

**FINAL ANNUAL REPORT  
LETTERS OF AUTHORIZATION:**

**TAKING MARINE MAMMALS INCIDENTAL TO SPACE  
VEHICLE AND MISSILE LAUNCHES AND AIRCRAFT TEST  
FLIGHT AND HELICOPTER OPERATIONS AT VANDENBERG  
AIR FORCE BASE, CALIFORNIA**

**1 DECEMBER 2011 TO 30 NOVEMBER 2012**



*Submitted to:*

National Oceanic and Atmospheric Administration  
National Marine Fisheries Service  
Permits, Conservation and Education Division  
Office of Protected Resources  
1315 East-West Highway  
Silver Spring, MD 20910

*Submitted by:*

United States Air Force  
30<sup>th</sup> Space Wing  
30 CES/CEA  
1028 Iceland Avenue  
Vandenberg Air Force Base, CA 93437

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December 2012

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## 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 U.S. Air Force, Vandenberg Air Force Base (VAFB), 30<sup>th</sup> Space Wing (NOAA 2011 and 2012). 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 listed in the LOAs 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 considered a species of concern in addition to the three species mentioned for VAFB.

During the reporting period (1 December 2011 to 30 November 2012) there were two space vehicles and two missiles launched. The first launch, the Delta IV NROL-25 on 3 April, 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 this launch because sonic boom modeling indicated that pressures in excess of 1 psf (pound per square foot) were not expected to occur there. Monitoring was required at SMI during one Atlas V launch, however. No indications of significant disturbances, abnormal behavior, injury or mortality were reported as a result of either of these two launches (ManTech SRS Technologies, Inc. [MSRS] 2012; Science Applications International Corporation and Marine Mammal Consulting Group [SAIC and MMCG] 2012a). Auditory Brainstem Response (ABR) testing was not required for either launch because such testing had already been performed for this type of rocket.

Two missile launches occurred from north VAFB during the reporting period. The westward trajectory of these launches did not necessitate any sonic boom modeling for the northern Channel Islands, particularly SMI, so no biological monitoring was required there, either. These launches occurred outside of the harbor seal pupping season, so no monitoring was required. No ABR studies were required for the missile launches because such testing had already been performed for this type of rocket.

During the reporting period, 651 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. No indications of significant disturbances, abnormal pinniped behavior, injury or mortality were reported as a result of these operations (Evans 2012b).

# 1 Introduction

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). This permit was issued on 25 June 2009 and is valid through 30 June 2014. This report also is in accordance with two Letters of Authorization (LOAs) issued by NOAA to the United States Air Force, Vandenberg Air Force Base (VAFB), 30<sup>th</sup> Space Wing. The LOAs cover the periods from 7 February 2011 through 6 February 2012, and from 7 February 2012 through 6 February 2013, respectively (NOAA 2011 and 2012). The period covered by this report extends from 1 December 2011 through 30 November 2012, thus overlapping the two LOAs.

Marine mammal species of concern at VAFB listed in the LOAs include Pacific harbor seals (*Phoca vitulina richardsi*), California sea lions (*Zalophus californianus c.*) and northern elephant seals (*Mirounga angustirostris*). At San Miguel Island (SMI), the northern fur seal (*Callorhinus ursinus*) is a species of concern in addition to the three species already mentioned for VAFB.

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.

Monitoring was required at SMI during one rocket launch because the modeled sonic booms exceeded the 1 psf threshold. Monitoring was required at VAFB during one rocket launch which fell within the harbor seal pupping season (1 March through 30 June). No ABR tests were required for any of the launches because these had already been performed for both types of rockets. This report describes the methods and results of the marine mammal mitigation efforts and discusses the impacts of Air Force operations.

## 2 Background

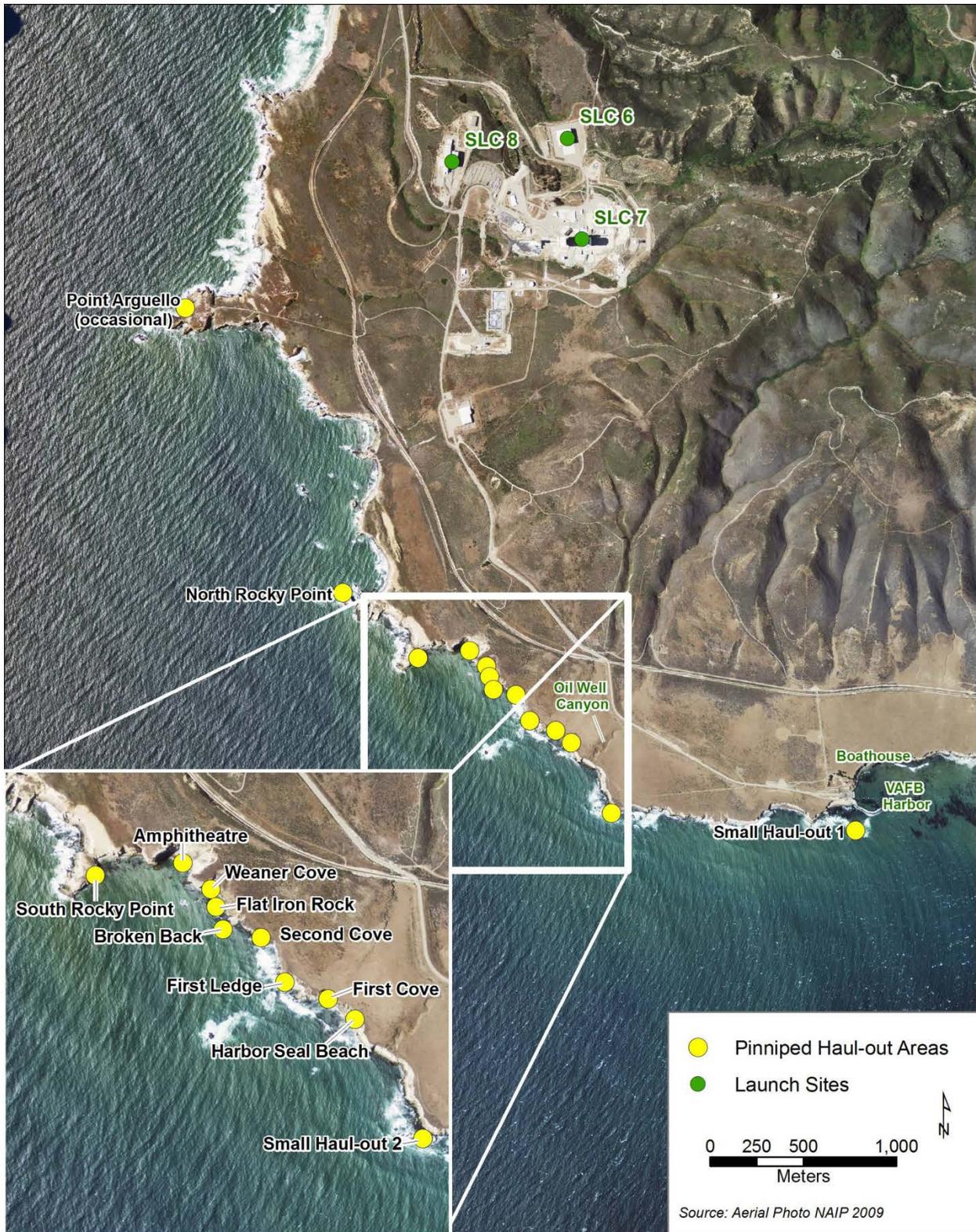
### 2.1 VAFB Operations

#### 2.1.1 Space Vehicle Launches

Two launches of space vehicles occurred during the reporting period (Table 1). Both rockets carried classified payloads for the National Reconnaissance Office (NRO) and were launched from Space Launch Complex (SLC)-6 and SLC-3E (east), respectively, on south VAFB. The locations of these sites in relation to pinniped haul-out areas are shown in Figures 1 and 2.

**Table 1. Space Vehicle Launches**

| <i>Vehicle Type</i> | <i>Facility</i> | <i>Planned Launch Date</i> | <i>Actual Launch Date</i> |
|---------------------|-----------------|----------------------------|---------------------------|
| Delta IV NROL-25    | SLC-6           | 29 March 2012              | 3 April 2012              |
| Atlas V NROL-36     | SLC-3E          | 2 August 2012              | 13 September 2012         |



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



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

### 2.1.2 Missile Launches

Two missile launches occurred during the reporting period (Table 2). Both were Minuteman III launches. Minutemen IIIs are Intercontinental Ballistic Missiles (ICBMs), launched from silos on north VAFB. Each launch facility (LF) is abbreviated and numbered. Both launches were made from LF-10.

**Table 2. Missile Launches**

| <i>Missile Type</i>       | <i>Facility</i> | <i>Planned Launch Date</i> | <i>Actual Launch Date</i> |
|---------------------------|-----------------|----------------------------|---------------------------|
| Minuteman III<br>GT-203GM | LF-10           | 25 February 2012           | 25 February 2012          |
| Minuteman III<br>GT-206GM | LF-10           | 1 March 2012               | 14 November 2012          |

### 2.1.3 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.

## 2.2 Pinniped Species of Concern

NMFS is concerned about the potential impacts of anthropogenic noise on marine mammals (Carretta *et al.* 2011). Potential impacts include harassment from rocket or missile 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 399 for 2011, while the greatest number seen hauled out at any one time so far in 2012 was 178 in January (MMCG and SAIC 2011 and 2012b). Harbor seals regularly haul out on isolated sandy coves, ledges and rocks. On south VAFB (Figure 1), 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 and freely wander between individual sites depending upon tides, potential threats from land and other factors. This stretch is really an almost continuous haul-out and rookery area. Over the past three years, this stretch has been utilized less and less by harbor seals (Sections 5.4 and 6.1).

North Rocky Point, the northernmost haul-out site on south VAFB, lies about 1.5 km west of the nearest launch facility. This haul-out site is used by California sea lions, which haul out in greatest numbers in late spring and summer. A few pups reportedly 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.

North Rocky Point was also used in late spring and early summer 2012 by Steller sea lions (*Eumetopias jubatus*). This was the first time this species has been reported at VAFB during any of numerous launch monitoring efforts and monthly surveys conducted over the past two decades. Steller sea lions once had two small rookeries on San Miguel Island, but these were abandoned following the 1982-1983 El Niño event. These rookeries once represented the southernmost colonies of the eastern stock of this species. The eastern stock of Steller sea lions, which is currently threatened under the Endangered Species Act of 1973, has been considered for de-listing.

Four distinctly separate harbor seal haul-out sites exist on north VAFB. One is at the end of Spur Road, another at Purisima Point, a third at Lion’s Head, and the last just west of LF-06. (Access to Purisima Point was restricted for a few years because of unexploded ordnance but was partially reopened in March 2012.) The first two sites lie between 0.7 and 1.3 km from the nearest launch facilities, the third site (Lion’s Head) is about 1.3 km from the nearest facility, and the last site (Little Sal) is 0.5 km from LF-06 (Figure 2).

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; however, challenges related to private land access have temporarily halted monitoring there.

### 3 Methods

Table 3 presents launch mitigation requirements by individual launch.

**Table 3. Launch Mitigation Requirements**

| <i>Vehicle or Missile</i> | <i>Launch Date</i> | <i>Monitoring</i> | <i>ABR Testing</i> | <i>Boom Model</i> | <i>Acoustics</i> | <i>Time-lapse</i> |
|---------------------------|--------------------|-------------------|--------------------|-------------------|------------------|-------------------|
| Minuteman III             | 25 February 2012   | Not required      | Not required       | Not required      | Not required     | Not required      |
| Delta IV                  | 3 April 2012       | Required at VAFB  | Not required       | Required          | Not required     | Required          |
| Atlas V                   | 13 September 2012  | Required at SMI   | Not required       | Required          | Required         | Not required      |
| Minuteman III             | 14 November 2012   | Not required      | Not required       | Not required      | Not required     | Not required      |

#### 3.1 Sonic Boom Modeling

As required in the LOAs, sonic boom modeling was performed prior to both of the scheduled space vehicle launches. PCBoom4, a commercially available modeling program, was used, and

launch parameters specific to each launch were incorporated into the model. These included launch direction and trajectory, rocket weight, length, engine thrust, engine plume drag, launch profile (vehicle position versus time from launch to first-stage burnout) among other aspects. Various weather scenarios were analyzed from NOAA weather records for the region and were run through the model. Among other factors, these included the presence or absence of the jet stream, and if present, its direction, altitude and velocity. The type, altitude, and density of clouds were also considered. From these data, the models predicted peak amplitudes and impact locations.

Modeling was not required for the missile launches, because of the vehicles' trajectories west of SMI and previously well-documented acoustic properties.

## **3.2 Launch Monitoring**

### **3.2.1 Timing**

Pinniped monitoring during launches is required at VAFB by the LOAs during the harbor seal pupping season, from 1 March through 30 June. The Delta IV rocket 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 the launch window as possible. Nighttime monitoring is not allowed because of personnel safety concerns—the bluffs overlooking the haul-out sites are unstable and subject to sudden collapse (Section 6.1.4). Visual monitoring was not allowed during the launch itself because of personnel safety concerns, but the monitors returned to the observation point as soon as the launch area was reopened. Time-lapse video was used during launch day to record the reactions of the animals to the launch. Four hourly visual counts were made each day during pre- and post-launch monitoring for the 3 April Delta IV launch.

During the 13 September Atlas V launch, monitoring was required at SMI because the sonic boom projected for the launch exceeded the 1 psf threshold. The timing was the same, except that visual monitoring was allowed during the launch itself. Also, since the launch was originally scheduled for nighttime, night vision equipment was used during the first set of observations. The originally scheduled launch was postponed, then cancelled. The next set of observations was conducted in daylight because the launch window had shifted to daytime.

### **3.2.2 Site Selection**

For the 3 April Delta IV launch, the area from Harbor Seal Beach to south Rocky Point was selected as the closest accessible harbor seal haul-out area to the SLC-6 launch site.

For the 13 September Atlas V launch, Cardwell Point, on the east end of SMI, was selected as the observation point. Three species of pinnipeds were present in relatively small groups at Cardwell Point. This presented a rare opportunity to observe the reactions of all three species of pinnipeds to a sonic boom, since the groups were relatively small and could be monitored simultaneously. Also, each group could be photographed just before the launch and just after the launch to double-check counts.

Three focal groups were selected:

- Focal Group 1, comprising juvenile and adult California sea lions as well as northern elephant seals, was hauled out on the north end of Cardwell Point;
- Immediately to the south, along a sandy stretch of beach, Focal Group 2 was composed entirely of harbor seals and;
- Focal Group 3, on the southeast corner of the island, included both sea lions and elephant seals.

### **3.2.3 Visual Monitoring**

Monitors observed harbor seals from the bluffs overlooking the haul-out sites. High-end binoculars, which provided clear and bright magnification of the animals, were used. Counts were made hourly or more often if any significant changes occurred. Only pinnipeds 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.

### **3.2.4 Remote Time-lapse Video Photography**

Time-lapse video photography was set up to count seals before, during, and after the 3 April 2012 Delta IV launch. The camera was directed toward a selected section of First Ledge on south VAFB (MSRS 2012), where the greatest numbers of harbor seals congregated during this monitoring period. Remote video monitoring was not required during the other launches from VAFB.

### **3.2.5 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 in boats or low-flying aircraft. 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 launch, tidal data were obtained from a tidal prediction program, JTides 5.2, using data from Avila (MSRS 2012).

For the Atlas V rocket launch, 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 Cuyler Harbor, the closest spot on SMI to the observation site. Air temperature, wind direction and velocity, and swell direction and height were recorded onsite (MMCG and SAIC 2012a).

### **3.3 Acoustic Measurements**

Acoustic measurements were made at SMI of the sonic boom from the Atlas V launch. Recordings were also made of ambient sounds. Specifications of this equipment and accessories are detailed in the launch report (MMCG and SAIC 2012a).

### **3.4 Monthly Surveys**

The monthly marine mammal surveys were usually timed to coincide with the lowest daytime tides of each month, when the greatest 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 half 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 were used (MMCG and SAIC 2011 and 2012b).

When a decline in the number of harbor seals seemed apparent at VAFB, several voluntary surveys, along with an aerial survey, were conducted by MMCG - SAIC along the entire VAFB coastline to determine whether the animals had moved elsewhere, either to other haul-out sites or to new ones.

### **3.5 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 2012b).

## **4 Results**

### **4.1 Sonic Boom Modeling**

Sonic boom modeling was required for both rocket launches. Detailed reports that include sonic boom modeling results were prepared for these two launches (MSRS 2012; MMCG and SAIC 2012a). The following table summarizes the results of the two sonic boom models.

**Table 4. Sonic Boom Modeling Results**

| <i>Vehicle</i>   | <i>Launch Date</i> | <i>Sonic Boom Modeling Results</i>  |
|------------------|--------------------|-------------------------------------|
| Delta IV NROL-25 | 3 April 2012       | < 1 psf at northern Channel Islands |
| Atlas V NROL-36  | 13 September 2012  | > 1 psf at northern Channel Islands |

Modeling was not required for the missile launches because of their westerly trajectories and known acoustic characteristics.

## **4.2 Launch Monitoring**

Biological monitoring was not required for the missile launches because of their westerly trajectories and known acoustic properties. The following subsections describe launches during which monitoring was required.

### **4.2.1 Visual Monitoring during the 3 April 2012 Delta IV Launch**

The pre-launch monitoring period extended from 26 March through 2 April 2012. This was longer than usual because of several launch delays. During this period, from 2 to 111 adult and sub-adult harbor seals were noted at south VAFB. From zero to 16 pups were also observed, along with one California sea lion. On 26 March, a dead harbor seal pup washed ashore at First Ledge with wounds suggestive of a shark attack. The next day, a dead, newly born pup with its umbilicus still attached was noted at Amphitheatre. Two days later, a dead harbor seal pup and a badly decomposed carcass of what may have been another pup were recorded at south Rocky Point. Whether either of these was the same dead pup noted at Amphitheatre on 26 March was not known. Neither of these pups could be examined to determine the cause of death (MSRS 2012).

Post-launch counts ranged from 88 to 144 adult and sub-adult seals, and from 8 to 12 pups. One emaciated, recently weaned northern elephant seal was also observed during post-launch monitoring. The two-week follow-up count revealed up to 154 adult and sub-adult harbor seals and up to 25 pups. No more dead animals were recorded during the post-launch and two-week follow-up surveys (MSRS 2012).

Pre-launch and launch counts were generally lower at First Ledge at or near launch time and higher afterwards (Table 5).

### **4.2.2 Time-lapse Video Monitoring during the 3 April 2012 Delta IV Launch**

During the 3 April Delta IV launch, all 42 animals hauled out on First Ledge on south VAFB were alerted by the noise and moved rapidly toward the sea. All but two scurried into the water. Up to ten animals soon returned, but went back in the ocean as the tide rose (MSRS 2012).

### 4.2.3 Visual Monitoring during the 13 September 2012 Atlas V Launch

Monitoring for this launch was conducted at Cardwell Point, SMI. This launch was originally scheduled for 2 August 2012. Accordingly, monitoring began on 30 July. After a one-day delay, the launch was cancelled, so the team stopped monitoring. The launch was re-scheduled for 13 September, so the team returned to SMI on 10 September, leaving two days after the launch on 15 September. As mentioned in Section 4.2.2, three relatively small focal groups were selected, comprising three different species of pinnipeds. The maximum number in any one group was 470. No pups of any species were observed. One badly decomposed California sea lion was seen on 30 July, the first day of monitoring. Table 6 presents a summary of the sightings. Additional details can be found in the launch monitoring report (MMCG and SAIC 2012a).

The California sea lions and northern elephant seals displayed no reaction whatsoever to the sonic boom from the Atlas V. Of the 36 harbor seals present at the time of the boom, 20 dashed into the water. They began returning to shore within half an hour of the launch.

### 4.2.4 Environmental Conditions

Environmental conditions were noted in detail in both launch monitoring reports and in all of the monthly survey reports. Environmental conditions did not preclude accurate viewing at any time (MMCG and SAIC 2011 and 2012a and b; MSRS 2012). The effects of environmental conditions on the relative abundance of animals are discussed in Section 6.1.

## 4.3 Acoustic Measurements

Acoustic measurements were required only for the Atlas V launch. Appendix 1 contains a glossary of acoustic terminology used throughout this section and in Sections 6.2.1 and 6.3.

**Table 5. Harbor Seals at First Ledge, Delta IV Launch Monitoring<sup>1</sup>**

| <i>Date</i>                  | <i>Adults</i> | <i>Juveniles</i> | <i>Pups</i>   | <i>Totals</i> |
|------------------------------|---------------|------------------|---------------|---------------|
| 26 March 2012                | 0             | 0                | 0             | 0             |
| 27 March 2012                | 31            | 7                | 1             | 39            |
| 28 March 2012                | 8             | 3                | 1             | 12            |
| 29 March 2012                | 40            | 3                | 3             | 46            |
| 30 March 2012                | 53            | 8                | 2             | 63            |
| 31 March 2012                | 40            | 4                | 7             | 51            |
| 1 April 2012                 | 25            | 2                | 3             | 30            |
| 2 April 2012                 | 71            | 11               | 2             | 84            |
| 3 April 2012<br>(Launch day) | Not specified | Not specified    | Not specified | 42            |
| 4 April 2012                 | 68            | 12               | 3             | 83            |
| 5 April 2012                 | 79            | 12               | 3             | 94            |
| 17 April 2012                | 112           | 8                | 11            | 131           |

<sup>1</sup>These are monitoring results during launch time or as close as available to launch time. For complete survey results, see MSRS (2012).

**Table 6. Pinnipeds at Cardwell Point, San Miguel Island, Atlas V Launch Monitoring**

| <i>Date</i>                       | <i>California Sea Lions<br/>Min./Max.<sup>1</sup></i> | <i>Northern Elephant Seals<br/>Min./Max.<sup>1</sup></i> | <i>Pacific Harbor Seals<br/>Min./Max.<sup>1</sup></i> |
|-----------------------------------|---|--|---|
| 30 July 2012                      | 672   | 16   | 31  |
| 31 July 2012                      | 558-637   | 15-24  | 12-16   |
| 1 August 2012                     | 233-912   | 14-20  | 4   |
| 2 August 2012                     | 474   | 26   | 28  |
| 10 September 2012                 | 356-648   | 1-51   | 2   |
| 11 September 2012                 | 209-569   | 0-2  | 6-35  |
| 12 September 2012                 | 287-423   | 8-101  | 0-35  |
| 13 September 2012<br>(Launch day) | 186-240   | 50-78  | 0-36  |
| 14 September 2012                 | 290-407 <sup>2</sup>                                  | 44-83  | 0 <sup>2</sup>  |
| 15 September 2012                 | 190-426   | 46-78  | 0-22  |

<sup>1</sup>The minimum and maximum numbers are juveniles and adults combined in all three focal groups. In some cases, the number remained the same during the observations. No pups were present.

<sup>2</sup>The surf was very large the day after the launch, with heavy surges and backwashes preventing the harbor seals from hauling out, although they were present just outside the breakers. Juvenile sea lions also had trouble hauling out that day.

#### **4.3.1 Atlas V Sonic Boom**

The sonic boom consisted of two positive peaks (overpressures) separated by approximately six-tenths of a second, both of which were followed by negative spikes (underpressures). The maximum overpressure was 2.1 psf, while the maximum underpressure (rarefaction) was 0.76 psf. This signature represents the compression of air from a double shock wave from a sonic boom, followed by a corresponding release of pressure. Some reverberations occurred after this, gradually stabilizing as the sounds died away. Interestingly, a third spike, followed by an underpressure, occurred 6.4 seconds after the double boom. All three spikes were heard by the monitors. The third spike was no means as loud as the second of the first two booms, yet the underpressure was almost as significant as the first one. This third boom was a reflection, presumably off the ocean. Reflections invert the pressure trace, hence the large underpressure.

The frequency spectrum of the acoustic energy from the sonic boom was predominantly low frequency, with a peak value of 106.3 Pa<sup>2</sup>/hertz (Hz) dB re 20 μPa, at 2.67 Hz, dropping off to below 86 dB re 20 μPa at 130 Hz, then remaining relatively flat to about 250 Hz before falling off again. At about 350 Hz, the sound levels rapidly fell below 80 dB re 20 μPa to about 75 dB at 500 Hz, then gradually declined to about 66 dB at 5000 Hz. Additional details can be found in the launch report (MMCG and SAIC 2012a).

#### **4.3.2 Atlas V Acoustic Measurements**

The peak unweighted sound level of natural ambient sounds combined with the sonic boom was 122.8 dB re 20 μPa. During the 15 minutes preceding the launch and the 15 minutes after the launch, the lowest ambient noise was 82.7 dB re 20 μPa, while the highest sounds—not associated with the launch—were 113.1 dB re 20 μPa. The average ambient sound level over this period was 98.1 dB re 20 μPa.

The recordings indicate some wind noise, even though a windscreen was used on the microphone and it was sheltered from the wind. Winds at the observation site at Cardwell Point at launch time were 10 to 12 knots. In addition to wind sounds, surf up to 2.0 m high contributed significantly to the background noise, especially during large sets. Vocalizations from the seals added to the ambient din. Additional details can be found in the launch report (MMCG and SAIC 2012a).

#### **4.4 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. None of the monthly surveys suggested any changes in haul-out patterns as a result of the three launches (MMCG and SAIC 2011 and 2012a and b). However, an apparent overall decline was noted in the population of harbor seals at VAFB (MMCG and SAIC 2012b).

Surveys were conducted on foot and by air by MMCG - SAIC along the entire VAFB coast. The goal was to determine whether the population had truly dropped or the animals had moved to other areas. Some seals appear to have moved to a small cove immediately east of Point Conception, while others have taken to resting in kelp beds, both at VAFB and in Cojo Bay, southeast of Point Conception (MMCG and SAIC 2012b; Laroche 2012).

During the course of these surveys, up to 16 Steller sea lions were noted at north Rocky Point in late spring and early summer of 2012. Some individuals with distinctive scars and marks were noted repeatedly over some weeks, indicating that these were not just transients hauled out for a brief rest before continuing on their way. Although both adult males and females were noted, no pups were seen.

North of Rocky Point lies Point Arguello. At the north end of the point, a ledge in a deep crevice was found which was being used by small numbers of harbor seals. This is the first time this site has been reported.

Northwest of Lion's Head, on north VAFB, a small point juts seaward to the west of LF-06. This site looked promising from the air, so it was examined on foot during the September monthly survey. A total of 26 harbor seals were hauled out there, so this site is now included in the monthly surveys (Figures 3 and 4). It has been informally dubbed Little Sal.

The rest of the VAFB coast does not appear suitable habitat for harbor seals because virtually all of it is readily accessible from land.

## **4.5 Fixed-wing Aircraft and Helicopter Operations**

During the reporting period, 651 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. No indications of significant disturbances, abnormal pinniped behavior, injury or mortality were reported as a result of these operations (Evans 2012b).

## **5 Discussion**

### **5.1 Natural Effects on Haul-out Patterns**

#### **5.1.1 Environmental Conditions**

Numerous environmental factors affect pinniped haul-out patterns, summarized from previous reports (MMCG and SAIC 2011 and 2012b):

- Higher tides reduce or eliminate haul-out areas at VAFB;
- More haul-out area is available when surf is small;
- In undisturbed areas, more harbor seals haul out in afternoons, regardless of tides and surf, provided adequate haul-out space is available out of reach of waves and tides;
- Where haul-out space is limited, tides and breakers can limit haul-out patterns;
- Wind and wind chill, along with temperature, combine either to make haul-out sites desirable or untenable;
- Abundant prey has been suggested as a cause for animals to remain offshore longer. If abundant prey remains nearby, the opposite is true and;
- In areas subject to chronic daytime disturbance, harbor seals often shift to a nighttime haul-out pattern to avoid harassment (Howorth 1995), go to other haul-out areas or rest in offshore kelp beds (MMCG and SAIC 2011 and 2012b).

#### **5.1.2 Seasonal and Cyclic Effects**

Seasonal and cyclic effects have been discussed in previous documents (MMCG and SAIC 2011 and 2012b) and are summarized below:

- In winter, unusually high tides, large surf and strong currents can strip sand from beaches, resulting in less haul-out area;
- When sand builds beaches back up in mild conditions, tides must be higher to reach the same point because the beach is higher from sand build-up. More haul-out area is available;
- Sand deposition from landslides can make rocks normally isolated by water accessible from land or even bury the rocks, making such areas less desirable as haul-outs;

- The area from Harbor Seal Beach to Weaner Cove was all but abandoned. The sites had become accessible from shore, rendering the seals vulnerable to attack from land;
- Harbor seals generally haul out in substantial numbers during the pupping and breeding season, from March through June at VAFB and;
- In general, the largest numbers of harbor seals haul out during molting season, from May into summer.



***Figure 3. New Harbor Seal Haul-out Site West of LF-06***



***Figure 4. Close-up of New Harbor Seal Haul-out Site West of LF-06***

### 5.1.3 Landslides

This subject has also been explored in depth in previous documents (MMCG and SAIC 2011 and 2012b) and is also summarized and updated below.

- Starting in late July or early August 2010, a series of landslides continued at Weaner Cove (Figure 5). Slides have also occurred at Amphitheatre, immediately to the north;
- Weaner Cove once had a sizable beach for seals, but now it is all but buried. It is quite possible that some harbor seals were buried during one of the first major slides;
- The slides are caused by natural erosion, especially during heavy rains. This same phenomenon occurs frequently throughout Southern California;
- Many areas of the bluffs show long cracks as much as six feet deep. Entire sections of the bluff are poised to collapse;
- Weaner Cove has been virtually abandoned by the harbor seals. A few occasionally haul out on rocks immediately offshore from what was once the cove and;
- The seals may have dispersed to other sections of the coast to the north and south of Weaner Cove, although many sites immediately downcurrent from the cove became accessible to terrestrial predators when sand began to build up (Sections 6.1.2 and 6.1.4).



**Figure 5. Landslide at Weaner Cove**

#### 5.1.4 Effects of Terrestrial Predators

This subject has also been explored in depth in previous documents (MMCG and SAIC 2011 and 2012b) and is summarized and updated below.

- 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);
- 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;
- No seals were present, regardless of tides, when coyotes were seen on the beaches;
- Behavioral observations of the seals suggest their wariness of coyotes. The seals haul out on rocks surrounded by fairly deep water, even when beaches and rocks closer to shore are readily accessible. As the tide comes in, the seals move onto rocks closer to shore;
- If sand deposition has filled in the channels surrounding the rocks, making them accessible from land, the seals avoid hauling out on them;
- Once on the rocks, the seals position themselves so that at least some of them have a clear view of shore. The seals quickly 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 and;
- In areas that lack terrestrial predators, pinnipeds stay ashore throughout tidal cycles provided space remains available above high tide and out of reach of the breakers.

#### 5.1.5 Predation by Sharks

- During monitoring for the 3 April 2012 Delta IV rocket launch, a harbor seal was observed with wounds likely inflicted by a shark;
- Increased numbers of dead seals, sea lions and sea otters killed by white sharks have been reported at VAFB by U.S.G.S. biologists and by observers during launches and monthly surveys from 2010 into 2012 (MMCG and SAIC 2011 and 2012b; MSRS 2012; Evans 2010, 2011 and 2012a);
- Unusual numbers of live-stranded seals and sea lions with bite wounds inflicted by great white sharks (*Carcharodon carcharias*) were recorded in other parts of Santa Barbara County from 2010 into 2012 (Santa Barbara Marine Mammal Center 2010-2012);
- The body of evidence from numerous reliable sources indicates that an increase in shark attacks has occurred in the region during the period 2009 into 2012;
- Shark attacks are a contributing factor in the decline of harbor seals at VAFB. Whether this is occurring at a significant level is not known at this time and;
- California Department of Fish and Game (CDFG) biologists think it likely that attacks by white sharks from San Luis Obispo County into northern Santa Barbara County is now the main limiting factor to population growth for the southern sea otter (Harris 2012).

## **5.2 Effects of Human Activities**

### **5.2.1 Responses from Launches**

#### **3 April 2012 Delta IV NROL-25 Launch**

Time-lapse video monitoring revealed that all 42 harbor seals on First Ledge, south VAFB, alerted and moved rapidly toward the water when the launch occurred. All but two of these animals went into the water. Ten animals hauled out soon after the launch, but returned to the water as the tide rose, covering the ledge. On the eight days prior to the launch, from zero to 84 animals were present at First Ledge at or near launch time. During the two days after the launch and on the 14-day follow-up count, the numbers ranged from 83 to 131. The maximum total number of pups before the launch was 7; after the launch, this climbed to 11. These observations indicated that the launch noise resulted only in short-term disturbances of no significance.

#### **13 September 2012 Atlas V NROL-36 Launch**

As discussed in Section 5.2.3, California sea lions and northern elephant seals on Cardwell Point did not react to the sonic boom. The number of adult sea lions on launch day varied from 281 to 360, while juveniles ranged from 45 to 91. The total range for juvenile and adult sea lions combined was 326 to 451. Juveniles are believed to be more sensitive to sudden loud noises, both because they usually hear better than adults, but also because they react more strongly to sudden events that are unusual for them. Nonetheless, none of the sea lions reacted to the sonic boom. In the two days following the launch, counts revealed similar numbers of animals present (MMCG and SAIC 2012a).

Northern elephant seals, both juvenile and adults, are known to be the least sensitive pinniped to sonic booms. From 3 to 6 adults were present on launch day, along with 47 to 65 juveniles. Maximum combined totals were 6 to 71. None of the elephant seals reacted to the sonic boom. In the two days following the launch, counts revealed similar numbers of animals present (MMCG and SAIC 2012a).

On the three days prior to the launch, from zero to 35 adult Pacific harbor seals were present and from zero to 6 juveniles. Maximum combined totals were 35 at any one time. On launch day, from zero to 36 adults were present. Of these, 20 of 36 animals dashed into the water when the sonic boom struck. They began hauling out again soon after the boom. The day following the launch, the surf was very high, causing heavy surges and backwashes. The juvenile sea lions had trouble hauling out, and although numerous harbor seals were noted beyond the breakers, none ventured ashore. Conditions had moderated somewhat by the second day and zero to 20 adults hauled out at Cardwell Point (MMCG and SAIC 2012a).

Of the three species, the harbor seal is by far the most sensitive to airborne sounds. This alone does not explain the reaction of the seals, however. First, by far the greatest sound pressure was generated at 2.67 Hz, well below the hearing frequency range of the seal. The peak pressure was extremely brief, lasting milliseconds, so even a very intense sound could not be felt by the seals because of its extremely short duration. Nonetheless, the noise of the boom was loud enough to be heard by the observers and by at least some of the harbor seals. This is because the higher

low-frequency sounds were still loud enough to be heard, even though they did not generate anywhere near as much pressure. Harbor seals, unlike other pinnipeds in this region, are quite sensitive to low frequency airborne sounds in the 500 Hz range; in fact, such sounds can be detected by harbor seals at as low an intensity as 26 dB re 20  $\mu$ Pa. By contrast, the other two species don't come close to such sensitivity. Figure 6 compares the hearing sensitivity of the three species. This explains why the harbor seals reacted and the other species did not. Nonetheless, the disturbance was very short-lived and of no significance. Other human-related disturbances, not related to VAFB operations, caused considerably greater disturbances (Section 6.2.2; MMCG and SAIC 2012a).

### **5.2.2 Human Activities near Haul-out Areas during Launches**

Other than launch noise impacts, no other human-related impacts were observed during monitoring at VAFB for the Delta IV launch on 3 April. On 30 July, during the start of the Atlas V launch monitoring, 30 to 40 California sea lions were frightened into the water when an urchin boat approached closely to Cardwell Point from the west along the north shore, headed east at high speed toward Santa Rosa Island. On 12 September, the day before the launch, 33 harbor seals reacted to the sound of a twin-engine propeller-driven aircraft by scurrying into the water. The aircraft was flying at approximately 2500 feet. Each of these disturbances was more significant than impacts from the sonic boom. No other human-related impacts—except for the sonic boom—were noted at SMI during the Atlas V monitoring.

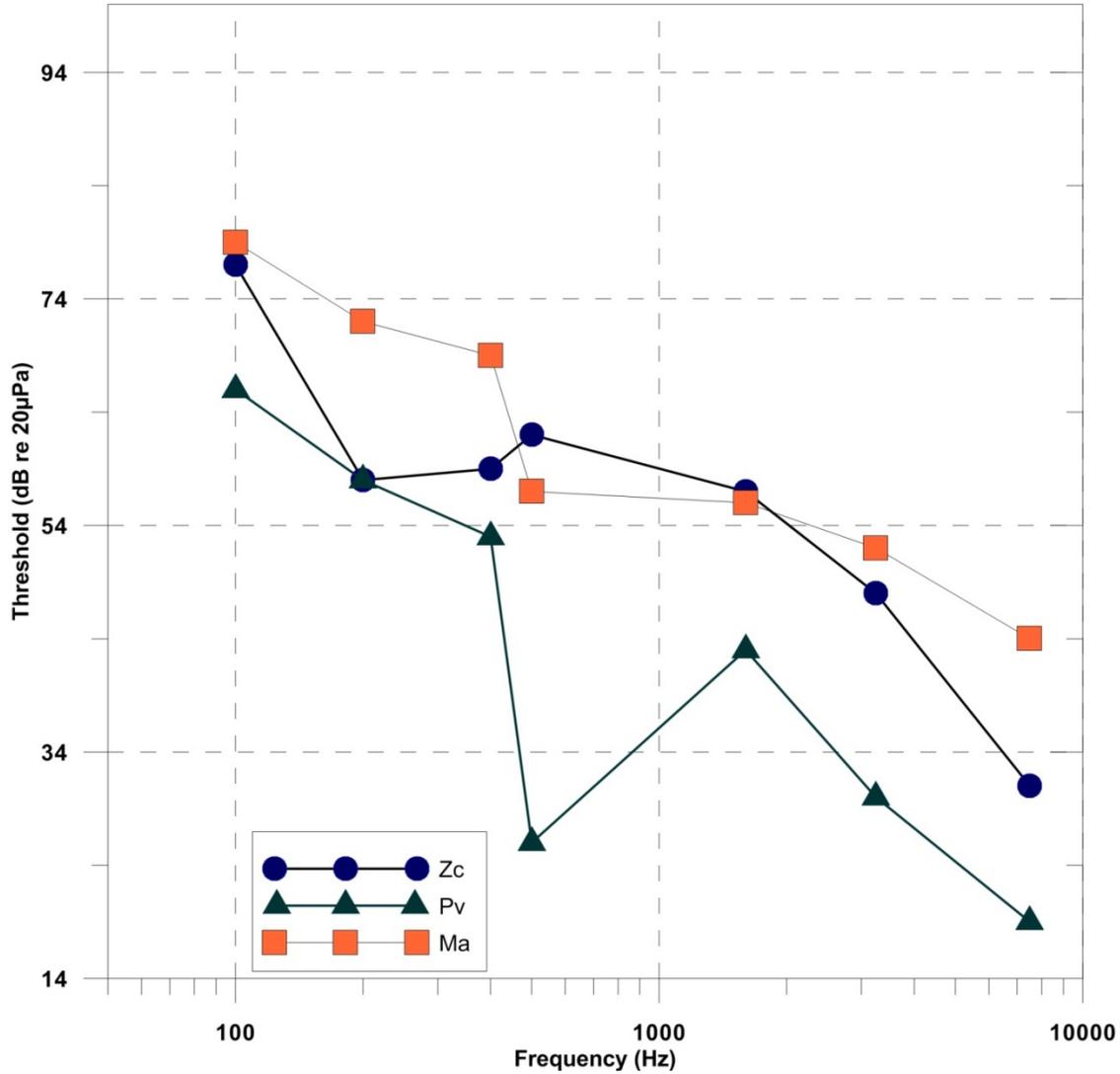
### **5.2.3 Human Activities near Haul-out Areas during Monthly Surveys**

Close approaches by humans from shore out to the harbor seals will frighten the seals into the water. During the December 2011 survey, two fishermen were noted on the intertidal rocks at Small Haul-out 1. No seals were hauled out at the time. It is not known whether the seals were frightened into the water by the fishermen, but this appears likely, since several seals were seen nearby in the water and this is a site normally occupied by the seals during low tides. During the January 2012 survey, the same thing occurred, this time because of a person walking among the intertidal rocks. Whether this person frightened seals into the water is unknown, but again, seals were nearby, so this seems likely. A University of California research team was noted on the rocks inshore from the haul-out area at Little Sal during the 13 November survey.

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.)

## **5.3 Acoustic Measurements**

In some past launches, weighted sound level measurements were presented. 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). Consequently, A-weighting was not calculated for the Atlas V sound measurements. C-weighting, which deemphasizes sounds at frequencies below 50 Hz, is



**Figure 6. Hearing Thresholds of Three Pinniped Species**

designed to assess potential impacts to humans from loud impulse sounds, including sonic booms. This would have further understated the sounds of the sonic boom, so C-weighting was not calculated for the Atlas V launch. Unweighted sound exposure levels may overstate the measurements, but they are useful in that sound intensity over a reasonably comprehensive spectra of frequencies is represented, allowing detailed analyses within various frequency ranges to which marine mammals are most sensitive. The highest level during the Atlas V launch, including both the sonic boom and ambient sounds, was 122.8 dB re 20 μPa. Even though this may tend to overstate the sound level heard by the pinnipeds, it still was orders of magnitude below 145 dB re 20 μPa, which was proposed by the U.S. Navy as the lowest airborne sound level at which a temporary [hearing] threshold shift could occur in California sea lions and Pacific harbor seals (U.S. Navy 2002).

## 6 Conclusions and Recommendations

The launch monitoring and monthly surveys were effective. Consistent results were obtained. No indications of significant disturbances, abnormal behavior, injury, or mortality were reported as a result of launch or aircraft operations. Responses to launches, when they did occur, were short-lived and of no significance. We do not recommend any changes to the monitoring methods at this time.

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## Appendix 1: Glossary of Acoustic Terminology

Digital Audio Tracking (DAT): A method of recording sounds digitally.

Decibel (dB): A logarithmic scale used to measure the intensity of sound. For every 3 dB increase, the sound intensity doubles. For every 10 dB increase, the sound intensity increases tenfold.

Hertz (Hz): A measure of the pitch of a sound, measured in cycles per second. One Hz equals one cycle per second, an extremely low sound. Human hearing ranges from about 20 Hz to 15,000 to 20,000 Hz

Infrasonic: A sound that is lower than the hearing frequency range of a human or animal.

Kilohertz (kHz): 1000 Hz.

Micropascal ( $\mu\text{Pa}$ ): A unit of pressure equal to one-millionth of a pascal, which equals one newton per square meter (see also newton).

Millisecond (ms): Equal to  $1/1000^{\text{th}}$  of a second. 100 ms equal  $1/10$  second.

Newton: A force which imparts to a mass of one kilogram an acceleration of one meter per second.

Pounds per square foot (psf): A measurement used to assess the over- or underpressure generated by the shock wave from a sonic boom.

Power density spectrum (in this report, presented as  $\mu\text{Pa}^2/\text{Hz}$ ): Distribution of power in a signal versus frequency, where continuously distributed sound (not tones) is the important component. Power is proportional to the mean square pressure and pressure is the measured quality.

Reference pressure (re): For sound intensity to have relevance, it must be referenced to pressure. In air, decibels are often referenced to  $20 \mu\text{Pa}$ , as in X dB re  $20 \mu\text{Pa}$ .

Weighting: Weighting is used to deemphasize certain frequencies of sounds to more accurately assess impacts to humans:

A-weighting: Deemphasizes sounds below 1000 Hz and above 6000 Hz. Used to assess noise impacts on humans.

C-weighting: Deemphasizes sounds below 50 Hz. Used to assess impacts of loud impulse sounds, such as explosions and sonic booms, on humans.

Unweighted: Sounds within a given frequency range are presented as they occur, with no weighting.