1 Executive Summary

This report is prepared in accordance with a National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS; also called NOAA Fisheries Service) five-year permit for the incidental harassment of marine mammals (NOAA 2009), and with two Letters of Authorization (LOAs) issued by NOAA to the United States Air Force, Vandenberg Air Force Base (VAFB), 30th Space Wing (NOAA 2010 and 2011). The period covered by this report extends from 1 December 2010 through 30 November 2011, which overlaps the two LOAs. The report is also required in support of VAFB's pending request to renew the current LOA.

This report describes pinniped monitoring conducted in association with space vehicle and missile launches, together with fixed-wing aircraft and helicopter operations. Species of concern at VAFB include Pacific harbor seals (*Phoca vitulina richardsi*), California sea lions (*Zalophus californianus c.*) and northern elephant seals (*Mirounga angustirostris*). At San Miguel Island (SMI), which sometimes is impacted by sonic booms from space vehicles, the northern fur seal (*Callorhinus ursinus*) is also considered a species of concern in addition to the three species mentioned for VAFB.

During the reporting period there were ten launches involving seven space vehicles and three missiles. Three of the space vehicle launches occurred within the harbor seal pupping season (1 March through 30 June) when monitoring is mandatory at VAFB. Monitoring was not required at SMI for two of these launches because sonic boom modeling indicated that pressures in excess of 1 psf (pound per square foot) were not expected to occur there. (Had this threshold been exceeded, monitoring would have been required there.) Monitoring was required there during one Atlas V launch, however. No indications of abnormal behavior, injury or mortality were reported as a result of any of these three launches (SAIC-MMCG 2011a and b; ManTech SRS 2011b). When reactions to launch effects did occur, they were very short-lived and not significant.

Four other space vehicle launches took place outside the pupping season. Two of these launches were not monitored at SMI because acoustic modeling indicated that no sonic boom exceeding the accepted threshold of 1 psf would occur over the northern Channel Islands, including SMI. Finally, Auditory Brainstem Response (ABR) testing was required for only one of the seven space vehicle launches.

Three missile launches occurred during the reporting period, all from north VAFB. The westward trajectory of these launches from this area did not necessitate any sonic boom modeling for the northern Channel Islands, particularly SMI, so no biological monitoring was required there, either. Two of the missile launches occurred outside of the harbor seal pupping season, so no monitoring was needed for them. One of the missile launches occurred in June,

however, so monitoring was conducted at VAFB for that launch. No indications of abnormal behavior, injury or mortality were reported as a result of this launch (Tetra Tech, Inc. 2011). Finally, no ABR studies were required for any of the missile launches.

During the reporting period, approximately 1694 operations were conducted from the VAFB airfield. Most of these consisted of training exercises involving "touch and goes". A few were logistics flights involving the transfer of supplies and personnel. Ten flights involved unmanned aerial vehicles (UAVs). No indications of abnormal pinniped behavior, injury or mortality were reported as a result of these operations (Evans 2011a).

2 Introduction

This report is prepared in accordance with a NOAA - NMFS five-year permit for the incidental harassment of marine mammals (NOAA 2009). This permit was issued on 25 June 2009 and is valid through 30 June 2014. This report also is in accordance with two LOAs issued by NOAA to the United States Air Force, VAFB, 30th Space Wing. The LOAs cover the periods from 7 February 2010 through 6 February 2011, and from 7 February 2011 through 6 February 2012, respectively (NOAA 2010 and 2011). The period covered by this report extends from 1 December 2010 through 30 November 2011, thus overlapping the two LOAs.

This report provides background information on various operations at VAFB that have the potential for harassment, injury or mortality of marine mammals. Such operations include space vehicle and missile launches as well as fixed-wing aircraft and helicopter operations. The background section also describes marine mammal species of concern in the areas of operation. Species of concern at VAFB include Pacific harbor seals (*Phoca vitulina richardsi*), California sea lions (*Zalophus californianus c.*) and northern elephant seals (*Mirounga angustirostris*). At SMI, the northern fur seal (*Callorhinus ursinus*) is also a species of concern in addition to the three species already mentioned for VAFB. Monitoring was required at SMI in three cases because the modeled sonic booms exceeded the 1 psf threshold. Finally, only one ABR test was required.

The methods section describes techniques used to model sonic booms over the northern Channel Islands. It discusses pinniped monitoring techniques conducted in association with space vehicle and missile launches. It also mentions methods used during monthly pinniped surveys. Finally, it discusses methods used for the ABR tests and acoustic measurements. The results section summarizes the results of the modeling, monitoring, ABR testing, acoustic measurements, and surveys. The discussion section describes natural and human factors that influence haul-out patterns of pinnipeds at VAFB. The report concludes with a discussion of the relative effectiveness of the monitoring and testing efforts and recommendations for future monitoring efforts. A literature cited section is included to guide the reader to various references used in the preparation of this report.

3 Background

3.1 VAFB Operations

3.1.1 Space Vehicle Launches

Seven launches of space vehicles occurred during the reporting period (Table 3.1.1, below). These included one Delta IV Heavy rocket, two Delta II rockets, two Minotaur rockets, one Taurus rocket, and one Atlas V rocket. The Delta IV Heavy rocket carried a classified payload for the National Reconnaissance Office (NRO). The first Delta II rocket carried a satellite that maps salt concentrations in the world's oceans. The second Delta II rocket carried a satellite that collects data on atmospheric and sea surface temperatures, humidity, biological activity on land and at sea, and cloud and aerosol properties. The first Minotaur IV rocket carried a classified payload for the NRO. The second Minotaur IV vehicle carried a Hypersonic [reentry] Technology Vehicle for the Defense Advanced Research Projects Agency (DARPA). The Atlas V rocket carried a classified payload for the NRO. The Taurus carried a satellite designed to gather data on black carbon and aerosols in the earth's atmosphere, and solar irradiation and its long-term effects on the earth's climate. Four of the rockets were launched from south VAFB and three from north VAFB. Each space launch complex (SLC) is usually referred to by an alphanumeric designation. During the period of this report, launches were made from SLC-2W (west), SLC-3E (east), SLC-6, SLC-8, and LF (Launch Facility) 576E (east). The locations of these sites in relation to pinniped haul-out areas are shown in Figures 1 and 2.

Table 3.1.1 Space Vehicle Launches

Vehicle	*Facility*	*Planned launch date*	*Actual launch date*
Delta IV Heavy NROL-49	SLC-6	1 December 2010[1]	20 January 2011[1]
Minotaur IV NROL-66	SLC-8	9 November 2010	6 February 2011
Taurus Glory F-01	LF 576E	22 November 2010	4 March 2011
Atlas V NROL-34	SLC-3E	8 September 2010	14 April 2011
Delta II Aquarius/SAC-D	SLC-2W	29 October 2010	10 June 2011
Minotaur HTV-2B DEMO	SLC-8	10 August 2011	11 August 2011
Delta II NPP	SLC-2W	25 October 2011	28 October 2011

[1]Originally scheduled for 2009, this launch was rescheduled several times. This was the first Delta IV Heavy launch from the West Coast.

3.1.2 Missile Launches

Three missile launches occurred during the reporting period (Table 3.1.2). These included two Minuteman III launches. Minutemen IIIs are Intercontinental Ballistic Missiles (ICBMs), launched from silos on north VAFB. The third launch involved a Missile Defense Agency (MDA) missile, also launched from a silo on north VAFB. Each launch facility (LF) is

abbreviated and numbered. During the period of this report, launches were made from LF-04, LF-10 and LF-23.

Table 3.1.2 Missile Launches

Missile	*Facility*	*Planned launch date*	*Actual launch date*
MDA	LF-23	14 December 2010	15 December 2010
Minuteman III GT-204GM	LF-10	22 June 2011	22 June 2011
Minuteman III GT-205GM	LF-04	27 July 2011	27 July 2011

3.1.3 Fixed-wing Aircraft and Helicopter Operations

Various types of fixed-wing aircraft fly from VAFB. All aircraft are required to maintain a 1000-foot "bubble" around pinniped haul-out and rookery sites; in other words, they must stay 1000 feet above or around any pinniped site. Helicopters, used mainly for launch surveillance and search and rescue operations, must also maintain the same bubble. Exceptions can be made if an emergency search and rescue operation, a security breach or an aircraft emergency occurs.

3.2 Pinniped Species of Concern

NMFS is concerned about the potential impacts of anthropogenic noise on marine mammals (Carretta *et al.* 2010). Such potential impacts include harassment from launch or aircraft noise, particularly sonic booms, which may result in a startle response. In some cases, sudden disturbances from a variety of causes have resulted in the trampling of pups by adult animals, resulting in injuries or mortalities. Other potential noise impacts include temporary [hearing] threshold shift (TTS), in which an animal's hearing is temporarily diminished over part or all of its hearing range. Severe cases can involve permanent [hearing] threshold shift, in which the animal's hearing is permanently diminished over part or all of its hearing range. The requirements of the incidental harassment permit and LOAs, including mitigation monitoring, ensure that such impacts are very unlikely to occur as a result of VAFB operations.

Harbor seals are the most abundant pinnipeds at VAFB. The last estimate of total population size at VAFB was 1,115, made in 2002, while the greatest number seen hauled out at any one time was 502 (SRS Technologies 2003). Harbor seals regularly haul out on isolated sandy coves, ledges and rocks. Three main harbor seal haul-out sites exist on north VAFB (Figure 1). On south VAFB (Figure 2), a small haul-out area exists on some rocks and ledges immediately offshore from the breakwater at Vandenberg Harbor. Approximately 0.7 kilometers (km) to the west, a series of rockbound sandy coves, ledges and offshore rocks begins, extending for about 1.9 km northwest to south Rocky Point. Here, harbor seals haul out and bear their young. Although individual sites have been named, the animals freely wander from one location to the next depending upon tides, potential threats from land and other factors. This stretch is really an

almost continuous haul-out and rookery area. South Rocky Point, the northernmost haul-out site on south VAFB, lies about 1.8 km south of SLC-8, the nearest launch facility.

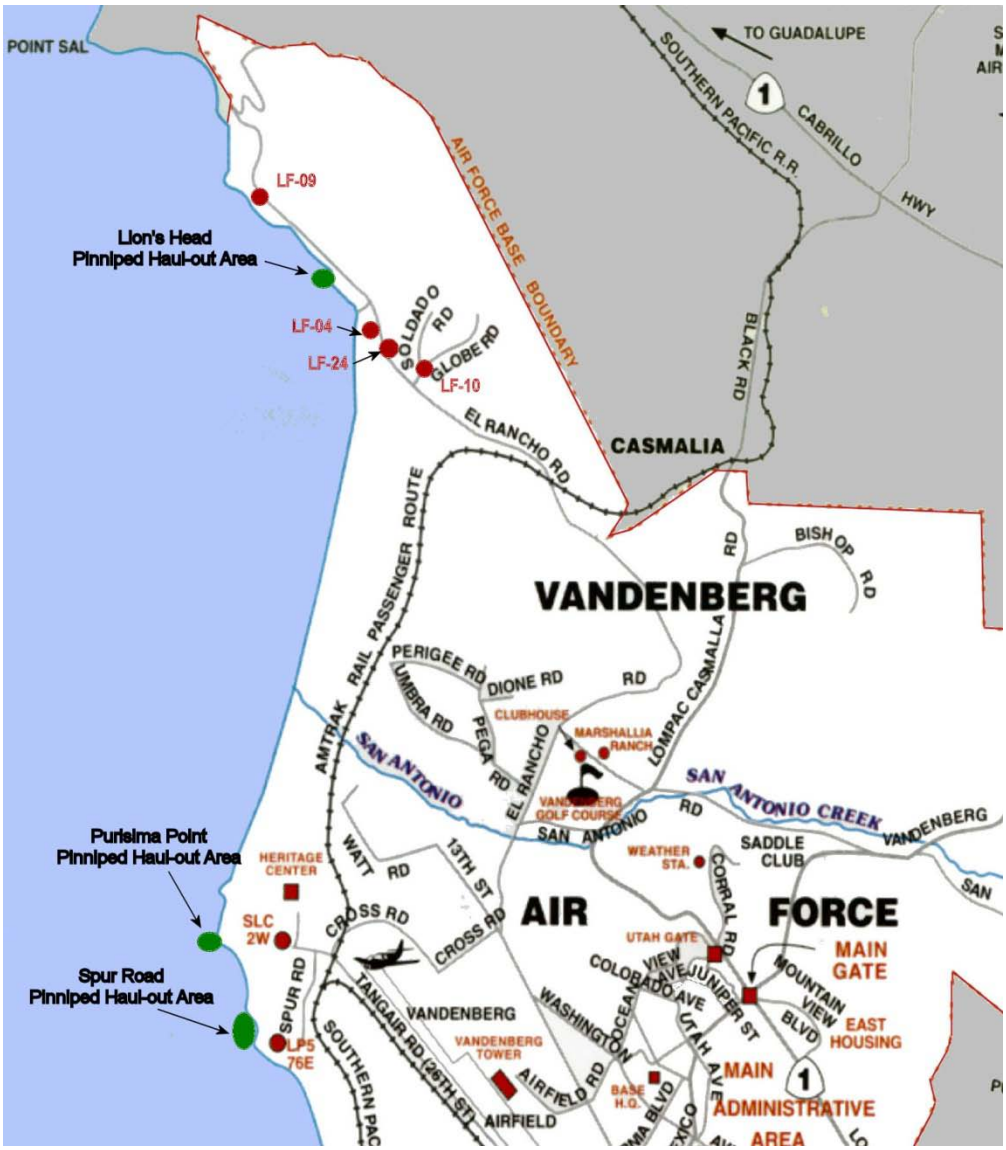

Figure 1. Launch Sites and Pinniped Haul-out Areas on North VAFB

These are distinctly separate sites. One is at the end of Spur Road, another at Purisima Point, and a third at Lion's Head. (Access to Purisima Point is currently restricted because of recently discovered unexploded ordnance.) The first two sites lie between 0.7 and 1.3 km from the nearest launch facilities, while the last site (Lion's Head) is about 1.3 km from the nearest facility (Figure 1).

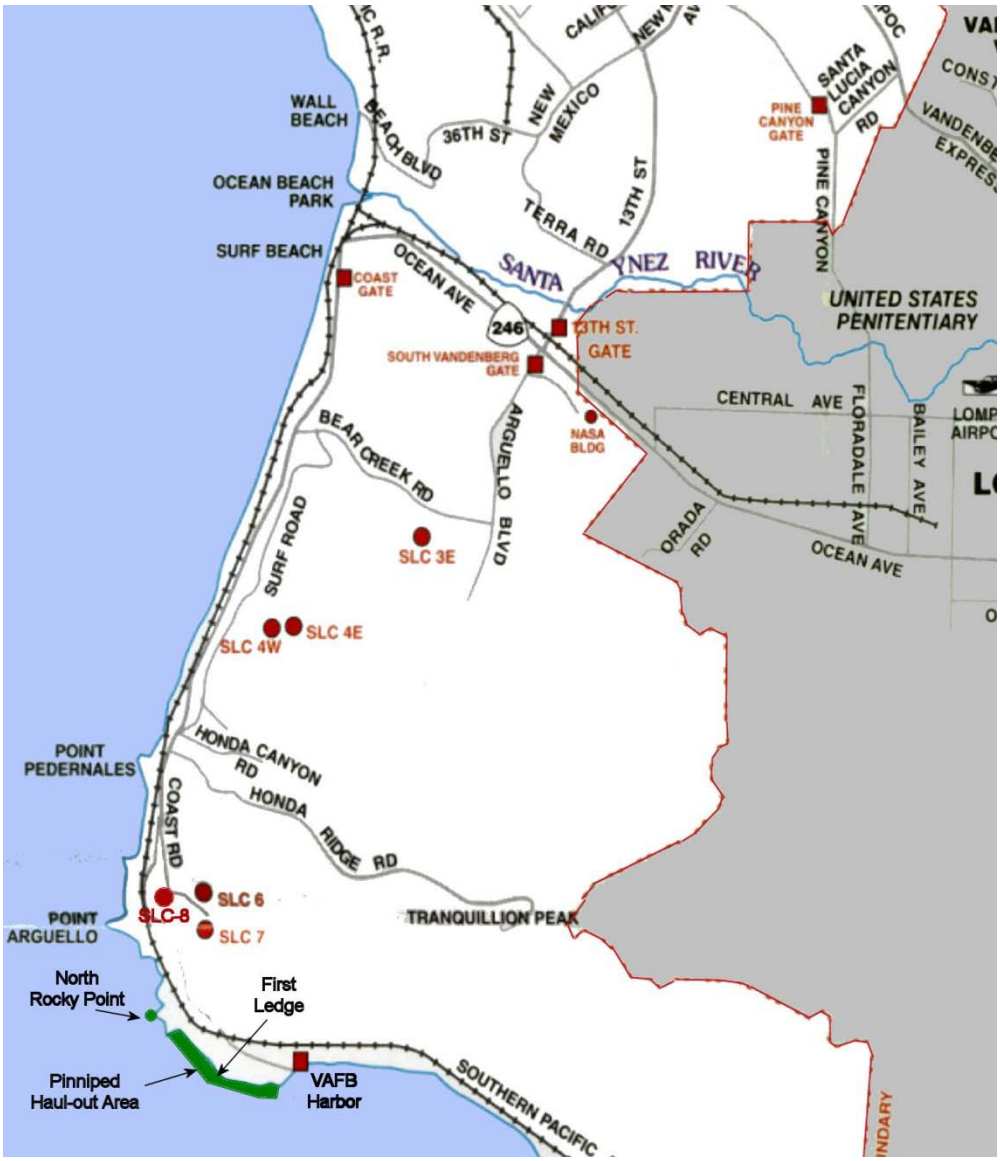

Figure 2. Launch Sites and Pinniped Haul-out Areas on South VAFB

California sea lions haul out in late spring and summer at north Rocky Point, about 1.5 km west of the nearest launch facility. A few pups have been born there some years, but the site is not considered an established rookery. Sea lions are frequently seen immediately offshore of VAFB and individuals occasionally haul out at various locations throughout the base. These are considered transients, or in some cases, stranded animals.

Northern elephant seals haul out occasionally at VAFB, usually as individuals. A small haul-out area at Point Conception, south of VAFB, has been established by these seals. Challenges related to private land access have temporarily halted monitoring there.

4 Methods

For reasons described in the following sections, mitigation requirements varied from launch to launch. These are summarized below:

Table 4.0 Launch Mitigation Requirements

Vehicle or missile	*Launch date*	*Monitoring*	*ABR Testing*	*Boom Model*	*Acoustics*	*Time Lapse*
MDA	15 December 2010	Not required	Not required	Not required	Not required	Not required
Delta IV Heavy	20 January 2011	Required	Required	Required	Required	Required
Minotaur IV	6 February 2011	Not required	Not required	Not required	Not required	Not required
Taurus Glory	4 March 2011	Required	Not required	Required	Not required	Not required
Atlas V	14 April 2011	Required	Not required	Required	Required	Not required
Delta II	10 June 2011	Required	Not required	Required	Not required	Required
Minuteman III	22 June 2011	Required	Not required	Not required	Not required	Required
Minuteman III	27 July 2011	Not required	Not required	Not required	Not required	Not required
Minotaur	11 August 2011	Not required	Not required	Not required	Not required	Not required
Delta II	28 October 2011	Required	Not required	Required	Not required	Not required

4.1 Sonic Boom Modeling

Pre-launch sonic boom modeling was performed prior to five of the seven scheduled space vehicle launches. Nominal flight trajectory information from each launch vehicle was incorporated into PCBoom3 or PCBoom 4, a sonic boom prediction program, along with numerous samples of various meteorological conditions that might be expected during each launch. From these data, the models predicted peak amplitudes and impact locations.

For the other space vehicle launches, modeling was not required because of the vehicles' westerly trajectories or previously well-documented acoustic properties. Since the missile launches were to be performed at north VAFB in a westerly trajectory north of SMI, no modeling was necessary for these launches, either.

4.2 Launch Monitoring

Monitoring methods were essentially the same except as noted otherwise in the following subsections. Biological monitoring during the rocket launches was conducted by two firms. MMCG-SAIC monitored during the 4 March Taurus Glory launch and the 14 April Atlas V launch (MMCG and SAIC 2011a and b). ManTech SRS monitored during the 20 January Delta IV Heavy launch (ManTech SRS 2011a) and the 10 June (ManTech SRS 2011b) and 28 October Delta II launches (ManTech SRS in prep). Monitoring was required during only one missile launch, on 22 June. This was conducted by Tetra Tech, Inc. (2011).

Monitoring was not required for all launches. Launches that were not expected to produce a sonic boom of 1 psf or more over the northern Channel Islands did not have to be monitored on the islands. In other cases, the trajectories of the vehicles or missiles carried them away from the

northern Channel Islands so no sonic boom could have occurred there, hence no modeling or monitoring was required at the northern Channel Islands. In other cases, the rockets or missile types and configurations in relation to the noise they produce had been well-documented and did not require further acoustic or biological monitoring. Sites at VAFB often did not have to be monitored if the launches occur outside of the harbor seal pupping season.

4.2.1 Timing

Pinniped monitoring during launches is required by the LOAs during the harbor seal pupping season, from 1 March through 30 June. Three rocket launches and one missile launch occurred during this period. Under the LOAs, the monitoring must start at least 72 hours before each launch and continue to 48 hours after the launch. Follow-up monitoring must also be conducted two weeks after each launch during pupping season. Monitoring must be conducted as close to each launch window as possible. Marine mammal counts were made hourly during each monitoring period, or more often if substantial changes occurred in the number of animals present. Nighttime monitoring was not allowed because of personnel safety concerns—the bluffs overlooking the haul-out sites were unstable and subject to sudden collapse. Visual monitoring was not allowed during launches because of personnel safety concerns, but the monitors returned to the observation points as soon as each launch area was reopened. This was not always possible on launch days, especially with afternoon launches.

4.2.2 Site Selection

On north VAFB, Spur Road was the closest accessible harbor seal haul-out area to the SLC-2W and LF 576E rocket launch sites. Purisima Point was actually closer to SLC-2W, but access to the point was restricted at the time because of unexploded ordnance (MMCG and SAIC 2011a and b; ManTech SRS 2011a). The closest harbor seal haul-out area to the 22 June 2011 Minuteman III launch at LF-10 was at Lion's Head. The next closest site, at Purisima Point, was more than 11 km away (Figure 1). At south VAFB, the closest haul-out sites to SLC-3E and SLC-6 began at north Rocky Point and extended to VAFB Harbor (Figure 2).

4.2.3 Monitoring

Monitors observed harbor seals from the bluffs overlooking the haul-out sites. When possible, animals in view from a distance were counted prior to reaching the observation point in case something disturbed them before the observer arrived. By approaching very slowly and maintaining a minimal profile, disturbances to the animals were avoided. High-end binoculars, which provided clear and bright magnification of the animals, were used. For distant animals, a 20- to 60-power spotting scope on a tripod was used. Counts were made hourly or more often if any significant changes occurred. Only harbor seals hauled out of the water were counted, in accordance with accepted NOAA Fisheries Service monitoring methods. (Animals in the water, especially when numerous, are impossible to distinguish from one another as they surface to

breathe, submerge, then re-surface, often in another location.) Sightings of other marine mammal species, whether in the water or not, were also recorded, along with other wildlife such as seabirds or terrestrial animals on or over the bluff. Such sightings were incidental and not meant to be comprehensive because the focus was upon pinnipeds.

4.2.4 Data Recording

Data were recorded as to species observed, total number of animals observed, number of males and females (if determinable), number of adults, juveniles and pups, and their behavior. Remarks were recorded as appropriate, including the nature and cause of any disturbance, including natural factors as well as human-related disturbances, such as people on the bluffs or beaches, in boats, low-flying aircraft, or passing trains. Incidental information was recorded on other wildlife.

Environmental data recorded included time and level of tides, visibility, percentage and type of cloud cover, air temperature, wind direction and velocity, and swell direction and height. In recording environmental data for the Delta IV Heavy and Delta II launches, tidal data were obtained from a tidal prediction program, JTides 5.2, using data from Port San Luis. Although another station, Avila, was closer, it was felt by ManTech SRS that conditions at Port San Luis more accurately reflected conditions at VAFB (ManTech SRS 2011a and b).

A remote approach toward recording environmental data was used by Tetra Tech, Inc., when monitoring for the 22 June Minuteman II launch. Wind speeds were downloaded from the Pt. Arguello weather station (Station PTGC1), and when that was not available, from the Santa Maria weather buoy (NOAA Station 46011), which is 21 nautical miles northwest of Pt. Arguello and some 15 miles offshore, while swell heights and temperatures were obtained from Platform Harvest, more than 20 nautical miles south and also well offshore from the monitoring site. This was done because swell height and temperature data were not available from the other stations. Data were not recorded on site (Tetra Tech, Inc., 2011).

For the other two rocket launches, MMCG – SAIC recorded actual environmental conditions on site upon arrival and hourly thereafter until departure. Environmental data were also recorded when any significant changes occurred, such as sudden increases in wind or rapid onset of fog. Tidal data were obtained from NOAA for Point Arguello itself. Air temperature, wind direction and velocity, and swell direction and height were recorded onsite (MMCG and SAIC 2011a and b).

4.2.5 Remote Video Photography

In two instances, time-lapse video photography was set up to count seals before, during, and after launches. For the 20 January 2011 Delta IV Heavy launch, time-lapse video was directed toward a selected section of Flat Iron Rock, on south VAFB (ManTech SRS 2011a), where large

numbers of harbor seals congregated. For the 10 June 2011 Delta II launch, time-lapse video was set up overlooking the haul-out rocks at the Spur Road trailhead (ManTech SRS 2011b). No remote video monitoring was performed during the 22 June missile launch because of "access restrictions and unannounced delays" (Tetra Tech, Inc. 2011).

Remote video monitoring was not performed during the 4 March and 14 April rocket launches because these occurred in darkness (MMCG and SAIC 2011a and b).

4.3 ABR Testing

Auditory brainstem response (ABR) testing was performed for the 20 January 2011 Delta IV Heavy launch. ABRs are electrical potentials generated by the discharge of neurons in major cell groups in the brainstem when the ear is stimulated by sound. To perform an ABR test, a seal is captured, then restrained. Restraining "boards" can be used for this purpose; this technique is so gentle that seals sometimes fall asleep during testing. Occasionally, seals are administered sedatives if they remain agitated under restraint.

Headphones are placed over the ears of the seals. Sound stimuli in the form of clicks and bursts are broadcast through the left earphone; low level white noise in the right to reduce electrical potentials from the right ear. The sound stimuli are delivered at levels sufficient to record reliable waveforms, then diminished 10 decibels (dBs) at a time until the response from the seal is no longer definite. At this point, the levels are increased in 10 dB increments until the original level is reached. Responses are measured through sterile electrodes inserted under the skin.

The first test is performed before the launch; a second one after it to determine whether any changes have occurred in the ability of the animal to hear the faintest sounds. Following testing, the animals are allowed to recover from the effects of sedatives (if any), tagged on the hind flippers, then released (ManTech SRS 2011a).

4.4 Acoustic Measurements

Acoustic measurements were made at VAFB of the launch noise of the Delta IV Heavy launch, using a TEAC DAT recorder and a Larson-Davis sound level meter. Specifications of this equipment and accessories are detailed in the launch report (ManTech SRS 2011a). Acoustic monitoring was also performed during the 14 April Atlas V launch, this time at San Miguel Island. A Larson-Davis sound level meter was also used for the measurements, along with a Sony DAT recorder. Specifications of this equipment and accessories are detailed in the launch report (MMCG and SAIC 2011b).

4.5 Monthly Surveys

The monthly marine mammal surveys were generally timed to coincide with the lowest daytime tides of each month, when the largest numbers of animals would presumably be hauled out. This timing was not always possible if the tides occurred too close to sunrise or sunset, since about two hours was required for surveying each end of VAFB (north and south), for a total of four hours of surveys, starting two hours before the low tide and ending two hours afterwards. Occasional base or area closures also sometimes precluded monitoring on a given day, in which case the next best day was selected.

During the monthly surveys, the MMCG - SAIC team had one NOAA-approved monitor, as required in the LOAs, visit each site. In addition, another person accompanied the monitor for safety reasons. In case of accident, the safety person could have radioed for assistance. Counts were made and recorded at each site, then the team would move to the next site. Other than not repeating the counts every hour, the same monitoring protocols described in Section 4.2.3, above, were used (MMCG and SAIC 2011c and in prep).

4.6 Fixed-wing Aircraft and Helicopter Operations

Records from the Vandenberg Airfield were checked to determine the number and nature of flights performed during the reporting period. Questions were asked as to whether any reactions to flights on the part of marine mammals were observed or reported (Evans 2011a).

5 Results

5.1 Sonic Boom Modeling

Sonic boom modeling was required for five of the seven rocket launches. The two others involved comparatively small Minotaur rocket launches, which had been modeled several times in the past, so no modeling was required for them, nor was any modeling required for any of the three missile launches because of their westerly trajectories and known acoustic characteristics. The following table summarizes the results of the five sonic boom models. Detailed reports that included sonic boom modeling results were prepared for launches in which sonic booms were expected to exceed 1 psf at the northern Channel Islands (ManTech SRS 2011a and b; MMCG and SAIC 2011b; Ball 2011). In addition, a detailed report is available for the 4 March 2011 Taurus Glory launch, since biological monitoring was required at VAFB because this launch occurred within the harbor seal pupping season (MMCG and SAIC 2011a).

Table 5.1.0 Sonic Boom Modeling Results

Vehicle	*Launch Date*	*Sonic Boom Model Results*
Delta IV Heavy NROL-49	20 January 2011	< 1 psf at northern Channel Islands
Taurus Glory F-01	4 March 2011	< 1 psf at northern Channel Islands
Atlas V NROL-34	14 April 2011	> 1 psf at northern Channel Islands
Delta II Aquarius/SAC-D	10 June 2011	< 1 psf at northern Channel Islands
Delta II NPP	28 October 2011	> 1 psf at northern Channel Islands

5.2 Launch Monitoring

5.2.1 Visual Monitoring

Biological monitoring was not required for all of the launches, as described previously. The following subsections describe launches during which monitoring was required.

20 January 2011 Delta IV Heavy Launch

During the pre-launch monitoring period, from 17 through 19 January, from 0 to 142 harbor seals of all age classes were noted at south VAFB, although no dependent pups were reported. No visual monitoring was conducted during the launch (please see Section 5.2.3). Post-launch counts were lower than pre-launch counts and ranged from 0 to 55 animals. High tides and swells on the day following the launch may account for the lower numbers. No sick, injured or dead animals were noted, nor were any disturbances from any source reported. One male northern elephant seal was seen on the first day of monitoring (ManTech SRS 2011a).

4 March 2011 Taurus Glory Launch

Initial pre-launch monitoring started near the Spur Road trailhead at VAFB on 20 February 2011 and continued through 23 February, at which time the launch was postponed. Counts ranged from 1 to 34 adult harbor seals and 1 to 5 juveniles, for a maximum total at any one time of 39. Pre-launch counts were again started on 1 March and continued through 3 March. From 4 to 43 adults were seen, 1 to 11 juveniles, and a maximum of 53 animals at any one time during this period. Once access to the site was gained a few hours after the launch, the count was from 3 to 44 adults, 1 to 9 juveniles and a maximum number at any one time of 53. Post-launch counts on 5 and 6 March ranged from 1 to 24 adults, 1 to 9 juveniles, and a maximum of 34 animals at any one time. The follow-up count on 18 March totaled 1 to 17 adults, 1 to 2 juveniles, and up to 19 animals at one time. No pups were noted during any of the counts.

One juvenile California sea lion was noted offshore on 5 March. Southern sea otters (*Enhydra lutris* nereis) were noted nearshore on all monitoring days. Numbers varied from 1 to 10 adults, 0 to 2 juveniles, and 0 to 2 pups. Coastal bottlenose dolphins (*Tursiops truncatus*) were

observed on two occasions. Two were recorded on 21 February, then on 1 March, two groups were seen, with seven adults and two juveniles in one pod, and six adults in another. Two gray whales (*Eschrichtius robustus*) were seen offshore on 21 February, along with a single animal on 1 March MMCG and SAIC 2011a).

14 April 2011 Atlas V Launch

Monitoring for this launch was conducted throughout the 11 harbor seal haul-out sites on south VAFB, along with separate monitoring at Cuyler Harbor, San Miguel Island. During the pre-launch monitoring period at VAFB, from 12 through 14 April (the day of the launch), from 128 to 138 adult harbor seals were noted. During this same period, from 11 to 19 juveniles were reported, along with between 35 to 39 pups. Maximum totals on any one day were 207. Post-launch monitoring was conducted from 15 through 17 April. (The extra day of sightings was gained because sea otters had to be counted for up to three days after the launch.) Total numbers of adults ranged from 137 to 183; juveniles from 33 to 59, and pups from 40 to 48, with a maximum total on any one day of 280. A follow-up count was made on 28 March, in which 214 adults were reported, along with 29 juveniles and 46 pups, for a maximum total of 289 animals. One gray whale was seen on 17 April (MMCG and SAIC 2011).

Northern elephant seals congregated in a small cove within Cuyler Harbor, on San Miguel Island. Pre-launch counts conducted from 11 through 13 April ranged from 81 to 259 adults and 112 to 212 "weaners" (newly weaned pups), for a maximum total on any one day of 468. Counts on launch day ranged from 220 to 239 adults and 200 to 219 weaners. Maximum total on that day was 445. Post-launch counts, performed from 15 through 16 April, ranged from 240 to 273 adults and from 208 to 288 weaners, for a maximum total of 561 animals (MMCG and SAIC 2011).

Harbor seals were noted in the nearshore waters on two separate days. Numbers varied from one to four. From one to two California sea lions were also seen in the nearshore waters on 13 and 16 April. A juvenile gray whale, likely the same animal, was seen between Prince Island and Cuyler Harbor on 14 and 15 April (MMCG and SAIC 2011b).

10 June 2011 Delta II Launch

During the pre-launch monitoring period, from 6 through 9 June, counts of harbor seals, near the Spur Road trailhead on VAFB, ranged from zero to six, including one pup on 8 June. No seals were seen on launch day, 10 June, on the post-launch survey days, 11 through 12 June, and during the follow-up survey on 17 June. Tides were relatively high during the period 10 through 12 June, however, submerging the most desirable haul-out sites. Moreover, coyotes were seen prowling among the intertidal rocks on 17 June (ManTech SRS 2011b).

22 June 2011 Minuteman III Launch

Pre-launch monitoring was conducted at Lion's Head on VAFB on 18 June and on 20 through 21 June. Between three and seven adult harbor seals were noted. From three to seven animals were noted about two hours after the launch on 22 June. (Access was not allowed until that time because of personnel safety concerns.) Time lapse video counts were not made at the time of launch (please see Section 5.2.3). A post-launch count, conducted on 23 June, revealed from eight to nine animals. A follow-up survey, in which two to four animals were noted, was made on 7 July. No pups were observed during any of the counts (Tetra Tech, Inc. 2011).

28 October 2011 Delta II Launch

Biological monitoring for this launch was required at San Miguel Island, since the sonic boom models predicted overpressures in excess of 1 psf there. Monitoring was conducted at a section of east Adam's Cove. California sea lions, northern elephant seals and northern fur seals were present. Numbers of California sea lions ranged from 211 to 1,105 animals. These numbers rose on the day of the launch and during the two days afterwards, probably because many females and juveniles returned from the sea, coupled with others coming from a nearby area. Numbers of northern fur seals declined slightly during the same period, probably displaced by the sea lions. Their numbers ranged from 73 to 315. Elephant seal numbers ranged from 56 to 127.

No reactions were noted on the part of the sea lions and elephant seals, either from the launch, which was plainly visible during the predawn hours, or from the sonic boom, which was heard at 0253 hours. Six adult fur seals raised their heads in response to the sonic boom, but settled back down after two to four minutes. No evidence of injury, mortality or abnormal behavior was reported as a result of the launch (Ball 2011). Additional details will be available when the launch monitoring report has been completed (ManTech SRS in prep).

5.2.2 Environmental Conditions

Recording environmental conditions is important for two primary reasons: First, conditions can affect the ability of an observer to accurately monitor a given area; second, conditions can affect the presence, absence or relative abundance of animals at a given site.

Visibility is a prime factor for viewing, both on land and out (or at) sea. Fog, haze, rain, glare, or dwindling light can affect visibility. In some cases, such conditions can be avoided by checking weather conditions before setting out or by timing observations for periods when visibility is most likely to be clear. Glare over the water makes viewing very difficult, but if the observer can move to avoid glare, this problem is easily solved. In reduced visibility, the observer can always move closer to the site, taking care not to disturb the animals. Very strong wind can also be a problem because it is difficult to see, especially if the wind blows toward the observer. However, selecting a sheltered site can greatly alleviate this problem. Environmental conditions

were noted in detail in various launch monitoring and monthly survey reports, but suffice to say that environmental conditions did not preclude accurate viewing at any time (MMCG and SAIC 2010, 2011a, 2011b, 2011c, and in prep; ManTech SRS 2011 a and b; Tetra Tech, Inc. 2011).

Environmental conditions can and did affect the presence, absence and/or relative abundance of animals at given sites. High breakers or high tides sweeping over haul-out rocks are discussed in numerous places in this report as a reason why animals were either not present or were present in low numbers. Visibility is also a factor in that harbor seals in areas frequented by humans often switch to a nocturnal haul-out pattern to avoid detection. These effects are discussed throughout this report and in the launch monitoring and monthly survey reports (MMCG and SAIC 2010, 2011a, 2011b, 2011c, and in prep; ManTech SRS 2011a and b; Tetra Tech, Inc. 2011).

5.2.3 Time-lapse Video Monitoring

Time lapse video monitoring during launch days was required for only three launches, which follow below.

20 January 2011 Delta IV Heavy Launch

Prior to the launch, which occurred at 1310 Pacific Standard Time (PST), 48 adult harbor seals were hauled out within view of the camera frame at Flat Iron Rock. As the launch began, the seals raised their heads and started for the water. Within slightly more than one minute after the launch, all but two seals had entered the water. The last two had moved to within eight feet of the water. Within 50 minutes after the launch, 57 harbor seals had hauled out, a few at a time, in the same area (ManTech SRS 2011). Because of the limited view of the camera, the total number of animals disturbed at the site could not be determined, nor the total number that had returned to the site. It is very possible that some of the seals taped after the launch could have returned from the immediate area but from outside the camera frame. However, the fact that more animals returned indicates that effects from the launch were very transitory and not significant (ManTech SRS 2011a).

10 June 2011 Delta II Launch

Although a remote video camera was set up near the Spur Road trailhead for this launch, no seals were recorded before, during or after the launch (ManTech SRS 2011b).

22 June 2011 Minuteman III Launch

No remote video monitoring was performed during the 22 June missile launch because of "access restrictions and unannounced delays" (Tetra Tech, Inc. 2011).

5.3 ABR Testing

ABR testing was required only for the Delta IV Heavy on 20 January 2011. Three healthy juvenile harbor seals were captured near Pt. Conception 28 hours before the launch. They were taken to the Boathouse at Vandenberg Harbor, where they were kept in a shaded enclosure with a small, portable pool filled with salt water. They were placed on restraining boards for the testing. Two of the animals were very calm and even fell asleep during testing. One was somewhat agitated, so it was mildly sedated. ABR testing, as described in Section 4.3, was conducted the day before the launch and nearly three hours after the launch. (The delay in post-launch testing was because access to the site was limited after the launch because of personnel safety issues.) After testing, the animals were tagged and released at the Boathouse.

The animals showed no change in hearing sensitivity as a result of the tests, although it is possible that a mild TTS, from which the seals had already recovered, could have occurred. Launch noises to which the seals were exposed were not noted because the acoustic monitoring site was in Oil Well Canyon, 2.7 km from the ABR testing site (ManTech SRS 2011a).

5.4 Acoustic Measurements

Acoustic measurements were required during only two launches. Results follow below.

5.4.1 Delta IV Heavy Launch

Noise levels recorded during the Delta IV Heavy launch were in a very similar frequency domain compared to noise levels from two Delta II launches in 2006, although the Delta IV Heavy launch was somewhat louder. Most sound energy from the rocket launches was below 1 kHz (1000 Hz). With the Delta IV rocket, the highest levels were below 100 Hz. Unweighted peak levels were 131.8 dB re 20 µPa (ManTech SRS 2011a).

5.4.2 Atlas V Launch

The sonic boom consisted of two positive peaks separated by approximately 100 milliseconds (about one-tenth of a second), followed by a negative spike (underpressure) in which the two corresponding arrival times of the positive peaks nearly coincided. This represented the compression and release of air from a double shock wave from a sonic boom. The maximum overpressure at the recording site on San Miguel Island was 1.01398 psf and the unweighted peak was 109.4 dB re 20 µPa at 2.66 Hz. The frequency spectrum of the acoustic energy was predominantly low frequency, with unweighted peak levels exceeding 80 dB re 20 µPa below 500 Hz. The highest energy was below 100 Hz.

Soon after the rocket lifted off, and well before the sonic boom reached the island, an unusual phenomenon was observed. The water in the harbor appeared to be momentarily displaced in all

directions, even against the wind, which was blowing from 16 to 20 knots at the time on the beach (MMCG and SAIC 2011b; please see Section 6.2.4).

5.5 Monthly Marine Mammal Surveys

Marine mammal surveys are conducted monthly at all known haul-out and rookery sites at VAFB. The results of these surveys are reported monthly, quarterly and annually in separate reports. The results of these surveys can differ from the launch monitoring reports. The monthly surveys are typically conducted during the lowest daytime tides of each month, when the greatest numbers of animals are usually hauled out, whereas the launch surveys are conducted 72 hours before each launch, during each launch itself when possible, and for 48 hours after each launch. Thus, the launch dates and times do not coincide with the lowest tides of the month (MMCG and SAIC 2011c and in prep).

5.6 Fixed-wing Aircraft and Helicopter Operations

During the reporting period, approximately 1694 operations were conducted from the VAFB airfield. Most of these consisted of training exercises involving "touch and goes". A few were logistics flights involving the transfer of supplies and personnel. Ten flights involved unmanned aerial vehicles (UAVs). No indications of abnormal pinniped behavior, injury or mortality were reported as a result of these operations (Evans 2011a).

6 Discussion

6.1 Natural Effects on Haul-out Patterns

6.1.1 Environmental Conditions

Numerous environmental factors affect pinniped haul-out patterns. Tides would seem to be the most obvious: When tides are high, less haul-out area is exposed, especially when breakers are large and sweep over the haul-out areas. However, beach erosion and subsequent buildup of beaches can also affect available haul-out space in relation to tides (please see Section 6.1.2).

Breakers are another obvious factor: When breakers are small, much more haul-out area is available. When breakers are large and sweep over haul-out spots, however, animals can be washed into the surf. This is why MMCG – SAIC considered recording onsite breaker heights essential in reporting environmental conditions. Site-specific determination of breaker heights is important because distant offshore swell heights sometimes ranged as much as three or four times greater than breaker heights at specific locations at the same times and were thus a poor surrogate for on-site measurements (please see Section 4.2.4).

Wind and the resultant wind chill, along with temperature, combine either to make haul-out sites desirable or untenable. On very hot, still days, the animals can overheat and must go into the water frequently to stay cool. Conversely, on cool, windy days the animals often remain hauled out for extended periods. Like swell in remote stations versus at actual haul-out sites, wind velocities and even direction at haul-out sites varied greatly from measurements taken at remote stations. Even nearby stations, such as Point Arguello, often reported far different wind velocities than were actually measured at specific sites.

Visibility can be very significant and for this reason, local conditions should be reported. Fog comes and goes frequently at VAFB, occasionally rendering conditions at a given site impossible for viewing, while a nearby site might remain bathed in bright sunlight. Haze and glare can also affect viewing conditions.

The presence of abundant prey has been suggested as a cause for animals to remain offshore for longer periods. If abundant prey remains nearby, however, the opposite is true: The animals do not have to expend time and energy traveling great distances or seeking prey—it's there for the taking in a short period of time.

Still another factor is daytime versus night. In undisturbed areas, harbor seals typically haul out in the greatest numbers in the afternoons, regardless of tides and breakers, provided that adequate haul-out space is available. In areas where haul-out space is limited, tides and breakers can affect haul-out patterns, thus the seals may haul out during the days when tides and breakers are favorable. In areas subject to chronic disturbance—often from people and dogs on the beach—harbor seals often shift to a nighttime haul-out pattern to avoid harassment (Howorth 1995).

6.1.2 Seasonal and Cyclic Effects

In the previous section, the effect of tides, breakers, wind, temperature, and light on haul-out patterns was discussed. In winter, unusually high tides, large surf and strong currents can strip away sand from beaches, resulting in less haul-out area. With the sand gone, the water actually becomes deeper near shore, meaning even moderately high tides can smother haul-out beaches. Conversely, when sand is deposited during mild conditions and the beaches are built back up, tides must be much higher to reach the same point on shore because the deep area near shore has since been buried in sand. Thus, more haul-out area is available.

However, sand deposition can render rocks normally isolated by water accessible from land or even bury the rocks, sometimes making such areas far less desirable as haul-out sites because of their accessibility from land. As an example, the area from Harbor Seal Beach to Second Cove, on south VAFB, was all but abandoned from summer into fall of 2011. These sites had been occupied by harbor seals to varying extents in previous months. The sites had become accessible from shore because of sand deposition, rendering the seals vulnerable to attack from terrestrial predators (Section 6.1.4). At Broken Back, immediately to the north, large numbers of harbor

seals were congregated, probably because terrestrial predators could be seen from considerable distances from that haul-out site, allowing the seals plenty of time to scramble into the water.

The natural history of each species also is a significant factor in haul-out patterns. Harbor seals generally haul out in substantial numbers during the pupping and breeding season, from March through June at VAFB. Overlapping this to some extent is the molting season, which extends from May into summer. In general, the largest numbers of harbor seals haul out during molting season. Some overlap of haul-out patterns occurred during the course of these monitoring efforts. Following the molt, the numbers of animals hauled out dwindled.

In winter, storm surges, large breakers, strong currents, and/or very high tides can smash pups against the shore or carry them away from the rookeries. Although harbor seal pups can swim within minutes of birth, they often cannot survive heavy surf. If they do not remain where their mothers left them, they sometimes cannot be found, resulting in their becoming orphaned. This happened to one newborn pup from the Spur Road haul-out site. It was rescued, ultimately trained to catch its own meals and released (SBMMC unpublished reports 2011). Pups being washed away from the rookeries is a very common occurrence in other spots along the mainland coast of Santa Barbara County. Every year, orphaned pups are rescued near rookeries at Ellwood and Carpinteria following unusually high tides, large surf, strong currents, or storms. This has become so predictable that rescuers check the beaches near the rookeries immediately following such conditions. Many years ago, such pups were observed from hidden locations so that the mothers could reclaim them, but rescuers soon found that the mothers never returned unless the pups were very close to where they had been left. Pups that were able to stay in the rookeries mostly fared very well and showed no signs of starvation (Santa Barbara Marine Mammal Center 1976-2011).

Increased numbers of dead seals, sea lions and sea otters showing indications of shark bites have been reported by VAFB and U.S. Geological Survey biologists (Evans 2010a and 2011c). Unusual numbers of live-stranded seals and sea lions with bite wounds inflicted by great white sharks (*Carcharodon carcharias*) have been reported during the period 2009 to 2010 in other parts of Santa Barbara County (Santa Barbara Marine Mammal Center 1976-2011). A fresh-dead sea otter, later determined to have been killed by a great white shark, was found between the Spur Road trailhead and Purisima Point during monitoring for the Taurus Glory launch (MMCG and SAIC 2011a). A live harbor seal was observed during one of the monthly surveys with severe wounds likely caused by a great white (MMCG and SAIC in prep). Another was observed near the Spur Road trailhead during the June 2011 Delta II launch monitoring (ManTech SRS 2011b).

6.1.3 Landslides

A series of landslides occurred when the bluffs overlooking Weaner Cove, on south VAFB, began collapsing. A sizable cove once frequented by harbor seals was all but buried under earth

and rocks from the slides. It is quite possible that some harbor seals were buried during one of the major slides.

Figure 3. Landslide at Weaner Cove

The slides are assumed to be caused by natural erosion in an higher than average rainfall year. Beneath the topsoil lay a deposit of Monterey shale. Since the worst slide occurred during a rain, it is likely that the shale acted like a water-lubricated slide. This same phenomenon occurs frequently throughout Southern California. Following the big slide, many areas of the bluffs showed cracks as much as six feet deep and a few feet across. Entire sections of the bluff were poised to collapse with any disturbance, and many parts later did just that.

Weaner Cove has been virtually abandoned by the harbor seals. One or two occasionally hauled out on rocks immediately offshore from what was once the cove. Others began to congregate on small beaches immediately south of the cove, but when the bluffs began collapsing there as well, the seals left. The seals may have dispersed to other sections of the coast to the north and south of Weaner Cove. The entire stretch of coast, from Small Haul-out Two, west of Vandenberg Harbor, to south Rocky Point offers almost a continuous series of haul-out sites (please see

Figure 2). Unfortunately, however, many of these sites become accessible to terrestrial predators when sand begins to build up in the intertidal zone (please see Sections 6.1.1 and 6.1.2).

6.1.4 Possible Effects of Terrestrial Predators

Coyotes (*Canis latrans*) sometimes prey upon harbor seals, especially pups. Such behavior has been documented at VAFB (Hanan 1995) and in other parts of California (Howorth 1995) as well as in Washington State (Gearin *et al.* 1990; Gearin 1995), among other areas. During various monitoring efforts this year, as in past years, coyotes were observed along the top of the bluffs and on the beaches. In addition, coyote signs, including scat and tracks on the bluffs and on the beach were prevalent. At Spur Road, coyotes were repeatedly observed along the bluffs and even among the intertidal rocks. No seals were present, regardless of tides, when the coyotes were seen (MMCG and SAIC 2010 and in prep; ManTech SRS 2011b).

As canid predators, coyotes are attracted to the smell of blood and other products associated with birth. With frequent onshore winds, scents from nearby harbor seal birthing activities would be conveyed landward and could serve as an attractant to coyotes, which do prey on newborn pups and will attack juveniles and adults.

Behavioral observations of the seals suggest their wariness of coyotes. At most harbor seal haul-outs at VAFB, the seals haul out on rocks surrounded by fairly deep water, even when beaches and rocks closer to shore are readily accessible to the seals. As the tide comes in and waves begin washing the rocks upon which the seals haul out, the seals move onto rocks closer to shore. Before doing this, however, they carefully scrutinize the shore and surrounding area, presumably for any threats from land. If sand deposition has filled in the channels surrounding the rocks, making them accessible from land, the seals avoid hauling out on them (please see Sections 6.1.1 and 6.1.2). Once on the rocks, they position themselves so that at least some of the seals have a clear view of shore. The seals are quick to react to any movement from shore or from the bluffs. As the tide goes out, the reverse process occurs, with the seals moving to rocks surrounded by water and farther from shore. At south VAFB, some harbor seals do haul out in small coves, rocks surrounded by water or ledges with a clear view of the nearest approaches from land. In areas that lack terrestrial predators (e.g., many parts of the Channel Islands), pinnipeds remain on the same beaches and rocks throughout tidal cycles.

6.2 Effects of Human Activities

6.2.1 Humans near Haul-out Areas

Chronic disturbances from humans have caused harbor seals to switch to a nighttime haul-out pattern or even to abandon haul-out areas entirely. Such disturbances include people and dogs on the beach, and people engaged in water sports, and in other activities (Howorth 1995). From

numerous observations, VAFB appears to be a site largely undisturbed by such activities. At nearly all sites, the seals were aware of people on land but made no move to enter the water.

Close approaches by humans from shore out to the harbor seals will frighten the seals into the water. However, no humans were observed onshore near the harbor seal haul-out areas during the course of many surveys on VAFB conducted by the monitoring team—with one exception. On one occasion, people were seen walking among the intertidal rocks at Small Haul-out 1. No seals were present on any of the nearby rocks, even though the tide was low and seals normally hauled out there during low tides.

Humans silhouetted on the bluffs could also frighten the seals into the water, especially if they appeared suddenly, made rapid movements or made a lot of noise. This was not observed, however. (The monitoring team itself routinely avoided making sudden movements and noise, and maintained a low profile to prevent such disturbances.)

6.2.2 Responses from Launches

Monitoring was not required for all launches (please see Section 4). Moreover, time lapse video could not be set up to record during nighttime launches. Finally, access to monitoring stations near launch sites was not allowed during launches because of personnel safety concerns. Of the ten launches, direct reactions (or lack thereof) on the part of pinnipeds were recorded on time lapse video on two occasions and by visual observations on two other occasions.

During the 20 January Delta IV Heavy launch, 46 harbor seals were videotaped scrambling into the water within about a minute of the launch, but within 50 minutes, 57 animals were hauled out at the same site, suggesting that the effects had been very short-lived. During the 10 June Delta II launch, no harbor seals were seen before, during or after the launch. This was probably because the favored haul-out sites were submerged at the time of the launch and the next day as well. The presence of coyotes in the intertidal area the next day may also have deterred the seals from hauling out (ManTech SRS 2011b; please also see Section 6.1.4).

During the 14 April Atlas V launch, elephant seals vocalized strongly after the launch was seen but before the sonic boom hit the island. Vocalizations began immediately after water in the nearshore area appeared to be displaced in all directions, probably from a Rayleigh wave (please see Section 6.2.4, below). Northern elephant seals are known to be sensitive to Rayleigh waves emanating from the substrate (Shipley *et al.* 1992).

A more obvious explanation is that the seals reacted to the sight of the nighttime launch, which was readily visible. This explanation was rejected because the launch was quite visible well before the seals began vocalizing. The seals in fact began vocalizing the moment that the water was displaced, suggesting that they were reacting to tactile rather than visual stimuli. Since they

did not react to the boom and had even begun to quiet down before the boom struck and after the water quieted, the boom was ruled out as well (MMCG and SAIC 2011b).

Reactions from pinnipeds to the 28 October Delta II launch at San Miguel Island were minimal, with six northern fur seals raising their heads for a short time after the sonic boom (Ball 2011). More details should be provided in the pending launch report (ManTech SRS in prep.).

Monitoring conducted after each launch, either on the day of the launch, once the area was reopened, or on the following days, indicates that haul-out patterns returned to pre-launch levels and in some cases exceeded them. In a few instances, numbers decreased, but this appears to have been the result of haul-out areas becoming progressively submerged by higher tides, and in one case, by the presence of coyotes on the intertidal rocks. In the weeks following the launches, the seals maintained their usual haul-out patterns, suggesting that launch effects, if any, had been transitory.

Monthly monitoring, conducted outside the launch monitoring windows, did not indicate any abnormal haul-out patterns following launches (MMCG and SAIC 2011c and in prep).

6.2.3 ABR Testing

ABR, described in detail in Section 4.3, is a relatively benign test that determines whether changes have occurred in the hearing sensitivity of the animal as a result of loud noise from a launch. Other tests designed to test sensitivity to loud noise involve *inducing* or evoking a temporary [hearing] threshold shift (TTS), in which part or all of an animal's hearing range is temporarily diminished as a result of the test. The latter is a more invasive procedure designed to determine at what frequency, sound level and duration TTS actually occurs. This other method is explained here to avoid confusion with ABR testing, which is preferred because of its minimal effects on the animal.

6.2.4 Acoustic Data

Acoustic Measurements

Other noise levels were calculated for the Delta IV Heavy launch, including maximum fast sound levels (Lmax) and A- and C-weighted levels, but these likely have more relevance to effects on humans. As an example, A-weighting deemphasizes sounds below 1 kHz and above 6 kHz. Many marine mammalogists and acousticians have expressed reservations about applying A-weighting to marine mammal impact assessments because A-weighting may understate sounds heard by animals (as an example, see Richardson *et al.* 1995). Conversely, unweighted sound exposure levels may overstate them. However, unweighted sound exposure levels are useful in that sound intensity over a reasonably comprehensive spectra of frequencies is represented, allowing detailed analyses within various frequency ranges.

C-weighting, which deemphasizes sounds at frequencies below 50 Hz, is designed to assess potential impacts to humans from loud impulse sounds, including sonic booms. In this case, however, measurements were made of the launch noise at VAFB rather than of the sonic boom, which at its closest, would have impacted an area 14 km southwest of San Miguel Island and some 70 km south of the launch site.

A Possible Explanation for the 14 April 2011 Phenomenon

As discussed in Section 5.4.2, a strange phenomenon was observed in Cuyler Harbor, San Miguel Island, after liftoff of the Atlas V rocket but well before the sonic boom hit the island. Water was displaced in all directions in the harbor, even against fairly strong winds. Few phenomena are capable of displacing water in various directions without a visible cause. An undersea earthquake or a volcanic eruption could cause such a phenomenon, but no earthquakes were reported at the time of the launch and volcanic activity has long ceased in the region. In 1996 at San Miguel Island, however, researchers noticed that harbor seals fled into the water about 10 to 12 seconds after a sonic boom from a Titan IV rocket from VAFB struck part of the island, even though the boom was not detected where the seals had been hauled out (Stewart *et al.* 1996). The authors hypothesized that the boom struck the island, generating Rayleigh waves which spread to the haul-out area. Rayleigh waves are generally caused by earthquakes, but such waves have been detected in Los Angeles following the landings of space shuttles at Edwards Air Force Base, which is approximately 55 nautical miles distant (Stewart *et al.* 1996).

Rayleigh waves travel at varying speeds through various media. They can travel through rock at 5000 meters a second or more, through water at about 1500 meters a second, and through sand at 600 to 1800 meters a second. Considering that the launch site was approximately 39 nautical miles (72,228 m) from the waters of Cuyler Harbor, substrate-born Rayleigh waves from the launch itself—not from the boom—could easily have reached the island in less than 15 seconds, certainly well within the time frame reported by the monitor and before the sonic boom struck the island. In retrospect, placing a seismometer at the seal haul-out site would have recorded any seismic disturbance, including Rayleigh waves from the launch.

7 Conclusions and Recommendations

The launch monitoring and monthly surveys were effective. Consistent results were obtained. No indications of abnormal behavior, injury or mortality were reported as a result of launch or aircraft operations. Responses to launches, when they did occur, were very short-lived and of no significance. In the ABR tests conducted for the Delta IV Heavy launch, follow-up testing could not be conducted until two hours, fifty minutes after the launch. The follow-up tests revealed that no changes in hearing sensitivities had occurred, although it is possible that a mild TTS, from which the seals had already recovered, could have occurred (ManTech SRS 2011a). Recording received sound levels from launches at ABR test sites would be very helpful.

Regarding recording environmental data, we recommend that such data be obtained at each monitoring site rather than from remote weather stations.

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