions slightly, but they did not leave the immediate vicinity of the group. At both locations, all elephant seals settled back to rest within approximately 30 sec (Table 3.4).

***Follow-up Monitoring*.—** During follow-up monitoring the next day, the distribution, numbers, and behavior patterns of northern elephant seals were similar to those during the pre-launch period. No injury or mortality attributable to the missile launch was observed.

3.4.7 Double Vandal Launches, 22 February 2002

Two Vandals were launched 2 hr 43 min apart, both from the Alpha Launch Complex. Both were directed toward azimuth 270º, but on this date the elevation angle was much higher (42º) than for most other Vandal launches during the present monitoring study. Video recordings were made of northern elephant seals only, at Bachelor Beach North, which was located south of the launch azimuth (Table 3.1; Figure 1.7G). No harbor seals were hauled out during the video recordings at Pirates Cove or Redeye Beach. Sounds were monitored north of the launch azimuth at Building 809 and at Redeye Beach (Table 2.2; Figure 1.7G).

The adult female northern elephant seals and pups videotaped during both launches exhibited very little response to the missile or its noise. Most of the seals on Bachelor Beach glanced up as the missile sound reached them, but hardly any seals moved or shifted position. All elephant seals settled back to rest within seconds (Table 3.4).

Some gulls flew up in response to both the first and second launches. It appeared that the seals reacted in response to the movement of the gulls prior to hearing the missile flight noise.

***Follow-up Monitoring*.—** During follow-up monitoring the next day, the distribution, numbers, and behavior patterns of northern elephant seals were similar to those during the pre-launch period. No injury or mortality attributable to the missile launches was observed.

3.4.8 Vandal Launch, 6 March 2002

A single Vandal was launched from the Alpha Launch Complex at 11:20 toward azimuth 273º, with an elevation angle of 8º (Table 1.1). Video recordings were made of harbor seals at three sites north of the launch track (Pirates Cove, near 809 Camera, and Redeye Beach), and of California sea lions near 809 Camera (Table 3.1; Figure 1.7H). Launch sound levels were recorded at 809 Camera, Dos Coves, and an easterly location? Sheephead Ranch (Table 2.2; Figure 1.7H).

***Harbor Seals*.—**Most (98%) of the adult harbor seals and pups hauled out on a rocky ledge at Redeye Beach entered the water in response to the Vandal launch sounds (Table 3.2). Most seals left the beach quickly during the launch, but several individuals took as long as 6 min before they entered the water. Harbor seals returned to the beach 13 min after the launch. Seals hauled out on the rocky ledge near 809 Camera either looked up or moved in response to the launch, but did not enter the water. They were increasingly vigilant for several minutes following the launch, then settled back to the behavior pattern they exhibited prior to the launch (e.g., resting). At Pirates Cove, all harbor seals entered the water quickly in response to the launch. Harbor seals hauled out on the beach 16 min after the launch.

***California Sea Lions*.—**Most California sea lions near 809 Camera looked up and several moved in response to the Vandal launch sounds, but did not enter the water. Approximately 16% of sea lions in the focal subgroup entered the water, and these were mostly younger sea lions. Within 5 min, most sea lions had settled back to their pre-launch activities, although they were more vigilant for several minutes following the launch (Table 3.3).

***Follow-up Monitoring*.—** During follow-up monitoring the next day, fewer harbor seals were seen at Pirates Cove than the day before; this was attributed to warm weather. The distribution, numbers, and behavior patterns of California sea lions were described as similar to those during the pre-launch period. No injury or mortality attributable to the missile launch was observed.

3.4.9 Double Vandal Launches, 1 May 2002

Two Vandals were launched 1 hr 7 min apart from the Alpha Launch Complex; both were directed toward azimuth 273º. One of the Vandals (launched at 17:00:23) had a high elevation angle of 42º (Table 1.1). The first Vandal, which was launched at 15:53:20, malfunctioned and hit land. Video recordings were made of northern elephant and harbor seals at Pirates Cove and of California sea lions at 809 Camera; both sites are located north of the launch azimuth (Table 3.1; Figure 1.7I). No harbor seals were hauled out during the video recording at Redeye Beach. Sounds were monitored north of the launch azimuth at Building 809 and south of the launch azimuth at Bachelor Beach South (Table 2.2; Figure 1.7 I). The launch sound at Pirates Cove was barely audible to the human ear, even though other ambient noise was recorded using the camera's microphone.

***Harbor Seals*.—**Prior to the launches (both the first and second), harbor seal adults and pups were observed hauled out on the beach at Pirates Cove. During the first launch, most of the seals startled, but none entered the water. Only a small number (14%) of the seals moved in reaction to the launch; these were all pups. Within several minutes, the harbor seals at the haul-out site had settled back to their pre-launch activities (Table 3.2).

Harbor seals appeared to react more to the second launch. More seals startled and scattered, and 38% fled into the water. The majority of seals that entered the water were pups, which stayed in shallow water. The seals settled within minutes of the launch, and some seals returned to the beach within several minutes after the launch.

***Northern Elephant Seals*.—**Prior to the first launch, two elephant seals were hauled out on the beach at Pirates Cove. During the launch, they got up and moved slightly on the beach (Table 3.4). It is possible that they moved in response to the startled harbor seals, not the missile launch sound, as most elephant seals observed at other locations have not reacted to launches. Several minutes after the launch, the two elephant seals moved up the beach. No elephant seals were observed during the second launch. Incidental sightings of elephant seals were made at Redeye Beach. Although the seals could not be seen before or during the launch, they emerged from their resting places several seconds after the launch and moved down the beach towards the water.

***California Sea Lions*.—**Prior to the first and second launches, several sea lions were observed via 809 Camera. The sea lions appeared to show no distinct reaction to the first launch (Table 3.3), although the video quality was somewhat poor. However, during the second launch, most of the sea lions looked up and several moved slightly in response to the launch (mostly younger animals). Sea lions displayed increased vigilance after the launch, but settled within several minutes.

***Follow-up Monitoring*.—**During follow-up monitoring the next day, all three species of pinnipeds were once again hauled out at the same locations as on the previous day. One nursing harbor seal pup was observed. Overall, the distribution, numbers, and behavior patterns of all three species were similar to those during the pre-launch period. No injuries or mortality attributable to the missile launch were observed.

3.4.10 Vandal Launch, 8 May 2002

A single Vandal was launched from the Alpha Launch Complex, directed toward azimuth 273º, with an elevation angle of 8º (Table 1.1). Video recordings were made of all three species at Sea Lion Cove, well to the south of the launch azimuth (Figure 1.7J). In addition, harbor seals were observed at Pirates Cove and Redeye Beach, northern elephant seals were also monitored at Pirates Cove, and California sea lions were observed via 809 Camera. All sites, except Sea Lion Cove, are located north of the launch azimuth (Table 3.1; Figure 1.7J). Sounds were monitored at Pirates Cove, Sea Lion Cove, and Vizcaino Point, and near the launch pad at the Alpha Launch Complex (Table 2.2; Figure 1.7J).

***Harbor Seals*.—**Most of the harbor seals (at least 90%) hauled out at Sea Lion Cove entered the water in response to the Vandal launch and did not return to the beach prior to the end of the recording (Table 3.2). All harbor seals hauled out at Pirates Cove looked up in response to the launch, and some moved slightly. Only 7% of seals entered the water. Seals were more vigilant following the launch, but settled within several minutes. All harbor seals (approximately 50) hauled out on the rocky ledge at Redeye Beach rushed into the water in response to the launch. Seals started hauling out again at that location approximately 13 min after the launch (Table 3.2).

***Northern Elephant Seals*.—** Prior to the launch, elephant seals hauled out at Sea Lion and Pirates Cove were mainly resting, but some were moving around on the beach at Sea Lion Cove. At both locations, the seals looked up during the launches, but settled within seconds after the launch (Table 3.4).

***California Sea Lions*.—**Prior to the launch, California sea lions hauled out at Sea Lion Cove were resting, although some younger animals were moving around the beach. During the launch, most sea lions looked up, but did not move (Table 3.3). Sea lions near 809 Camera were resting prior to the launch. During the launch, all sea lions looked up, some got up and moved around, and several (33%) entered the water. At both sites, the sea lions showed increased vigilance immediately following the launches, but settled several minutes afterwards. The birds flew away several seconds before the sea lions reacted.

***Follow-up Monitoring*.—** During follow-up monitoring the next day, all three species of pinnipeds were once again occupying the same locations as the day before. However, there appeared to be fewer harbor seals at Redeye Beach compared with the day of the launch. The distribution, numbers, and behavior patterns of elephant seals and California sea lions were described as similar to those during the pre-launch period. No injuries or mortality attributable to the missile launches were observed.

3.4.11 AGS Test Launch (Slug, no Missile), 19 June 2002

The Advanced Gun 'Test' System, located at the Alpha Launch Complex, was fired with a slug. The slug was directed toward azimuth 305º, with an initial elevation angle of 63º, but it malfunctioned and hit land. The slug traveled about 8,950 ft (2,728 m) before striking the ground, about 330 ft (101 m) from the shoreline (Figure 1.7K). Video recordings were made of elephant seals at Redeye I (located slightly north of the launch azimuth) and of California sea lions via 809 Camera (located close to the launch azimuth; Table 3.1; Figure 1.7K). Sounds were monitored nearby at Redeye II (Table 2.2; Figure 1.7K).

***Northern Elephant Seals*.—** Prior to the launch, elephant seals hauled out at Redeye I were resting. During the launch, some seals looked up, but settled within seconds after the launch (Table 3.4).

California Sea Lions.—Prior to the launch, California sea lions hauled out at near 809 Camera exhibited periods of little or no movement interspersed with periods when animals were moving around. Most of the animals that were moving around were pups. During the launch, most sea lions sat up and some sea lions moved, but none entered the water (Table 3.3). The sea lions showed increased vigilance immediately following the launch and took longer than usual to settle (almost 10 min).

Follow-up Monitoring.—No follow-up monitoring was conducted the next day, as pinnipeds showed little response to the launch sound.

3.4.12 Dual RAM Launch, 21 June 2002

A dual RAM launch occurred from the 807 Building Launch Complex on the west end of San Nicolas Island. This was the only launch from a location other than the "inland" Alpha Launch Complex. The two RAM missiles were launched within 3 sec of each other. With regard to effects on pinniped behavior, these two launches could be distinguished and were not analyzed separately. Both were directed toward azimuth 240º at an elevation angle of 8º. Video recordings were made of elephant seals and California sea lions at Bachelor Beach North (located south of the launch azimuth); California sea lions were also observed at Dos Coves South (north of the launch azimuth; Table 3.1; Figure 1.7L). Sounds were monitored at Building 807 (Table 2.2; Figure 1.7L).

Northern Elephant Seals.—Prior to the dual launch, elephant seals hauled out at Bachelor Beach North were resting. All seals looked up during the launch, but none moved (Table 3.4). Seals settled within seconds after the launch.

California Sea Lions.—Prior to the dual launch, most of the adult sea lions hauled out at Bachelor Beach were resting, but several were moving around on the beach. During the launch, most sea lions looked up and some moved, but none entered the water (Table 3.3). The sea lions showed increased vigilance immediately following the launch, but settled within minutes afterwards. At Dos Coves, adults and pups were hauled out. Prior to the launches, there was considerable vocalizing and some pups were moving around the beach. Sea lions looked up during the dual launch, but did not move. Sea lions settled within minutes after the launch.

Follow-up Monitoring.—No follow-up monitoring was conducted the next day, as pinnipeds showed little response to the launch sound. However, sea lions were monitored 30 min after the dual launch. Most animals were resting, and several pups were observed nursing. There were several pups in the water without their mothers. These pups may have entered the water during the launch, but were not in the field of view of the camera during the launch. Navy personnel noted that it did not appear that females and pups were searching for each other, although quite a bit of vocalizing was occurring.

3.4.13 Double AGS Launch (Slug and Missile), 26 June 2002

A slug and an AGS missile were launched 1 hr 31 min apart from the Alpha Launch Complex. Both were directed toward azimuth 300º, with a high elevation angle of 62.5º (Table 1.1). The slug traveled approximately 6,630 ft before hitting the water about 200 ft offshore; the missile continued offshore. Video recordings were made of harbor seals and California sea lions at Redeye Beach; sea lions were also observed via 809 Camera. Both locations are located just south of the launch azimuth (Table 3.1; Figure 1.7M). Sounds were monitored at Redeye Beach, as well as at Vizcaino Point and near the launch pad at the Alpha Launch Complex (Table 2.2; Figure 1.7M).

***Harbor Seals*.—**Prior to both launches, harbor seals hauled out at Redeye Beach were resting. The seals looked up at the launch sounds, but did not move (Table 3.2). Seals settled within minutes after the launches.

***California Sea Lions*.—**Prior to both launches, most of the sea lions hauled out at Redeye Beach and near 809 Camera were resting, but several were moving around on the beach (mainly adult males) or in the water. The sea lions did not show much reaction to either launch; some sea lions looked up and several moved slightly in response to the launches (Table 3.3). They settled within seconds after the launch.

***Follow-up Monitoring*.—**No follow-up monitoring was conducted the next day, as pinnipeds showed little response to the launches.

3.4.14 Vandal Launch, 18 July 2002

A single Vandal was launched from the Alpha Launch Complex, directed toward azimuth 273º, with an elevation angle of 8º (Table 1.1). The Vandal passed near Dos Coves North, where a video recording of California sea lions was made (Table 3.1; Figure 1.7N). This recording had quite a narrow field of view, and only a few sea lions were observed. Sounds were monitored at Dos Coves, near the launch azimuth (Table 2.2; Figure 1.7N).

Prior to the launch, pups and adult female California sea lions at Dos Coves North were generally resting, although some pups were moving around. During the launch, all of the eight sea lions observed looked up, and four of those left the area immediately (Table 3.3). All but one sea lion left the immediate area within several minutes after the launch. The birds flew away several seconds before the sea lions reacted to the launch.

During follow-up monitoring the next day, the sea lions were hauled out on the beach in large numbers. There appeared to be more vocalization than the previous day, and pups were moving around on the beach. No injuries or mortality attributable to the missile launch were observed.

3.5 Responses of Pinnipeds to Launch Sounds and Conditions

Due to the limited number of ATAR recordings that were available at the pinniped monitoring sites, few comparisons of pinniped reactions to sound exposure levels (SEL) can be made with the data available to date. Thus, detailed dose-response relationships cannot be determined at this time. All SELs in this section are given in flat-weighted dB re 20 $\mu Pa^2 \cdot s$.

3.5.1 Harbor Seals

On seven occasions, harbor seals and sounds were monitored at the same location (Table 3.2). The most substantial seal responses occurred during two low-elevation Vandal launches: one with an SEL of 119 dB at the site monitored via 809 Camera on 20 September 2001, and another with an SEL of 92 dB at Sea Lion Cove on 8 May 2002. The first of these sites was ~1 km north of the missile flightline and 3.5 km from the launch pad. During this launch, most seals (75%) that were hauled out entered the water. The second site was ~2 km south of the flightline and 3 km from the launch pad. Another low-elevation Vandal launch, on 6 March 2002, did not elicit strong responses from seals near 809 Camera, even though the azimuth and elevation angle were similar to the other two Vandal launches and the SEL was slightly higher (121 dB). On that occasion, no seals entered the water, but some animals moved. It is uncertain why this group did not exhibit the same strong reaction as seals did on 20 September and 8 May. It is possible that clear observations of these animals were inhibited by poor video quality.

During a low-elevation Vandal launch on 5 October 2001, seals and sound were monitored at Phoca Reef, located about 2.5 km to the northeast of the launch pad. Not many seals responded to this launch; <10% entered the water. The minimal response to this launch was likely attributable to the substantial distance from the launch azimuth, and the fact that the missile traveled generally away from the monitoring site; thus the SEL was low (94 dB). Another low-elevation Vandal launch on 8 May 2002 produced an SEL of 96 dB at Pirates Cove, located ~2.5 km northeast of the launch pad not far from Phoca Reef. Again, harbor seals did not respond vigorously to this launch; about 7% entered the water. These results indicate that harbor seals are not strongly affected by such low received sound levels; however, a small percentage of the individuals present did react.

Two AGS launches on 26 June 2002 were monitored at Redeye Beach, located ~400 m from the azimuth and 2.3 km from the launch pad. These launches were at high elevation (62.5º) and produced SELs of 93 and 96 dB. They elicited minimal responses from harbor seals.

It is interesting to note that the low-elevation Vandal launch on 8 May elicited a strong response from harbor seals at Sea Lion Cove even though the SEL was relatively low (92 dB). Although it appears that harbor seals are generally less responsive to launch sounds with SELs less than 96 dB, they sometimes do react to fairly weak sounds. Reactions are variable, and additional data will be needed before it will be possible to evaluate the dose-response relationship for harbor seals. Some other factor, such as tide, weather, or characteristics of the haul-out site could have affected the response to launch sounds on 8 May. However, due to the small number of paired seal and ATAR observations, it is not yet possible to determine the other factors that could have potentially affected the response of harbor seals to the launches. Although the responses of harbor seals to launch sounds with SELs less than 92 dB were undetermined, it is expected that seals would show little response to sounds with SELs less than 90 dB.

3.5.2 Northern Elephant Seals

On five occasions, both elephant seals and sound levels were monitored at the same location. The highest SEL (123 dB) was produced during a low-elevation Vandal launch monitored at Bachelor Beach North on 14 February 2002. This site was located ~1 km from the flightline. Seals exhibited very little reaction to the launch. Responses to another low-elevation Vandal launch were monitored on 8 May 2002 at Pirates Cove and Sea Lion Cove. Pirates Cove is located 2.5 km northeast of the launch pad, and Sea Lion Cove is 2 km south of the missile flightline. These launches produced SELs of 92 and 96 dB. Again, elephant seals hardly responded to the launch sounds or other stimuli.

Elephant seals were monitored during two launches at high elevation angles (63-65º). A Terrier Orion launch was monitored at Bachelor Beach South, near the missile flightline, on 20 September 2001, and produced an SEL of 96 dB. A slug was launched on 19 June 2002 and was monitored at Redeye Beach. The slug malfunctioned and hit land west of Redeye Beach, about 330 ft from the shoreline. The launch produced an SEL of 97 dB. On both dates, elephant seals hardly reacted to the launch sounds.

Elephant seals tended not to react to launch sounds or other launch stimuli. Even sound levels as high as 123 dB did not elicit a strong reaction from northern elephant seals. However, on three occasions, elephant seals did react during the launch. Unfortunately, sound levels were not monitored at these sites. On 19 October 2001, elephant seals monitored at Bachelor Beach exhibited a stronger-than-usual response to a low-elevation Vandal launch, though still a minor response. Several elephant seals (20%) actually moved in response to the launch sound. There appeared to be nothing unusual about the launch, as the missile was launched at a similar elevation angle and azimuth as other missiles. In addition, the weather was similar to that on other launch dates. On 1 May 2002, two elephant seals that were hauled out at Pirates Cove moved slightly during the first Vandal launch. Approximately 1 min after the launch, they moved up the beach. On 8 May 2002, no elephant seals were observed during the launch, because they were hidden from view. However, several seconds after the launch, three animals were seen moving towards the water.

3.5.3 California Sea Lions

On nine occasions, sea lions and sound levels were monitored at the same location. The site near 809 Camera was monitored during low-elevation (8º) Vandal launches on 20 September 2001, 19 December 2001, 6 March 2002, and 8 May 2002. This site was located ~1 km from the flightline. SELs for these launches ranged from 119 to 122 dB. On all four occasions, most sea lions reacted strongly by moving around on the beach, and on 6 March and 8 May some animals entered the water.

A Vandal launch with a high elevation angle of 42º was also monitored near 809 Camera. This launch produced an SEL of 103 dB. During this launch, the sea lions were less responsive compared to low-elevation Vandal launches; most sea lions looked up and several moved, but none entered the water.

A low-elevation Vandal launch was monitored at Dos Coves on 18 July 2002. This site was located close to the flightline and had an SEL of 128 dB. Although the field of view of the camera during pinniped observations at this location was small, 50% of sea lions left the immediate area where the camera was focused.

The Terrier Orion launch was monitored at Sea Lion Cove and produced an SEL of ~96 dB. This launch was at a high elevation angle and passed over the beach at an elevation of 13,000 feet. Sea lions that were hauled out at this site showed little reaction to this launch.

Two AGS launches were monitored via 809 Camera as well as at Redeye Beach, ~600 and 400 m from the launch azimuth, respectively. The launches produced SELs ranging from 94 to 96 dB. Sea lions at both of these sites hardly reacted to the launch sounds at all, although some individuals looked up and several moved slightly.

Sea lions appeared to react only to launch sounds from low-elevation Vandals and to launch sounds with SELs greater than 103 dB. Since the Terrier and AGS launches were at high elevations, they produced low SELs at the monitored sites, and sea lions were virtually unaffected by these launches.

3.5.4 Summary

California sea lions and harbor seals appeared to be less responsive to launches of smaller missiles, such as the AGS and RAM, because these vehicles generally produced lower SELs. Launches at high elevation did not cause substantial responses from sea lions or harbor seals, presumably because missiles launched from the Alpha Complex at high elevation angles passed over or near the haul-out locations at high altitudes, producing low SELs at monitored sites. Harbor seals and sea lions hauled out at locations close to the missile flightline generally showed a greater response than animals located farther away from the flightline. Elephant seals were generally not very responsive to launches, irrespective of missile type, elevation angle, or location.

3.6 Quantitative Comparisons of Pinniped Behavior and Distribution Prior to and Following Launches

The "units of observation" for the quantitative studies were individual pinnipeds within the focal subgroups. Individuals were chosen that were clearly visible on the DVD recordings for the entire 1-min sampling period of interest (either pre- or post-launch or during follow-up monitoring). The individuals chosen for the focal subgroups before and after the 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 noise (e.g., young California sea lions or harbor seals). In the case of northern elephant seals, the focal animals were often the same individuals that were observed prior to the launch, and hence not as likely to be statistically independent.

Even though follow-up monitoring occurred on the day after the launches, the times of observation were similar to those when pinnipeds were observed during the day of the launch. Therefore, variables such as weather and tide should not be strongly confounding factors in determining any differences in pinniped behavior before the launch compared with during follow-up monitoring the next day.

For all tests, we included data from pinnipeds monitored during all missile launches, on all dates, and at all locations. In order to determine whether missile type had an effect on the results, tests were also run using only data obtained from Vandal launches. Although these tests are not presented below, the results obtained were similar.

An analysis comparing the number of ***body position changes*** of the three species showed that there were significant differences among the species both before (Kruskal-Wallis, $H = 10.26$, df = 2, $P = 0.006$) and after ($H = 14.81$, df = 2, $P = 0.0006$) the launches. Before launches, California sea lions were generally more mobile than both harbor and elephant seals (Table 3.5). After launches, California sea lions were significantly more mobile than harbor and elephant seals (Dunn's multiple comparison, $P < 0.02$).

Significantly more body position changes were made by focal California sea lions in the 1-min periods following missile launches than in the minute preceding the launches (Mann-Whitney *U*-test, $P < 0.001$; Table 3.5). Most of the difference for the sea lions can be attributed to the vigorous responses by young animals. Harbor seals also made significantly more body-position changes after-launch than before-launch ($P = 0.002$). Northern elephant seals did not become significantly more active (as indicated by frequency of body position changes) in response to launches ($P = 0.702$).

When the number of body position changes before launches was compared to the number during follow-up monitoring the next day, there were no significant differences for any of the three species (Table 3.5).

Total distances moved differed among the three species both before (Kruskal-Wallis, $H = 10.81$, df = 2, $P = 0.005$) and after ($H = 19.95$, df = 2, $P < 0.001$) the launches. Before launches, California sea lions generally moved greater distances compared to harbor and elephant seals (Table 3.5). After launches, California sea lions were significantly more mobile than harbor ($P < 0.01$) and elephant seals ($P < 0.005$).

The total distances moved by focal California sea lions in the 1-min sample periods following missile launches were significantly greater than in the minute preceding the launches (Mann-Whitney *U*-test, $P < 0.001$; Table 3.5). Harbor seals also moved significantly greater distances in the period following launches ($P = 0.002$). There was no pre- vs. post-launch difference for northern elephant seals ($P = 0.837$). Thus, sea lions and harbor seals moved significantly greater distances on the haul-out site after a launch as compared with movements just before a launch; elephant seals showed no clear difference. As for the body position changes, most of the difference for the sea lions can be attributed to the vigorous responses by young animals.

The total distance moved did not differ significantly between before-launch and follow-up periods for any of the three species (Table 3.5).

TABLE 3.5. Descriptive statistics for quantitative comparisons of pinniped behavior and distribution prior to and after launches, as well as during follow-up monitoring the day after the launch. N = number of animals; SD = standard deviation; *P* = significance level.

	Before Launch			**After Launch**				**Follow-up**			
Behavior Analyzed	N	Mean	SD	N	Mean	SD	*P*[a]	N	Mean	SD	*P*[b]
California Sea Lion											
Distance to Neighbor (m)	279	0.65	1.59	232	0.59	0.95	**	70	0.36	0.72	ns
Number of Position Changes	279	0.28	0.80	232	0.63	1.09	***	70	0.23	0.62	ns
Total Distance Moved (m)	279	0.29	1.35	232	0.97	2.74	***	70	0.21	0.82	ns
Harbor Seal											
Distance to Neighbor (m)	168	0.92	0.99	84	1.51	1.87	*	98	0.67	0.68	ns
Number of Position Changes	168	0.10	0.45	84	0.29	0.72	**	98	0.07	0.30	ns
Total Distance Moved (m)	168	0.03	0.18	84	0.09	0.24	**	98	0.04	0.20	ns
Northern Elephant Seal											
Distance to Neighbor (m)	108	0.14	0.43	89	0.14	0.44	ns	109	0.08	0.21	ns
Number of Position Changes	108	0.21	0.51	89	0.29	0.69	ns	109	0.10	0.35	ns
Total Distance Moved (m)	108	0.09	0.27	89	0.14	0.76	ns	109	0.04	0.24	ns

[a] Statistical significance column shows results of Mann-Whitney *U* tests comparing results before vs. after launch.
[b] Statistical significance column shows results of Mann-Whitney *U* tests comparing results before launch vs. during follow-up monitoring.
*** means $P \le 0.001$; ** means $0.001 < P \le 0.01$; * means $0.01 < P \le 0.05$; and ns means $P > 0.1$.

Distances between focal animals, shown in Table 3.5, differed significantly among the three species both before launches ($H = 105.50$, df = 2, $P < 0.001$) and after launches ($H = 106.33$, df = 2, $P < 0.001$). Before and after launches, distances between harbor seals were significantly greater than those between the other two species ($P < 0.001$). In addition, distances between focal sea lions were significantly greater than those between elephant seals ($P < 0.001$).

Focal sea lions were significantly closer together after launches (Mann-Whitney *U*-test, $P = 0.01$; Table 3.5), whereas harbor seals were significantly farther apart after launches ($P = 0.02$). Distances between individual elephant seals did not change significantly prior to compared with after the launches ($P = 0.652$).

The distances between focal animals did not differ for any of the three species before launches compared with the distances observed during follow-up monitoring the next day (Table 3.5).

3.7 Summary

Pinniped behavioral responses to launch sounds were usually brief and of low magnitude. Northern elephant seals exhibited little reaction to the launches. In contrast, more than half of the adult harbor seals hauled out on rocky ledges left their resting sites during most launches. Young California sea lions reacted more strongly to the launches than older animals, although all age classes often settled back to pre-launch behavior patterns within minutes of the launch time. However, the few older individuals that left the beach did not return during the recording period. No evidence of injury or mortality was observed during or immediately succeeding the launches. One or two dead pups (elephant seal and sea lion pups) were sometimes found by Navy personnel during follow-up monitoring the day after missile launches. The pups had apparently died several days prior to the actual launch dates, and it is unlikely that their deaths were related to the missile launches.

As expected, responses of California sea lions to the missile launches varied by individual and age group. Some sea lions exhibited brief startle responses and increased vigilance for a short period 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 rushing into the water. Interestingly, it was not uncommon for young sea lion pups playing in the shallow waters near haul-out sites to leave the water and rush ashore during a missile overflight. Adult sea lions already hauled out would mill about on the beach for a short period before settling, whereas those in the shallow water near the beach did not come ashore like the aforementioned pups. For sea lions, there were statistically significant before-launch vs. after-launch differences in inter-individual spacing, frequency of body position changes, and distances moved. Spacing tended to decrease after launches, whereas number of body position changes and distances moved tended to increase. Young sea lions accounted for much of the effect on body position changes and distances moved.

During the majority of launches, most harbor seals left their haul-out sites on rocky ledges to enter the water and did not return during the duration of the video-recording period (which sometimes extended up to several hours after the launch time). During monitoring the day following a launch, harbor seals were usually hauled out again at these sites. Inter-individual spacing increased significantly during the post-launch period. Frequency of body position changes was also significantly higher after launches. Increased dispersion of harbor seals after launches was a function of some seals leaving a haul-out site while the remaining animals stayed in their pre-launch locations.

Northern elephant seals exhibited little reaction to launch sounds. Most individuals merely raised their heads briefly upon hearing the launch sounds and then quickly returned to their previous activity pattern (usually sleeping). During some launches, a small proportion of northern elephant seals on the beach moved a short distance away from their resting site, but settled within minutes. For elephant seals, there were no statistically significant differences from before-launch to after-launch sampling periods in inter-individual spacing, frequency of body position changes, and distances moved.

Launches did not occur when visibility was extremely restricted (e.g., by heavy fog), so it is not possible to assess the influence of horizontal visibility on the types or magnitudes of pinniped behavioral responses to launch sounds.

The relatively limited number of monitored haul-out sites resulted in elephant seals being seen on sandy substrates only. Harbor seals were seen on rock ledges (or in nearby waters) and sand. California sea lions were seen on sand, cobble, rocky ledges, or shallow water. For the latter two species, we have seen no evidence of any discernible (or quantifiable) substrate-related differences in the types or magnitudes of behavioral responses to launches.

4. ESTIMATED NUMBERS OF PINNIPEDS AFFECTED BY MISSILE LAUNCHES[1]

4.1 Pinniped Behavioral Reactions to Noise and Disturbance

When the received level of noise exceeds some behavioral reaction threshold, some pinnipeds will show disturbance reactions. The levels, frequencies, and types of noise that elicit a response vary between and within species, individuals, locations, and seasons. For pinnipeds hauled out on land, behavioral changes may range from a momentary alert reaction or an upright posture to movement – either deliberate or abrupt – into the water. In addition, it is possible that pinnipeds hauled out on land may react to the sight, or the combined sight plus sound, of a missile launch. For pinnipeds in the water, the behavioral reaction may again be limited to a momentary alert response, or may involve a change in activity, possibly accompanied by movement away from the sound source and perhaps longer-term avoidance of the area. 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).

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 appears correct. Although dead pups (elephant seals and California sea lion pups) were sometimes reported during follow-up monitoring the day after missiles were launched, it is unlikely that they died because of the missile launch sounds. Observations indicated that these pups died several days prior to the launches. Some natural mortality of newborn pups is to be expected.

Thus, disturbance rather than injury or mortality is the primary concern in this project. Given that the pinniped reactions to the launches were brief or negligible, the minimum numbers of pinnipeds on the monitored beaches that might have been affected by the launch sounds were estimated. The Navy, consistent with NMFS (1996, 2000, 2001), assumes that those pinnipeds exhibiting momentary alert or startle reactions with no large-scale movement are not considered to be significantly affected.

In this report 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 equal to or greater than 145 dB re 20 μPa SEL for harbor seals and California sea lions, or 165 dB re 20 μPa SEL for northern elephant seals (see next subsection for rationale), 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.

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[1] By **John W. Lawson**, LGL Ltd., environmental research associates.

The numbers of such affected pinnipeds were calculated only for the period during and immediately following the 19 launches (including one dual RAM launch) on 14 days. 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. The harbor seals that remained hauled out were increasingly vigilant for several minutes, but then settled back to the behavior pattern they exhibited prior to the launches (e.g., resting).

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 is presumed to be higher, by a variable and generally unknown amount, than the level that induces barely-detectable TTS. The level associated with the onset of TTS can be considered to be a conservative (precautionary) estimate of the level below which there is no danger of permanent damage.

Although the effects of Vandal-like sounds on in-air hearing sensitivity of pinnipeds have not been measured, it is unlikely that launch sounds as received on any pinniped beach on San Nicolas Island were sufficient to cause TTS. 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 levels of about 131 dB SEL re 20 $\mu Pa^2 \cdot s$, flat-weighted (Table 1 in Greene 1999). A-weighted values were lower. During the August 2001 – July 2002 monitoring period, maximum measured SEL values (for Vandal launches) near beaches were 129 dB flat-weighted and 113 dBA re 20 $\mu Pa^2 \cdot s$ (Chapter 2). These received SEL values were below (usually by a wide margin) the "conservative" TTS criteria (see Table 1.2 in Chapter 1) of 145 dB SEL for harbor seals and California sea lions, and 165 dB SEL for northern elephant seals (re 20 $\mu Pa^2 \cdot s$). Rationale for these criteria is summarized in Table 1.2 of this report; see also Section 4.7.1.4 of Lawson et al. (1998). J. Francine, quoted in NMFS (2001, p. 41837), mentions evidence of mild TTS in captive California sea lions exposed to a 0.3-sec transient with level 135 dB SEL re 20 $\mu Pa^2 \cdot s$ (see also Bowles et al. 1999). With one possible exception, the measured SEL values near the pinniped beaches during missile launches were also below that 135 dB level.[6]

The TTS criteria assumed above might be conservative—i.e., lower than the minimum levels that can actually elicit TTS. The sound levels that might cause TTS in captive animals in an experimental chamber appear to be higher than those recorded to date during missile launches at SNI. However, more measured and/or modeled acoustic exposure data are needed to confirm this. Insofar as we are aware, no specific data on TTS thresholds in pinnipeds exposed to single short pulses, either in air or underwater, have been published (but see Bowles et al. 1999). TTS thresholds for pinnipeds exposed to prolonged sounds have been documented (Kastak et al. 1999), but these cannot be applied directly to single short

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[6] The exception involved the sounds from the high-angle Terrier Orion launch on 20 September 2001, for which SEL, as measured at Building 807, was determined to be 138 dB, and the A-weighted SEL was determined to be 130 dB (Tables 2.3, 2.4). These values were anomalously high, and the acoustical contractor suspects that some measurement problem resulted in incorrect acoustical estimates at that location (see §2.4.1). SEL values of 136 and 137 dB were measured 50 ft from the AGS launcher, but that was well inland and levels near the pinniped beaches were much lower (Table 2.3).

pulses. The data from Bowles et al. (1999) may be relevant to short sound pulses; however measurement methods, exposure paradigm, and differences in units render a comparison difficult. The TTS criteria used in this report for exposure of pinnipeds on land to transient in-air sounds are based on very limited data and need verification (see Section 4.7.1.4-A, *in* Lawson et al. [1998]). However, the acoustical monitoring results suggest that pinnipeds were not exposed to SEL values of 145+ dB re 20 µPa^2·s during the missile launches in August 2001 – July 2002. If any were exposed to an SEL above 135 dB, this was exceptional, and the SEL barely exceeded 135 dB.

Permanent hearing damage or "Permanent Threshold Shift" (PTS) would not be expected unless the received levels were considerably higher. This issue was discussed at the NMFS-organized "Acoustic Criteria" workshop (see also Gisiner [ed.] 1999). The consensus 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.

A number of ATARs overloaded during launches and thus provided no quantitative data on launch sounds (Chapter 2). It is possible that the average received level at overloaded ATARs was greater than that for non-overloaded ATARs. However, 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.

Overall, the results to date indicate that there is little potential for TTS or especially PTS in pinnipeds hauled out near the missile azimuths during the missile launch operations. This conclusion is necessarily speculative given the lack of directly relevant TTS data. In the event that levels ever are sufficiently high to cause TTS, these levels would be only slightly above the presumed thresholds for mild TTS. Thus, in the event that TTS ever did occur, it would presumably be mild and reversible (i.e., no PTS). Given the relatively infrequent launches from San Nicolas Island, and the fact that a given pinniped is not always present on land, there appears to be no likelihood of PTS from the cumulative effects of multiple launches.

4.3 Conclusions Regarding Effects on Pinnipeds

Disturbance was 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. Missile launch activities conducted during August 2001 – July 2002 appeared to cause no more than limited, short-term, and localized disturbance. With the exception of some harbor seals, most remained in the haul-out areas (see Chapter 3). There was no evidence that pinniped reactions to launches resulted in any pup mortality.

Levels of missile sounds recorded at beach locations around western San Nicolas Island during launch operations were up to 129 dB (and possibly 138 dB) SEL re 20 µPa^2·s flat-weighted, and up to 130 dBA SEL on an A-weighted basis. Although these values represent substantial noise pulses, they are generally below the level expected to be necessary to cause either temporary or especially permanent hearing impairment (see the discussion regarding ATAR overloading in the preceding section).

4.4 Estimated Numbers of Pinnipeds Affected by Launches

The approach to estimating the numbers of pinnipeds affected by launch sounds 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 and presumably reacting in the same manner. The total numbers of such affected pinnipeds were calculated only for the period during and immediately following the 19 launches on 14 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 site during a launch. The harbor seals that remained hauled out were increasingly vigilant for several minutes, but then settled back to the behavior pattern they exhibited prior to the launches (e.g., resting).

For California sea lion and northern elephant seal groups, which 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 section 4.1) were then extrapolated to the estimated total number of individuals hauled out in this area to derive an estimate of the total number of pinnipeds affected (Table 4.1). Despite this extrapolation, there may have been haul-out groups that were equally close to the launch azimuths that were not recorded at all, and not included in the extrapolation process. This would include pinnipeds on other beaches not monitored on a given launch date. Because of this, these estimates of the numbers of pinnipeds affected by launch sounds should be regarded as probable underestimates. While these numbers maybe underestimates, it is not likely that any of the pinnipeds present on western San Nicolas Island were adversely impacted by such reactions, given the results from the beaches that were monitored.

TABLE 4.1. Minimum estimated numbers of California sea lions, harbor seals, and northern elephant seals affected by launch sounds from the Navy's missile launch program on San Nicolas Island, August 2001 – July 2002. Includes only the animals on specific beaches that were monitored on each launch date.

Date	Missile Type	Cal. Sea Lions (focal+ extrap.)	Harbor Seals	Northern Elephant Seals
15 August	Vandal	60 + 85	22	-
20 September	Vandal	26 + 75	25	0
20 September	Terrier Orion	45 + 36		
5 October	Vandal	33 + 70	15	-
19 October	Vandal	56 + 60	-	10 + 35
19 December	Vandal	45 + 50	-	-
14 February	Vandal	-	-	0
22 February	Vandal	-	-	0
6 March	Vandal	20 + 70	60	-
1 May	Vandal	37 + 83	20	2*
8 May	Vandal	10 + 90	62	3*
19 June	AGS Test Slug	5 + 15	-	0
21 June	RAM	5 + 29	-	0
26 June	AGS	0	0	-
18 July	Vandal	7 + 30	-	-
	Total	1042	204	50

* Incidental sightings of elephant seals at harbor seal haul-out sites. These elephant seals seemed to react to the movement of the surrounding harbor seals, instead of the launch sounds.

Navy personnel did not sight any northern fur seals or Guadalupe fur seals on SNI from August 2001 to July 2002, and none were evident in the video segments that were analyzed.

There was no evidence of injury or mortality during any of the launches. However, dead pups were sometimes reported during follow-up monitoring the day after missiles were launched. Observations indicated that the pups died several days prior to the actual launch dates, and it is unlikely that their deaths were related to missile launches.

Most of the individuals that left the haul-out sites to enter the water during the launches remained in the shallow water near shore. There appeared to be no increase in aggressive interactions as a result of the reactions to the launches.

All of the haul-out sites continued to be occupied in subsequent days following the launches.

4.5 Summary

This chapter provides estimates of the numbers of pinnipeds affected by the Navy's missile launches on San Nicolas Island, California, August 2001 – July 2002, based mainly on information provided in previous chapters of this report.

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 138 dB SEL re 20 $\mu Pa^2 \cdot s$ or above 130 dBA SEL, so TTS is unlikely and PTS is highly unlikely. (Since some ATARs overloaded during recording, likely due to incorrect gain settings, more data will be necessary to confirm these maximum sound exposure levels.)

Approximately 1042 California sea lions, 204 harbor seals, and 50 northern elephant seals are estimated to have been affected by launch sounds. These pinnipeds left the haul-out site in response to the launch, or left the water at a vigorous pace, 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 these pinnipeds on San Nicolas Island were adversely impacted by such behavioral reactions.

The results suggest that any effects of these launch operations were minor, short-term, and localized, with no consequences for the pinniped populations. Any localized displacement of pinnipeds was of short duration (although some harbor seals may have left their haul-out site until the following low tide), and numbers occupying haul-out sites shortly after a launch, or the next day, were similar to pre-launch levels.

Several dead pups were seen during follow-up monitoring the day after missiles were launched. Since observations indicated that these pups died several days prior to the actual launch dates, their deaths probably were not related to missile launches. There was no evidence of injury or mortality during any of the launches, and the haul-out sites continued to be occupied in subsequent days.

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6. LITERATURE CITED

Bowles, A.E., L. Wolski, E. Berg and P.K. Yochem. 1999. Measurement of impulse noise-induced temporary threshold shift in endangered and protected animals--two case studies. **J. Acoust. Soc. Am.** 105(2, Pt. 2):932.

Burgess, W.C. and C.R. Greene, Jr. 1998. BQM-34S and vandal missile target launch sound measurements recorded at San Nicolas Island and NAWS Point Mugu. Rep. from Greeneridge Sciences Inc., Santa Barbara, CA, and Ogden Environ. & Energy Services Inc., Santa Barbara, CA, for Naval Air Warfare Cent., Weapons Div., Point Mugu, CA. 26 p.

Burgess, W.C. and C.R. Greene Jr., with R. Norman and R.W. Blaylock. 1999. Physical acoustics measurements. p. 3-1 to 3-65 *In:* W.J. Richardson (ed.), Marine mammal and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1998. LGL Rep. TA2230-3. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for Western Geophysical, Houston, TX, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 390 p.

Gisiner, R.C. (ed.). 1999. Proceedings/Workshop on the effects of anthropogenic noise in the marine environment, Bethesda, MD, Feb. 1998. Office of Naval Research, Arlington, VA. 141 p. Available at www.onr.navy.mil/sci%5Ftech/personnel/cnb%5Fsci/proceed.pdf.

Greene Jr., C.R. 1999. Vandal missile target launch sound measurements recorded at San Nicolas Island on 22 and 26 August 1999. Greeneridge Rep. 231-01. Rep. from Greeneridge Sciences Inc., Santa Barbara, CA, for Naval Air Warfare Cent., Weapons Div., Point Mugu, CA. 8 p.

Harris, F.J. 1978. On the use of windows for harmonic analysis with the discrete Fourier transform. **Proc. IEEE** 66(1):51-83.

Kastak, D., R.J. Schusterman, B.L. Southall, and C.J. Reichmuth. 1999. Underwater temporary threshold shift induced by octave-band noise in three species of pinniped. **J. Acoust. Soc. Am.** 106(2):1142-1148.

Kinsler, L.E., A.R. Frey, A.B. Coppens, and J.V. Sanders. 1982. Fundamentals of Acoustics. John Wiley & Sons, New York, NY. 480 p.

Kryter, K.D. 1985. The effects of noise on man. Academic Press, Orlando, FL. 688 p.

Lawson, J.W., W.R. Koski, W.J. Richardson, D.H. Thomson, and C.I. Malme. 1998. Biological consequences for marine mammals. p. 183-279 (plus Appendices) *In:* Point Mugu Sea Range marine mammal technical report. Rep. from LGL Ltd., King City, Ont., for Naval Air Warfare Cent., Weapons Div., Point Mugu, CA.

NMFS. 1996. Small takes of marine mammals incidental to specified activities; Titan II and IV launch vehicles at Vandenberg Air Force Base, CA/Notice of issuance of an Incidental Harassment Authorization. **Fed. Regist.** 61(234, 4 Dec.):64337-64342.

NMFS. 2000. Small takes of marine mammals incidental to specified activities; oil and gas exploration drilling activities in the Beaufort Sea. **Fed. Regist.** 65(197, 11 Oct.):60407-60411.

NMFS. 2001. Small takes of marine mammals incidental to specific activities; missile launch operations from San Nicolas Island, California. **Fed. Regist.** 66(154, 9 Aug.): 41834-41835.

Reeves, R.R., R.J. Hofman, G.K. Silber, and D. Wilkinson (eds.). 1996. Acoustic deterrence of harmful marine mammal-fishery interactions: proceedings of a workshop held in Seattle, Washington, 20-22 March 1996. NOAA Tech. Memo NMFS-OPR-10. U.S. Dep. Commerce, Nat. Mar. Fish. Serv. 70 p.

Richardson, W.J., C.R. Greene Jr., C.I. Malme, and D.H. Thomson. 1995. Marine mammals and noise. Academic Press, San Diego, CA. 576 p.

Welch, P.D. 1967. The use of FFT for the estimation of power spectra: a method based on time averaging over short modified periodograms. **IEEE Trans. Audio Electroacoust.** AU - 15(2):70-73.