

6 February 2019

Jordan Carduner
NOAA Fisheries Office of Protected Resources
Permits and Conservation Division
1315 East West Hwy
Silver Spring, MD 20910

RE: SpaceX IHA Annual Report – 2017/2018

Dear Mr. Carduner,

Space Exploration Technologies Corporation (SpaceX) operates the Falcon 9 program at Vandenberg Air Force Base (VAFB), California. As part of this program, SpaceX performs first stage recovery activities on VAFB and on barges stationed at contingency landing areas by performing a return flight and landing of the first stage. NOAA Fisheries issued an Incidental Harassment Authorization to SpaceX for take by Level B harassment of small numbers of marine mammals at VAFB and the Northern Channel Islands for the first stage recovery. Potential harassment of marine mammals as a result of Falcon 9 launch activities are authorized under a separate Letter of Authorization issued to VAFB. Two missions were performed that included return flight of the Falcon 9 first stage: SAOCOM (7 October 2018, 7:21 p.m.) and SSO-A (3 December 2018, 10:32 a.m.). The general methods and a summary of results are provided below. These are available in greater detail in the attached mission specific monitoring reports (previously submitted to NOAA Fisheries).

Monitoring Methods

The monitoring requirements vary by time of year and predicted location and level of sonic boom. Sonic boom modeling using PCBoom software was performed for each landing trajectory to predict levels and locations of sonic boom impacts. These were used to determine if and where pinniped monitoring would be performed (see IHA for specific requirements).

When required, pinniped monitoring on VAFB or the Northern Channel Islands (NCI) followed the protocols outlined in the IHA, which requires multiple daily counts beginning 72 hours prior to launch/landing and continuing to 48 hours after launch/landing. Safety related closures on south VAFB for launch preparations prevented monitors from performing counts during the day of the launch. A remote video camera is deployed during daytime launches to record the pinniped's reactions to the launch and estimated number of animals harassed; however, weather conditions (fog or rain) occasionally obscure video and limit its efficacy.

Pinniped monitoring was conducted on south VAFB at the primary haul-out sites, between Amphitheater and Flat Iron Rock, 4.43 to 4.95 mi. south of SLC-4 (Figures 1 and 2).

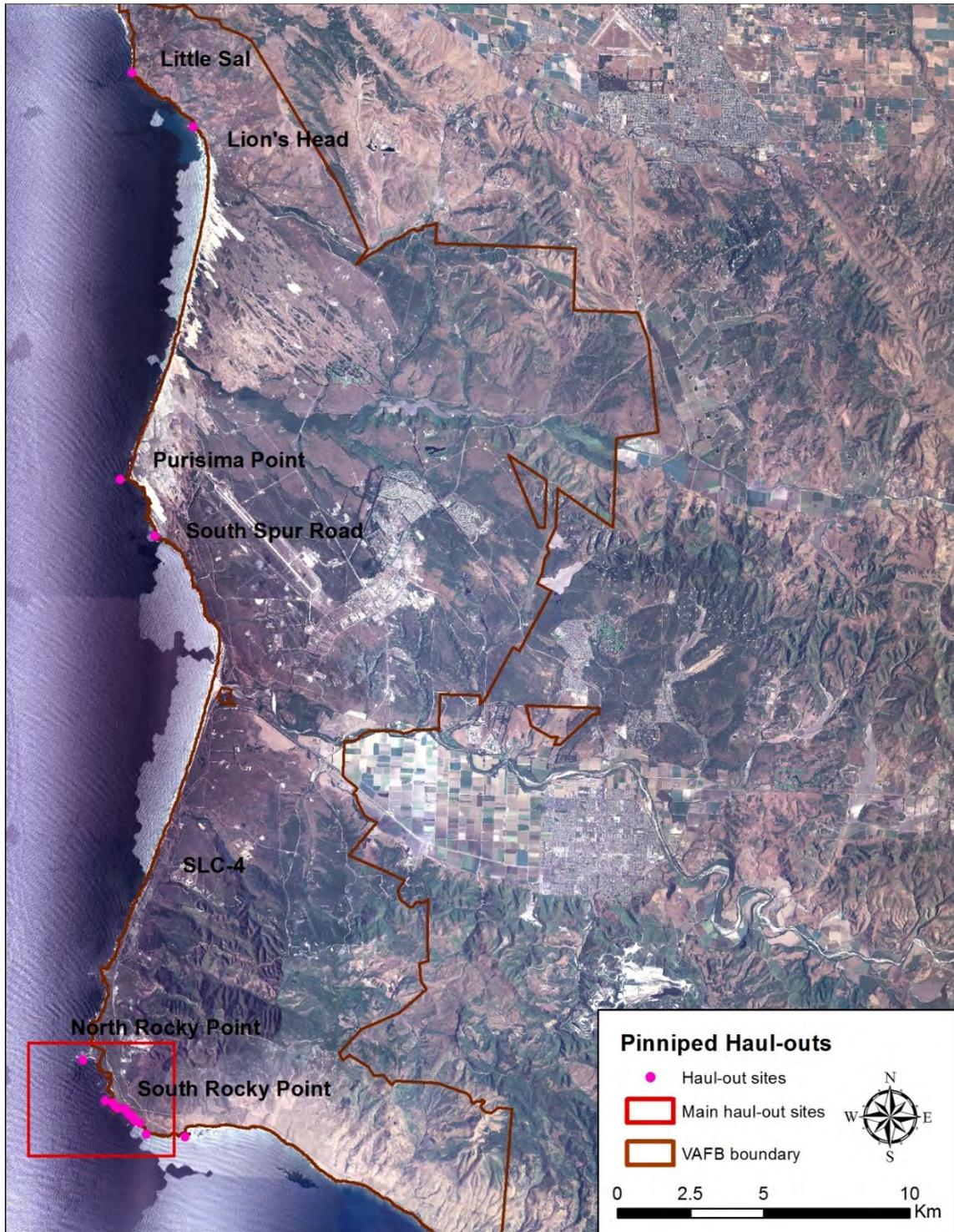


Figure 1. VAFB Pinniped Haul-outs.

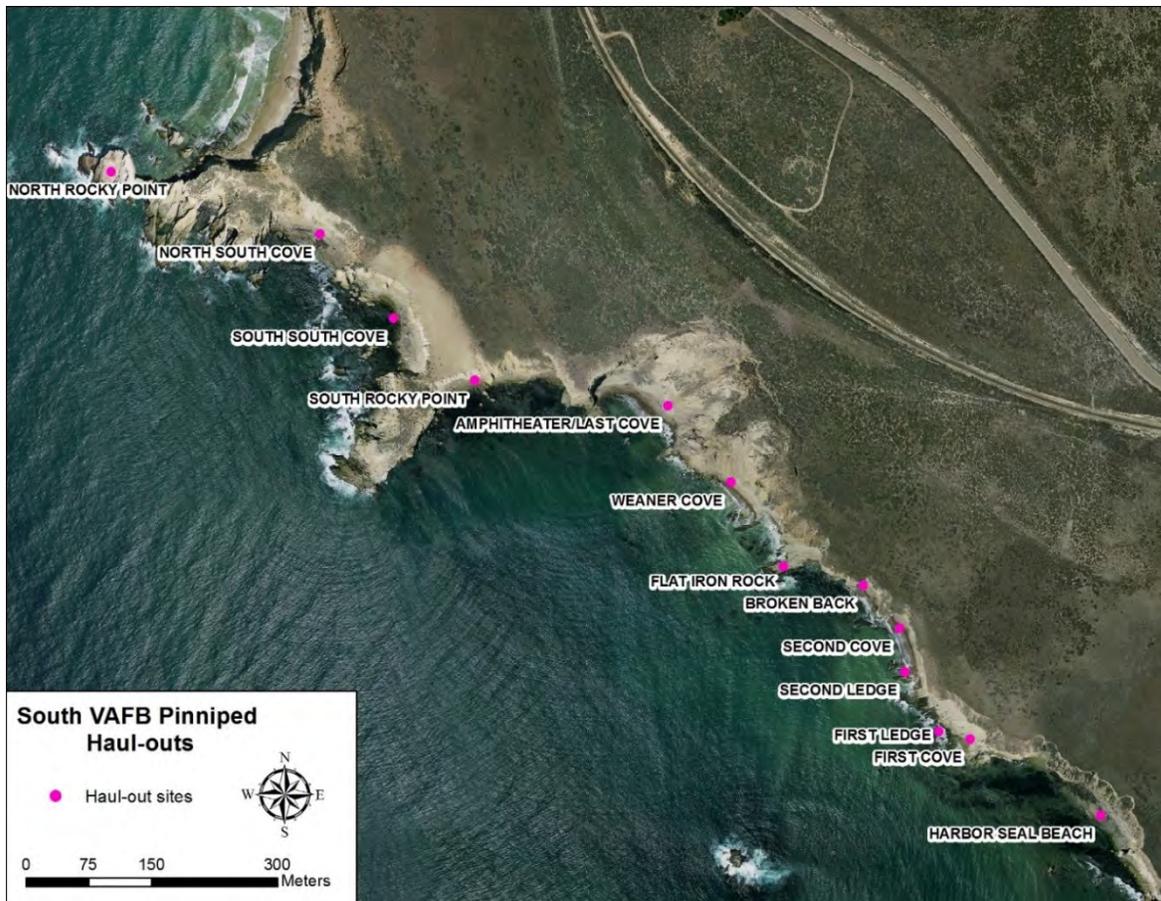


Figure 2. Primary South VAFB Pinniped Haul-outs.

A two-week follow-up count was not required during these two actions due to the timing of the activities. All counts were made over the course of four hours with count periods bracketed around the tide levels at the time of launch. Counts were made using 10 x 42 power binoculars and an 82-mm SWIFT® Sport Optics spotting scope at the primary count sites.

Each count included all pinnipeds hauled out at a site (not including animals in the water) at the time the count was made. Count data included species, number of animals, and age class. In addition, data on natural or human-caused disturbances and any unusual pinniped behavior was recorded. Environmental conditions were recorded at the monitoring site with a Kestrel 3000 hand-held wind gauge with a built-in thermometer. Tide data was obtained from the NOAA Tides and Currents website.

The following summary provides the mission summary information, which is available in greater detail in the attached mission specific monitoring reports (previously submitted to NOAA Fisheries).

Sonic Boom Modeling & Monitoring

Wyle Laboratories performed sonic boom modeling using PCBoom 6.6 to estimate the “far-field” sonic boom footprint associated with the return flight to SLC-4W. The results predicted that there would be no overpressure impacting the NCI at 2.0 psf or greater (Figure 3). SpaceX applied the NASA 1122 Model to estimate “near-field” levels, since it has been shown to be a more accurate model closer to the landing location (Figure 4).

The overpressure and engine noise generated during the return flight of the Falcon 9 first stage were recorded at bluff above the First Ledge haul out location (Figure 2). A Larson Davis SLM Model 831 recording unit was deployed at each location with a PCB 377A12 1/4- inch microphone and PCB PRM831 pre-amplifier. Each unit was deployed on a sturdy tripod so that the microphone was greater than six feet from the ground. Microphones were equipped with wind socks. Units were programmed to begin recording 30 minutes prior to the launch and landing event and cease recording 20 minutes after the event.

The time wave form and frequency spectra were extracted from the recordings and analyzed to estimate landing noise statistics. The sonic boom received at the pinniped monitoring location was estimated at 1.78 psf and the maximum landing engine noise at this location was estimated at 96.66 decibels (dB). The estimated maximum psf at this location was consistent with what was predicted by the PCBoom model (Figure 3), but less than that predicted by the NASA 1122 model (Figure 4).

Pinniped Monitoring

Pre-launch harbor seal counts, ranged from 3 to 45 adults and 1 to 3 juveniles. No pups were observed due to the time of year. Post-launch pinniped counts for harbor seals were between 9 and 16 adults and 2 to 8 juveniles. Numbers were observed to decline post-launch; however, this observation is more likely to be a result of the timing of the counts, which had to be shifted from afternoon to morning since the tide cycle shifted into the evening, and higher tides after the launch. Tides ranged from 1.3 to 4.7 feet prior to launch and 2.5 to 5.5 feet after the launch. Harbor seals tend to be hauled out in greater numbers during afternoon and during lower tides.

Northern elephant seal numbers ranged from 69 to 124 adults and 32 to 57 juveniles prior to the launch. Post-launch, elephant seals ranged from 102 to 144 adults and 31 to 80 juveniles, greater than pre-launch numbers. No elephant seal pups are present during the time of year of this event.

Only a single California sea lion was observed and only on a single day, two days prior to launch.

Because the launch occurred near dusk, video recording of pinnipeds was attempted but the recording was too dark to discern pinniped reactions to the launch and landing and

thus we could not estimate the exact number of animals harassed as a result of the landing event. Pre and post-launch count data suggest there were likely between 10 and 30 harbor seals, 100 to 180 northern elephant seals, and no California sea lions present at the monitoring locations during the event.

There was no evidence of mortality, injury, or abnormal behavior observed during the post-launch counts associated with the SAOCOM mission.



Figure 3. SAOCOM far-field sonic boom modeling results of landing flight using PCBoom model.

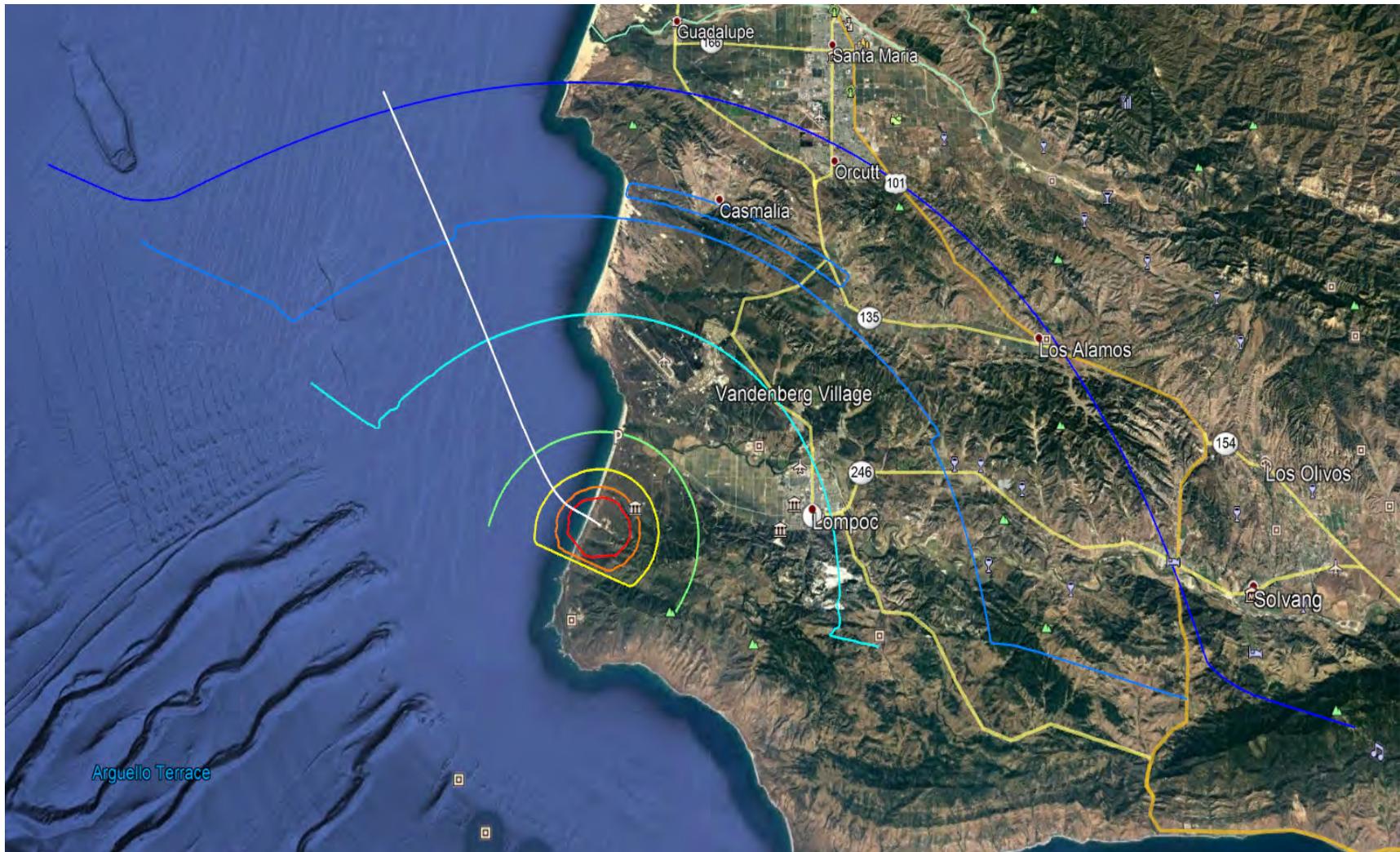


Figure 4. SAOCOM near-field sonic boom modeling results of return flight using NASA 1122 model.

Sonic Boom Modeling & Monitoring

Wyle Laboratories performed sonic boom modeling using PCBoom 6.6 to estimate the “far-field” sonic boom footprint associated with the return flight to the ASDS off the coast of VAFB. The results predicted that the maximum overpressure impacting the NCI would be approximately 0.2 psf (Figure 5). However, a boom predicted to exceed 1.0 psf was modeled to possibly impact the mainland, requiring pinniped monitoring on south VAFB.

The overpressure generated during the return flight of the Falcon 9 first stage was recorded at the bluff above the First Ledge monitoring location on South VAFB (Figure 4). A Larson Davis SLM Model 831 recording unit was deployed with a PCB 377A12 1/4-inch microphone and PCB PRM831 pre-amplifier. The unit was deployed on a sturdy tripod so that the microphone was greater than six feet from the ground. The microphone was equipped with a wind sock and programmed to begin recording 30 minutes prior to the launch and landing event and cease recording 20 minutes after the event.

The time wave forms were extracted from the recordings and analyzed to estimate overpressure levels. The landing created two sonic booms impacting the pinniped acoustic monitoring location approximately three seconds apart. Although the sonic boom modeling had predicted that an overpressure as great as 2.0 psf might impact the mainland monitoring area, the first sonic boom was calculated at only 0.0075 psf and the second was calculated at 0.011 psf. Therefore, the received overpressure levels at this location were significantly less than what was predicted by the PCBoom model.

Pinniped Monitoring

Pre-launch harbor seal counts, ranged from 1 to 46 adults and 1 to 15 juveniles. No pups were observed since they are not present at this time of year. Post-launch pinniped counts ranged between 4 and 50 adults and 2 to 5 juveniles. Pacific harbor seal numbers varied throughout the monitoring period based mainly on tide levels and weather conditions. At the time of the launch, the tide was approximately 2.5 feet. Overall, post-launch count totals were within range of pre-launch totals and the activity did not appear to affect this population.

Norther elephant seal numbers ranged from 33 to 47 adults, 36 to 49 sub-adult males, and 97 to 113 juveniles prior to the launch. Post-launch, elephant seals ranged from 19 to 40 adults, 42 to 60 sub-adult males, and 92 to 112 juveniles. Although the start of elephant seal pupping season typically starts in mid-December, no elephant seal pups were present during the early December time of monitoring. Pre- and post-launch totals were similar and the activity did not appear to have any impact on this species.

A single juvenile California sea lion was observed only on the two days prior to launch. The animal was observed coming and going at Amphitheater Cove throughout the hourly counts. Given that only a single animal was observed, it is difficult to infer any impacts from the launch on this species.



Figure 5. SSO-A far-field sonic boom modeling results of landing flight using PCBoom model.

Video footage indicated that nearly 45 of the 180 elephant seals, mostly juveniles, reacted to the initial launch by raising their heads but remaining in place. The remaining 135 elephant seals, adults and SAM's, showed no reaction and continued their current behavior of either sleeping or mock battling. 14 of the 15 harbor seals within the field of view of the video camera reacted to the initial launch by quickly moving into the water from their hauled-out location. The remaining harbor seal was alert but did not flush to the water. Over the next few minutes after the launch, seven harbor seals returned to the beach, but remained alert. However, at approximately 8 minutes 44 seconds after the launch, the sonic boom from the landing trajectory caused two of those seven harbor seals to retreat back into the water; the remaining five harbor seals moved toward the ocean but did not re-enter the water. Screen shots of the reaction to the launch and sonic boom are available for review upon request.

There was no evidence of mortality, injury, or abnormal behavior observed during the post-launch counts associated with the SSO-A mission

Please let us know if you have any questions.

Sincerely,

A handwritten signature in black ink, appearing to read 'm. thompson', with a long horizontal flourish extending to the right.

Matthew Thompson, SpaceX

Attachments:

- 1) Pinniped Monitoring for the 7 October 2018 SpaceX Falcon 9 SAOCOM Launch and Landing at Vandenberg Air Force Base, California.
- 2) Pinniped Monitoring for the 3 December 2018 SpaceX Falcon 9 SAOCOM Launch from Vandenberg Air Force Base, California.

Pinniped Monitoring for the 7 October 2018 SpaceX Falcon 9 SAOCOM Launch and Landing at Vandenberg Air Force Base, California



31 October 2018

Prepared for

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Acronyms and Abbreviations

30 CES/CEI	30 th Space Wing, Installation Management
ABR	Auditory Brainstem Response
dB	decibels
°F	degrees Fahrenheit
ft	feet
IHA	Incidental Harassment Authorization
LOA	Letter of Authorization
MSRS	ManTech SRS Technologies, Inc.
NCI	Northern Channel Islands
NOAA	National Oceanic and Atmospheric Administration
Pa	pascals
PDT	Pacific Daylight Time
psf	Pound per Square foot
SLC-4E	Space Launch Complex-4 East
SLC-4W	Space Launch Complex-4 West
VAFB	Vandenberg Air Force Base

Executive Summary

This report provides the United States Air Force, 30th Space Wing Installation Management Flight and the National Oceanic and Atmospheric Administration (NOAA) - National Marine Fisheries Service (Fisheries Service) with the results of biological monitoring of Pacific harbor seals (*Phoca vitulina richardii*), California sea lions (*Zalophus californianus*), and northern elephant seals (*Mirounga angustirostris*) on Vandenberg Air Force Base (VAFB) for the launch of the SpaceX Falcon 9 SAOCOM and first stage recovery. Steller sea lions (*Eumetopias jubatus*) were not observed. This launch occurred from VAFB's Space Launch Complex-4 East (SLC-4E) on 7 October 2018 at 19:21 Pacific Daylight Time (PDT). The first stage was recovered through a boost-back return flight and landing at Space Launch Complex-4 West (SLC-4W) approximately seven minutes after the launch.

Sonic boom modeling of the launch and landing trajectories determined that neither launch nor return flight would generate a sonic boom that would impact the Northern Channel Islands at a level that would trigger pinniped monitoring requirements. Therefore, no behavioral or acoustical monitoring was required or performed on the islands. Pinniped monitoring on VAFB was not required for the launch, since it was outside of the pupping season (1 January to 31 July); however, pinniped monitoring on VAFB was required for the landing because modeling results indicated that a sonic boom greater than one pound per square foot (psf) would impact haul-out locations; additionally, this was the first ever recovery of a first stage at VAFB.

Recording the sonic boom in order to estimate the level of the overpressure received by pinnipeds at the monitoring location was required. The estimated received overpressure was 1.78 psf at the pinniped monitoring location. Because the launch occurred near dusk, video recording of pinnipeds was attempted but the recording was too dark to discern pinniped reactions to the launch and landing. Hearing (Auditory Brainstem Response, or ABR) tests were not required.

Diurnal observations of pinnipeds were conducted at south VAFB haul-out sites. Four hourly counts were conducted at all haul-out locations between North Rocky Point and Weaner Cove (primary count locations); haul-out locations between Flat Iron Rock and Small Haul-out 2 were assessed by using a spotting scope from Amphitheater Cove.

Pre-launch pinniped counts were performed daily from 4 to 6 October. During this period, harbor seal numbers ranged from three to 45 adults and one to three juveniles. Post-launch harbor seal numbers varied from nine to 17 adults and two to eight juveniles. Pre-launch elephant seal counts ranged from 69 to 124 adults and 32 to 57 juveniles. Post-launch elephant seal counts ranged from 102 to 144 adults and 31 to 80 juveniles. Only one California sea lion was observed on the first day of monitoring. No pups of any species were present due to the time of year. A two-week follow-up count was not required.

1.0 Introduction

Under the Marine Mammal Protection Act (MMPA) of 1972, the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service issued a 5-year Programmatic Permit for unintentional take of small numbers of marine mammals incidental to space vehicle launch and test flight activities, and a 5-year Letter of Authorization (LOA) (NOAA Fisheries Service 2014a) to the 30th Space Wing at Vandenberg Air Force Base (VAFB) (NOAA Fisheries Service 2014b). Two amendments to this LOA were issued in 2017, the December 2017 amendment (NOAA Fisheries Service 2017) was followed for this launch action. The LOA allows specified launch programs, including the SpaceX Falcon 9 launch vehicle program at SLC-4E (Figure 1), to unintentionally take small numbers of marine mammals during launches. VAFB is required to comply with the conditions listed in the LOA and address NOAA Fisheries Service concerns regarding marine mammals at VAFB and the Northern Channel Islands (NCI). Under the LOA, monitoring of marine mammals on the NCI is required if sonic boom modeling predicts a sonic boom greater than one pound per square foot (psf) to impact one of the NCI between 1 March and 30 June, greater than 1.5 psf between 1 July and 30 September, and greater than 2 psf between 1 October and 28 February. In addition, pinniped monitoring is required on VAFB during launches from 1 January to 30 June.

NOAA Fisheries Services issued an Incidental Harassment Authorization (IHA) to SpaceX that authorizes the unintentional take of marine mammals incidental to Falcon 9 first stage recovery activities at SLC-4W. Under this IHA, if a sonic boom produced during the return flight of the first stage is predicted to impact the NCI greater than one psf between 1 March and 30 June, greater than 1.5 psf between 1 July and 30 September, and greater than 2 psf between 1 October and 28 February, monitoring at the NCI is required. In addition, monitoring at VAFB is required if a sonic boom greater than one psf is predicted to impact pinniped haulouts on Base. The Air Force is currently coordinating with NOAA Fisheries Service to incorporate the SpaceX IHA into the renewal of VAFB's LOA, which is expected in March 2019.

Pinnipeds haul out on remote sandy beaches and rocky ledges along the shores of VAFB. The main haul-out sites are near South Rocky Point on south VAFB, with smaller groups found at the Lion's Head, Spur Road, and Purisima Point areas on north VAFB (Figures 1-1 and 1-2). This report summarizes the monitoring performed on the haul-out sites on South VAFB for the 7 October 2018 SpaceX Falcon 9 SAOCOM launch and landing at VAFB.

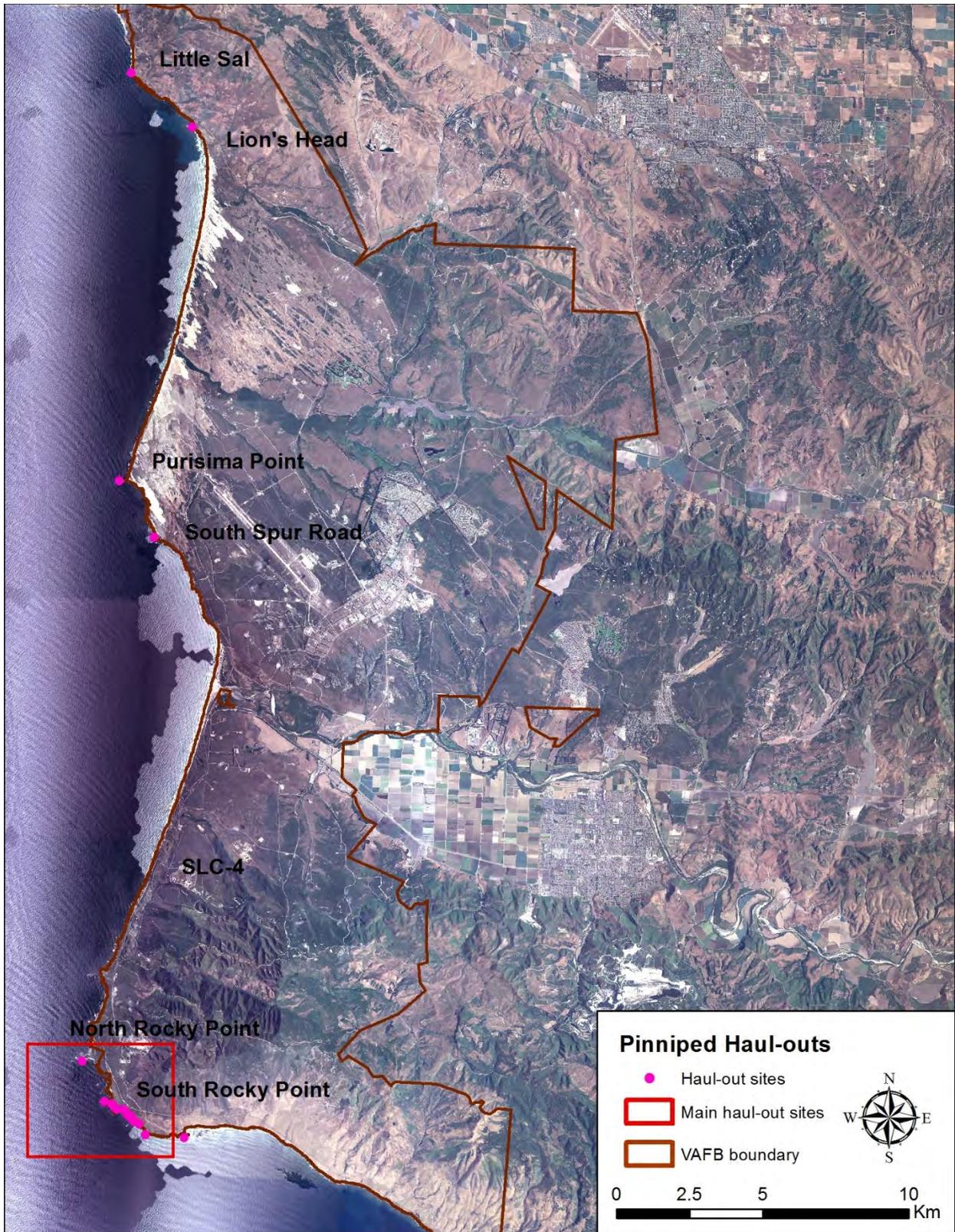


Figure 1-1. VAFB Pinniped Haul-outs.

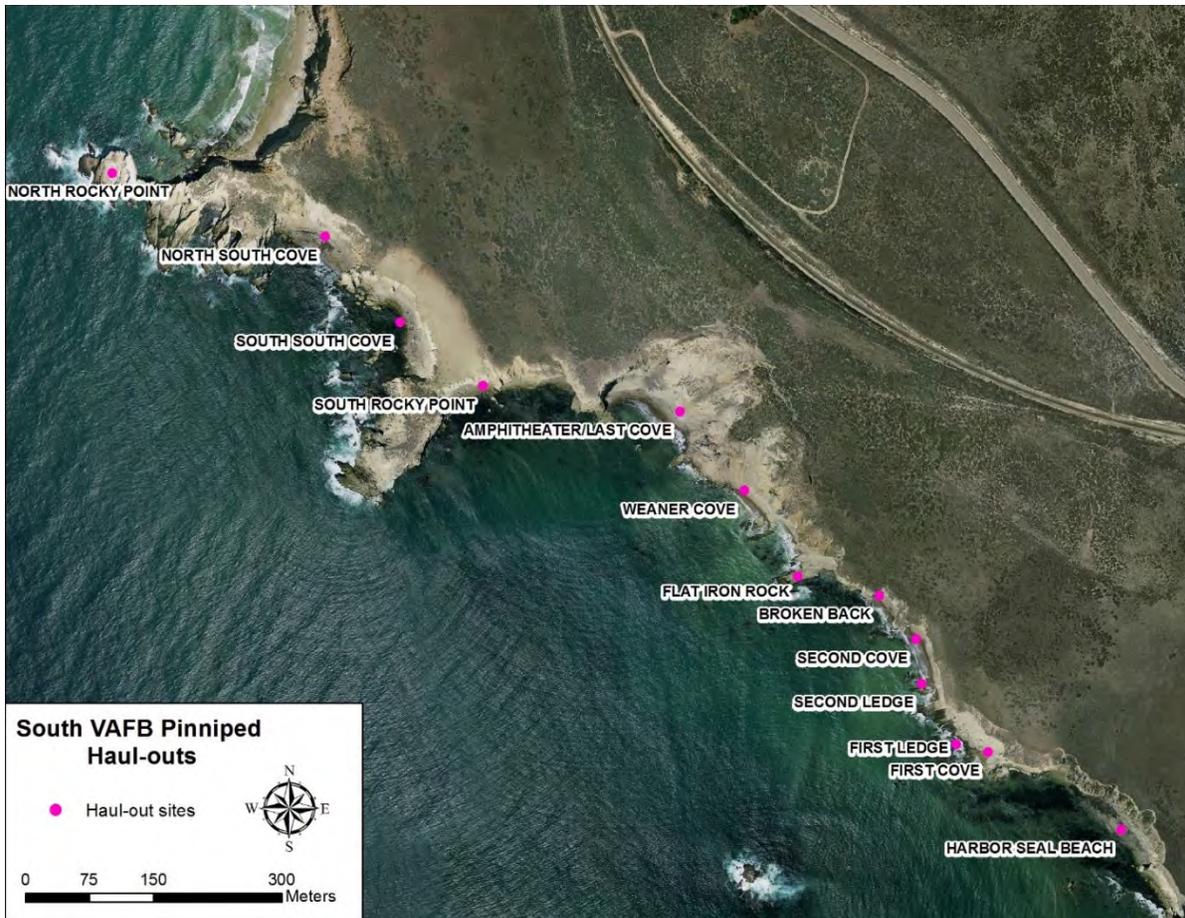


Figure 1-2. Primary South VAFB Pinniped Haul-outs.

2.0 Sonic Boom Monitoring

2.1 Sonic Boom Modeling

In accordance with the LOA issued to VAFB, ManTech SRS Technologies, Inc. (MSRS) performed sonic boom modeling using PCBoom3 to determine the potential impact location of a sonic boom generated by the SpaceX Falcon 9 launch from SLC-4E. Pre-launch sonic boom modeling used nominal flight trajectory information and multiple daily meteorological profiles to generate potential sonic boom footprints and levels. These were then analyzed to determine the likelihood of a sonic boom impacting the NCI during the launch and whether pinniped monitoring would be required on the NCI. The results revealed that no sonic booms would impact the surface of the earth as a result of the launch; therefore, there no pinniped monitoring was required on the NCI as a result of predicted launch related impacts.

In addition, Wyle Laboratories performed sonic boom modeling using PCBoom 6.6 to estimate the “far-field” sonic boom footprint associated with the return flight to SLC-4W. The results predicted that there would be no overpressure impacting the NCI at 2.0 psf or greater (Figure 2-1). SpaceX applied the NASA 1122 Model to estimate “near-field” levels, since it has been shown to be a more accurate model closer to the landing location (Figure 2-2).



Figure 2-1. Far-field sonic boom modeling results of landing flight using PCBoom model.

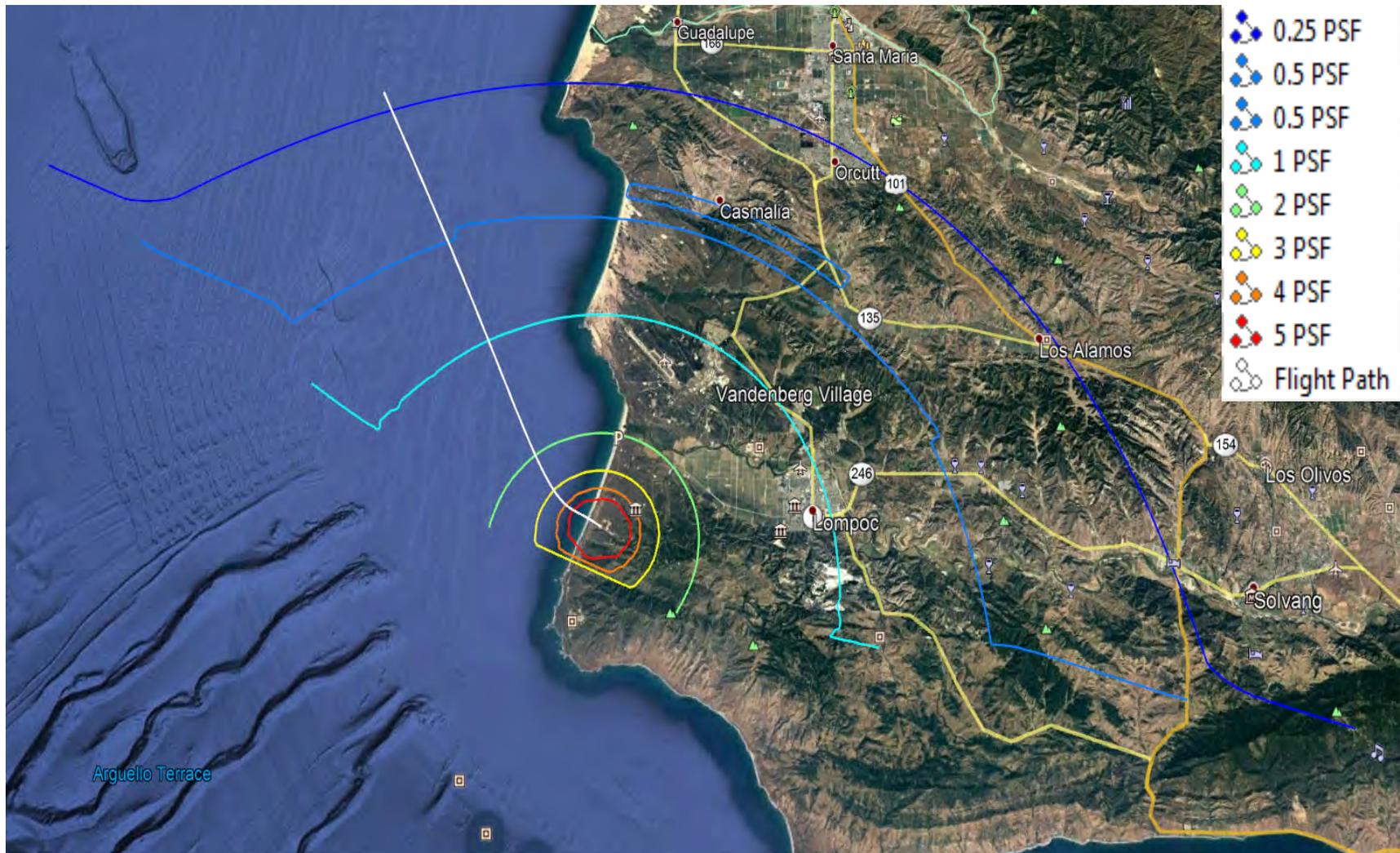


Figure 2-2. Near-field sonic boom modeling results of return flight using NASA 1122 model.

2.2 Sonic Boom Monitoring

The overpressure and engine noise generated during the return flight of the Falcon 9 first stage were recorded at the pinniped monitoring location on South VAFB, as well as the nearby southern sea otter monitoring location, as was required by the United States Fish and Wildlife Service Biological Opinion (Figure 2-3). A Larson Davis SLM Model 831 recording unit was deployed at each location with a PCB 377A12 1/4- inch microphone and PCB PRM831 pre-amplifier. Each unit was deployed on a sturdy tripod so that the microphone was greater than six feet from the ground. Microphones were equipped with wind socks. Units were programmed to begin recording 30 minutes prior to the launch and landing event and cease recording 20 minutes after the event.

The time wave form and frequency spectra were extracted from the recordings and analyzed to estimate landing noise statistics (Table 2-1; Figures 2-4 through 2-7). The sonic boom received at the pinniped monitoring location was estimated at 1.78 psf and the maximum landing engine noise at this location was estimated at 96.66 decibels (dB). The estimated maximum psf at this location was consistent with what was predicted by the PCBoom model (Figure 2-1), but less than that predicted by the NASA 1122 model (Figure 2-2).

Table 2-1. Falcon 9 SAOCOM landing noise levels.

Location	Latitude	Longitude	Max Landing Engine Noise dB	Boom Statistics		
				Max Pa*	Max dB	Max PSF
Pinniped	34.55662	-120.62506	96.66	85.912	132.6	1.78
Sea Otter	34.55732	-120.60360	99.50	33.834	124.56	0.71

* Maximum pressure in Pascals.



Figure 2-3. Acoustic monitoring locations for SpaceX Falcon 9 SAOCOM.

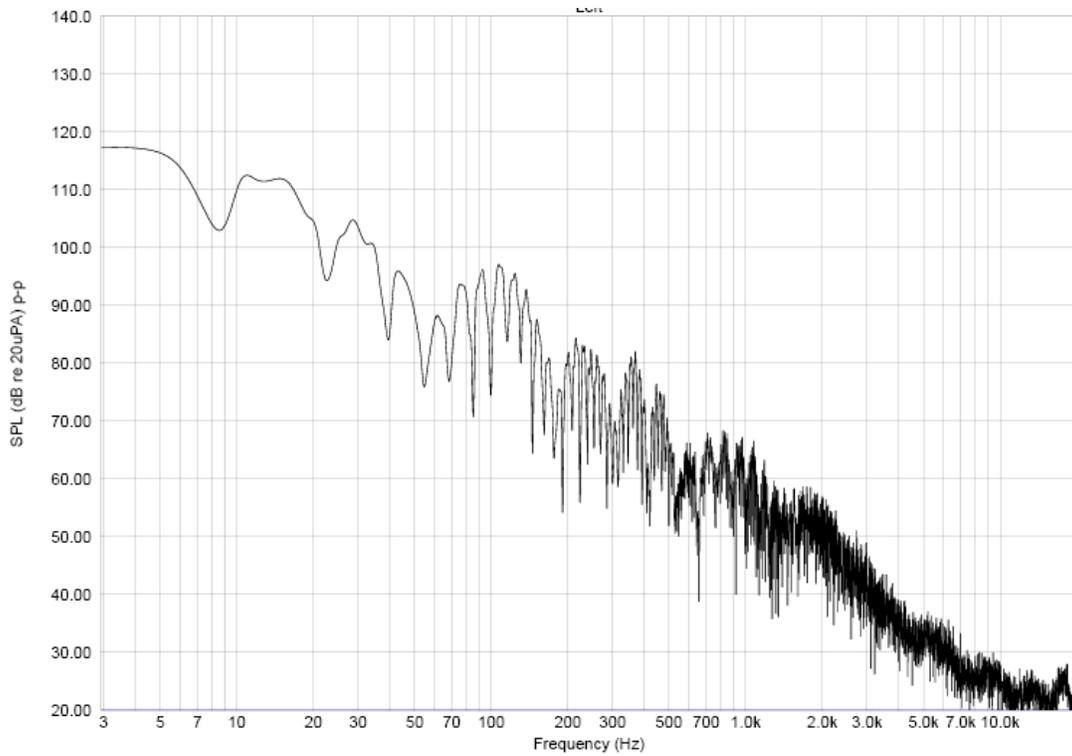


Figure 2-4. Frequency spectra of sonic boom at the pinniped monitoring location.

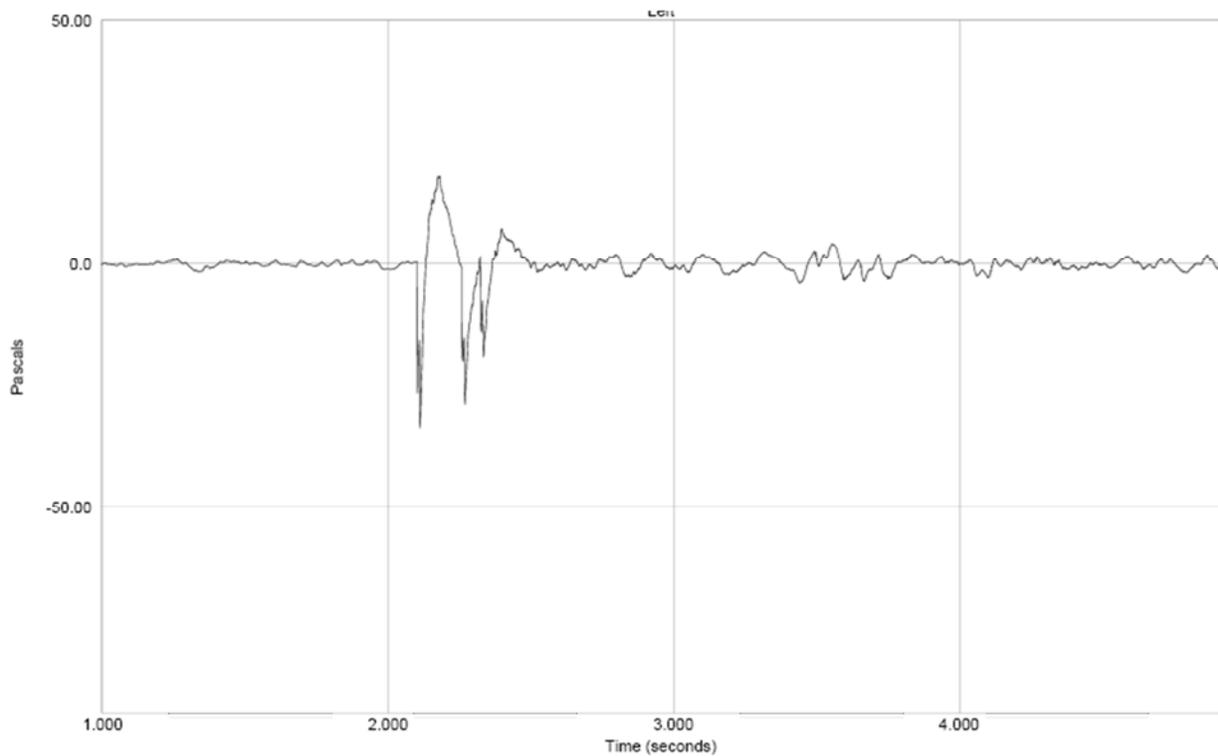


Figure 2-5. Time wave form of sonic boom at the pinniped monitoring location.

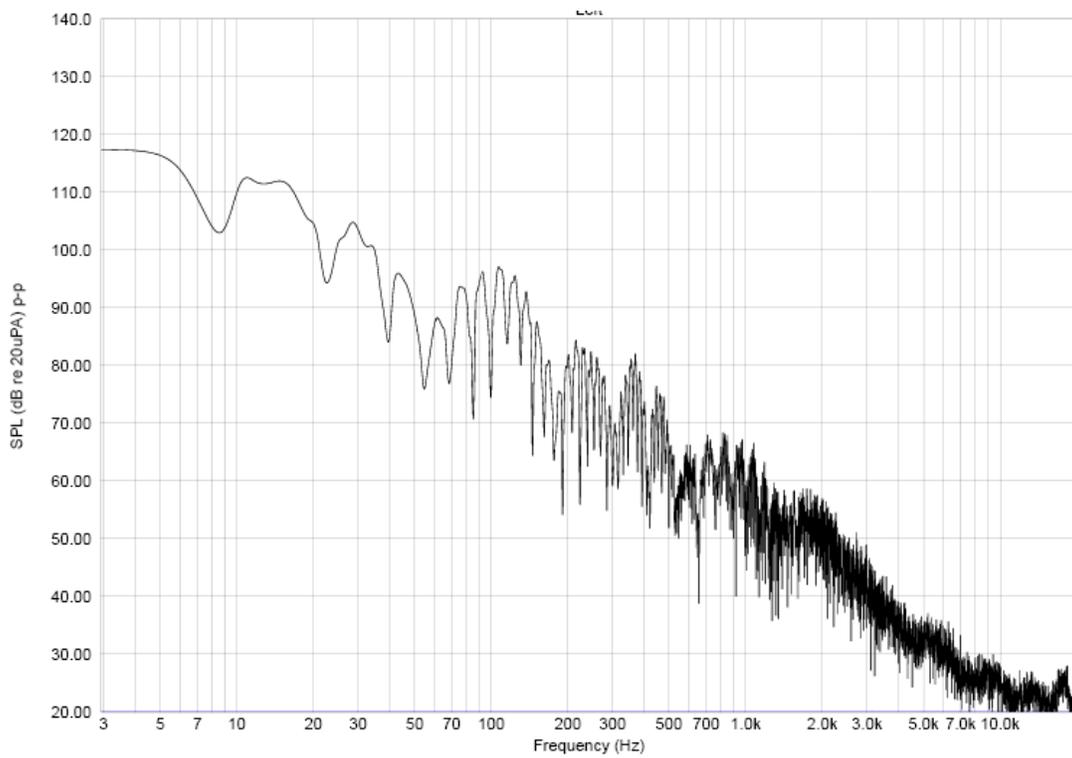


Figure 2-6. Frequency spectra of sonic boom at the southern sea otter monitoring location.

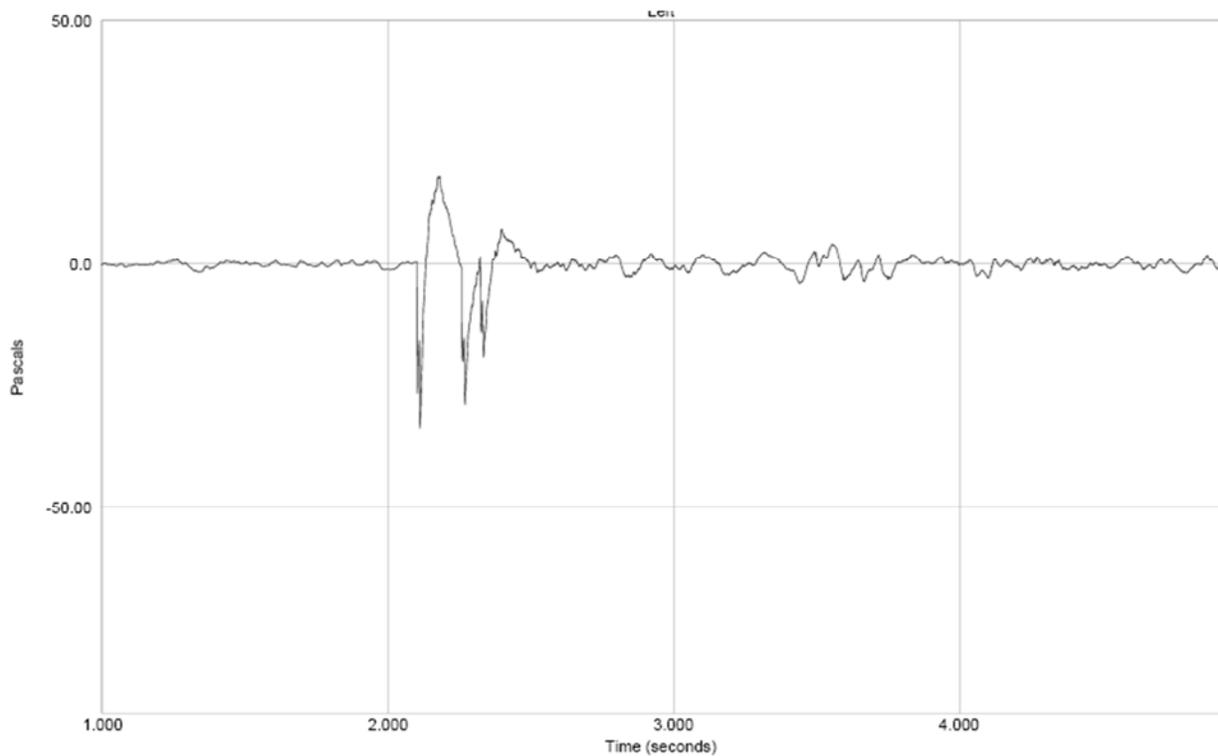


Figure 2-7. Time wave form of sonic boom at the southern sea otter monitoring location.

3.0 Pinniped Monitoring

3.1 Methods

Pinniped monitoring on VAFB followed the protocols outlined in the IHA, which requires multiple daily counts beginning 72 hours prior to launch and continuing to 48 hours after launch. Safety related closures on south VAFB for launch preparations prevented monitors from performing counts during the day of the launch. A remote video camera was deployed in an attempt to record the pinniped's reactions to the launch; however, it was too dark at the time of the event to discern any behaviors.

Pre-launch counts for pinnipeds on VAFB were initiated on 4 October 2018 on south VAFB. Animals were primarily distributed between Amphitheater and Flat Iron Rock, 4.43 to 4.95 mi. south of SLC-4 (Figures 1-1 and 1-2). Pre-launch counts were conducted 4 to 6 October 2018. Post-launch pinniped counts were performed on 8 October 2018 and 9 October 2018. A two-week follow-up count was not required. Pre-launch, post-launch, and two-week follow-up counts were made over the course of four hours with count periods bracketed around the tide levels at the time of launch. Counts were made using 10 x 42 power binoculars and an 82-mm SWIFT® Sport Optics spotting scope at the primary count sites.

Each count included all pinnipeds hauled out at a site (not including animals in the water) at the time the count was made. Count data included species, number of animals, and age class. For the purposes of these counts, adult-sized animals were considered adults, animals that were in the range of sub-adult to young of last year considered juveniles, and young of the year were considered pups. However, due to the similarities of weaned elephant seal pups (weaners) and young of last year, all weaned elephant seals that were not adults or nursing pups were considered juveniles. In addition, data on natural or human-caused disturbances and any unusual pinniped behavior was recorded. Environmental conditions were recorded at the monitoring site with a Kestrel 3000 hand-held wind gauge with a built-in thermometer. Tide data was obtained from NOAA Tides and Currents website (NOAA 2018).

3.2 Results

Pre-launch harbor seal counts, ranged from 3 to 45 adults and 1 to 3 juveniles (Figure 3-1). No pups were observed due to the time of year. Post-launch pinniped counts for harbor seals were between 9 and 16 adults and 2 to 8 juveniles (Figure 3-1). Numbers were observed to decline post-launch; however, this observation is more likely to be a result of the timing of the counts, which had to be shifted from afternoon to morning since the tide cycle shifted into the evening, and higher tides after the launch. Tides ranged from 1.3 to 4.7 feet prior to launch and 2.5 to 5.5 feet after the launch. Harbor seals tend to be hauled out in greater numbers during afternoon and during lower tides.

Elephant seal numbers ranged from 69 to 124 adults and 32 to 57 juveniles prior to the launch (Figure 3-2). Post-launch, elephant seals ranged from 102 to 144 adults and 31 to 80 juveniles, greater than pre-launch numbers (Figure 3-2). No elephant seal pups are present during the time of year of this event.

Only a single California sea lion was observed and only on a single day, two days prior to launch (Figure 3-3).

Temperatures, as recorded at the haul-out site during monitored hours, ranged from 65.4 to 78.3 degrees Fahrenheit (°F). Maximum wind speeds ranged from 1.2 to 9.6 miles per hour. Cloud cover varied substantially from 0 to 100-percent with heavy fog onshore, with relatively little cloud cover observed on 4 and 5 October and no cloud cover observed on 8 October.

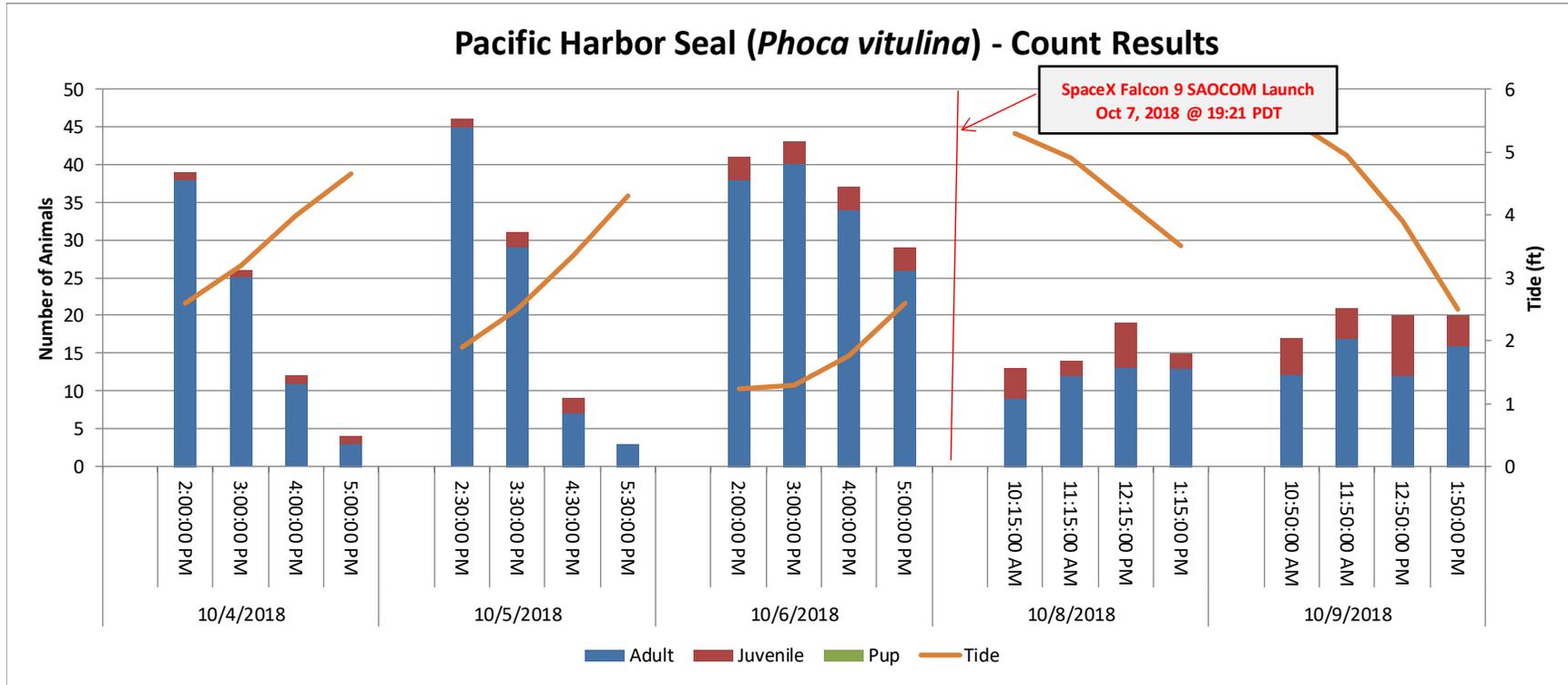


Figure 3-1. Harbor seal count results.

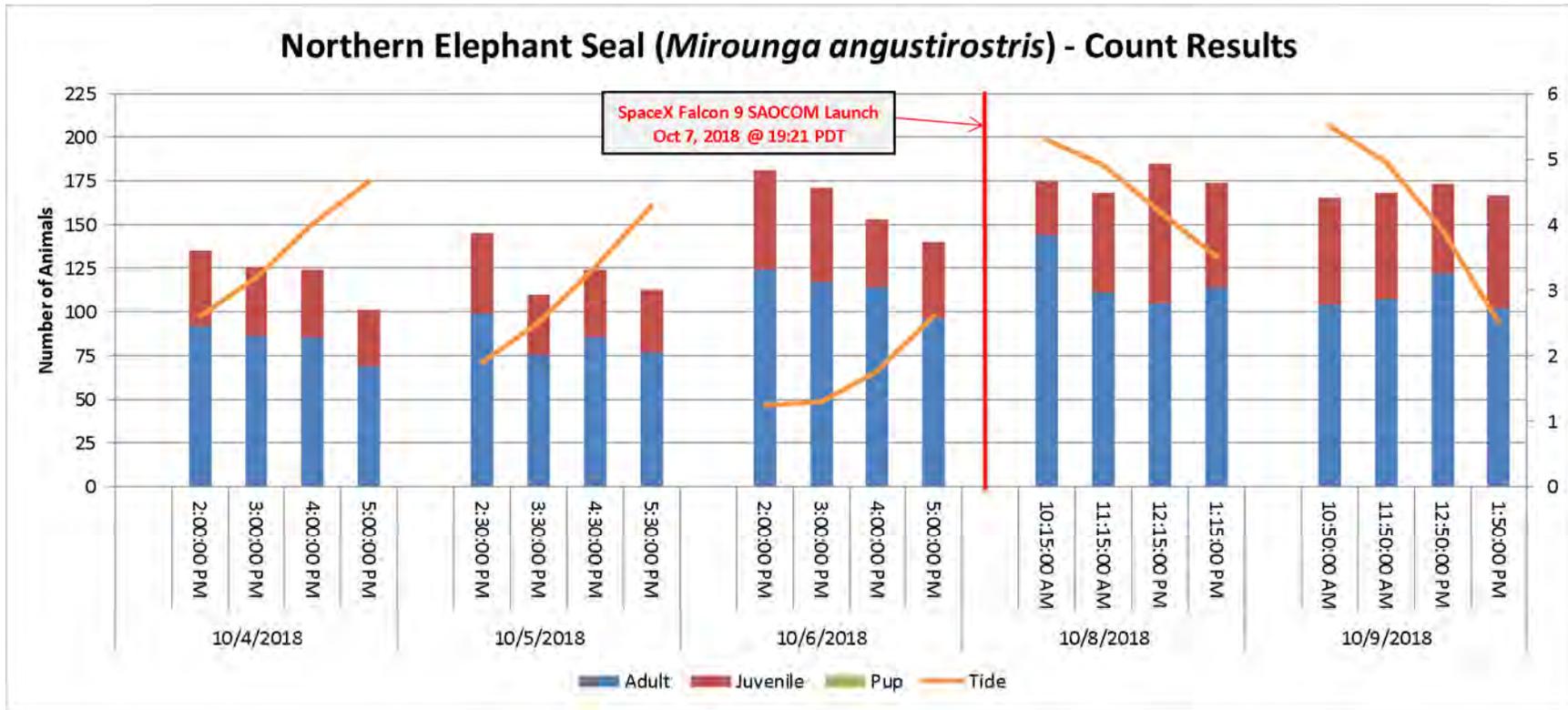


Figure 3-2. Northern elephant seal count results.

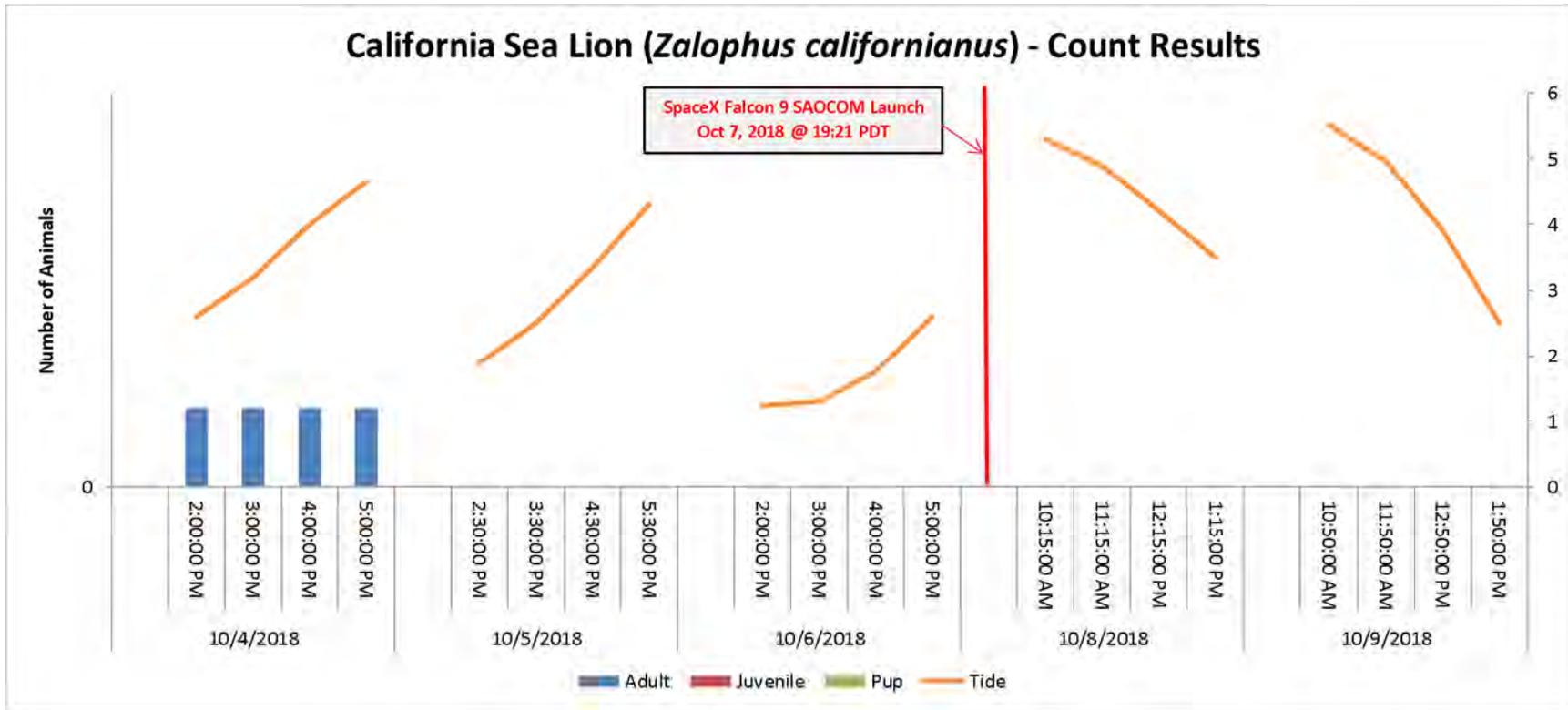


Figure 3-3. California sea lion count results.

4.0 Discussion

The physical counts of pinnipeds, including harbor seals, northern elephant seals, and California sea lions for the 48 hours post launch, indicate that there were no negative impacts as a result of the launch. Although harbor seal numbers fell post-launch, the decrease is likely a result of changes in the timing of the monitoring and higher tides. Elephant seal numbers were observed to increase and there were not enough California sea lions present to infer potential impacts.

No evidence of mortality, injury, or abnormal behavior was observed during the post-launch counts. Based on the results of monitoring, the 7 October 2018 launch of the SpaceX Falcon 9 SAOCOM did not appear to have a significant effect on pinnipeds present at the south VAFB haul-out sites.

5.0 Literature Cited

National Oceanic and Atmospheric Administration National Marine Fisheries Service (NOAA Fisheries). 2014a. Five Year Authorization: Taking of Marine Mammals Incidental to U.S. Air Force Launches, Aircraft and Helicopter Operations, and Harbor Activities Related to Launch Vehicles from Vandenberg Air Force Base (VAFB), dated 24 February 2014. Federal Register Vol. 70, No. 36, pp 10016-10028.

NOAA Fisheries. 2014b. Letter of Authorization, issued to the U.S. Air Force, 30th Space Wing. Valid March 26, 2014 through March 26, 2019. Dated March 26, 2014. 7 pp.

NOAA Fisheries. 2017. Letter of Authorization, issued to the U.S. Air Force, 30th Space Wing. Valid January 1, 2018 through March 26, 2019. Dated December 20, 2017. 7 pp

NOAA Fisheries. 2018. Tides and Currents. Tides/Water Levels. Port San Luis, CA. TWC0473 Point Arguello. <https://tidesandcurrents.noaa.gov/noaatidepredictions.html?id=TWC0473>

Pinniped Monitoring for the 3 December 2018 SpaceX Falcon 9 SAOCOM Launch from Vandenberg Air Force Base, California



24 January 2019

Prepared for

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Acronyms and Abbreviations

30 CES/CEI	30 th Space Wing, Installation Management
ABR	Auditory Brainstem Response
ASDS	Autonomous Spaceport Drone Ship
dB	decibels
°F	degrees Fahrenheit
ft	foot or feet
IHA	Incidental Harassment Authorization
LOA	Letter of Authorization
mph	miles per hour
MSRS	ManTech SRS Technologies, Inc.
NCI	Northern Channel Islands
NOAA	National Oceanic and Atmospheric Administration
Pa	Pascals
PST	Pacific Standard Time
psf	pound per square foot
SAM	sub-adult male (Northern elephant seal)
SLC-4E	Space Launch Complex-4 East
SLC-4W	Space Launch Complex-4 West
VAFB	Vandenberg Air Force Base

Executive Summary

This report provides the United States Air Force, 30th Space Wing Installation Management Flight and the National Oceanic and Atmospheric Administration (NOAA) - National Marine Fisheries Service (Fisheries Service) with the results of biological monitoring of Pacific harbor seals (*Phoca vitulina richardii*), California sea lions (*Zalophus californianus*), and northern elephant seals (*Mirounga angustirostris*) on Vandenberg Air Force Base (VAFB) for the launch of the SpaceX Falcon 9 SSO-A and first stage recovery. Steller sea lions (*Eumetopias jubatus*) were not observed during this time period. This launch occurred from VAFB's Space Launch Complex-4 East (SLC-4E) on 3 December at 10:32 a.m. Pacific Standard Time (PST). The first stage was recovered through a boost-back return flight and landing on an Autonomous Spaceport Drone Ship (ASDS), approximately 50 kilometers offshore, approximately eight minutes after the launch.

Sonic boom modeling of the launch and landing trajectories determined that neither launch nor return flight would generate a sonic boom that would impact the Northern Channel Islands at a level that would trigger pinniped monitoring requirements. Therefore, no behavioral or acoustical monitoring was required or performed on the islands. Pinniped monitoring on VAFB was not required for the launch, since it was outside of the pupping season (1 January to 31 July); however, pinniped monitoring on VAFB was required for the landing because modeling results indicated that a sonic boom greater than one pound per square foot (psf) could impact haul-out locations. Hearing (Auditory Brainstem Response, or ABR) tests were not required.

Acoustic monitoring of the sonic boom was also required in order to estimate the level of the overpressure received by pinnipeds at the monitoring location. The landing produced two separate overpressures that impacted the monitoring location approximately three seconds apart. The first received overpressure was calculated 0.0075 psf and the second received overpressure was 0.011 psf. Since the launch occurred during the day, video recording of pinnipeds was conducted at Amphitheater Cove. The results of the recording indicated that no pinnipeds were injured or killed as a result of launch and landing activities. All northern elephant seals remained hauled-out, with only a few individuals lifting their heads in response to the noise. All harbor seals hauled-out at the time of launch retreated into the water.

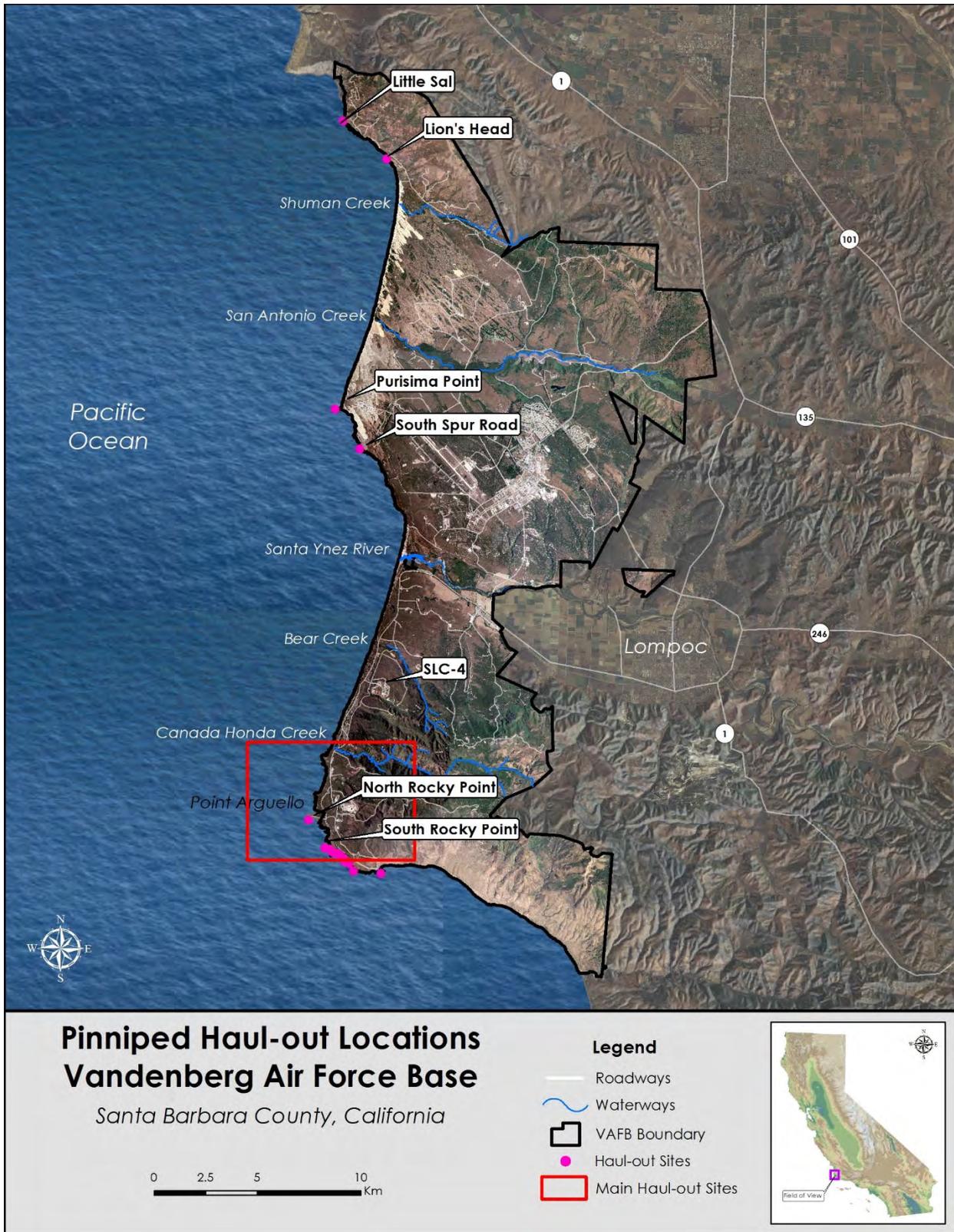
Daily counts were performed at south VAFB haul-out sites at four hourly intervals between South Rocky Point and Weaner Cove (primary count locations, Figure 1-2). In addition, the haul-out locations between Flat Iron Rock and Small Haul-out 2 were assessed at the first and last hourly counts due to the distance between the locations. Pre-launch pinniped counts were performed daily from 29 November to 1 December. During this period, harbor seal numbers ranged from 1 to 46 adults and 1 to 15 juveniles. Post-launch harbor seal numbers varied from 4 to 50 adults and 2 to 5 juveniles. Pre-launch elephant seal counts ranged from 28 to 47 adults, 39 to 49 Sub-adult males (SAM), and 97 to 113 juveniles. Post-launch elephant seal counts ranged from 19 to 40 adults, 42 to 60 SAM's, and 92 to 112 juveniles. Only 1 juvenile California sea lion visiting Amphitheater Cove was observed on the two days prior to launch. No pups of any species were present due to the time of year. A two-week follow-up count was not required.

1.0 Introduction

Under the Marine Mammal Protection Act (MMPA) of 1972, the National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service issued the 30th Space Wing at Vandenberg Air Force Base (VAFB) regulations (a “Final Rule”) for Taking Marine Mammals Incidental to U.S. Air Force Launches (etc.) (NOAA Fisheries Service 2014a), and a Letter of Authorization (LOA) (NOAA Fisheries Service 2014b). Two amendments to this LOA were issued in 2017, the December 2017 amendment (NOAA Fisheries Service 2017b) was followed for this launch action. The LOA allows specified launch programs, including the SpaceX Falcon 9 launch vehicle program at SLC-4E (Figure 1-1), to unintentionally take small numbers of marine mammals during launches. VAFB is required to comply with the conditions listed in the LOA and address NOAA Fisheries Service concerns regarding marine mammals at VAFB and the Northern Channel Islands (NCI). Under the LOA, monitoring of marine mammals on the NCI is required if sonic boom modeling predicts a sonic boom greater than one pound per square foot (psf) to impact one of the NCI between 1 March and 30 June, greater than 1.5 psf between 1 July and 30 September, and greater than 2 psf between 1 October and 28 February. In addition, pinniped monitoring is required on VAFB during launches from 1 January to 31 July.

NOAA Fisheries Services issued an Incidental Harassment Authorization (IHA) to SpaceX that authorizes the unintentional take of marine mammals incidental to Falcon 9 first stage recovery activities at SLC-4W (NOAA Fisheries Service 2017a). Under this IHA, if a sonic boom produced during the return flight of the first stage is predicted to impact the NCI greater than one psf between 1 March and 30 June, greater than 1.5 psf between 1 July and 30 September, and greater than 2 psf between 1 October and 28 February, monitoring at the NCI is required. In addition, monitoring at VAFB is required if a sonic boom greater than one psf is predicted to impact pinniped haul-outs on Base. The Air Force is currently coordinating with NOAA Fisheries Service to incorporate the SpaceX IHA into the renewal of VAFB’s LOA, which is expected in March 2019.

Pinnipeds haul out on remote sandy beaches and rocky ledges along the shores of VAFB. The main haul-out sites are near South Rocky Point on south VAFB, with smaller groups found at the Lion’s Head, Spur Road, and Purisima Point areas on north VAFB (Figures 1-1 and 1-2). This report summarizes the monitoring performed on the haul-out sites on South VAFB for the 3 December 2018 SpaceX Falcon 9 SSO-A mission at VAFB.



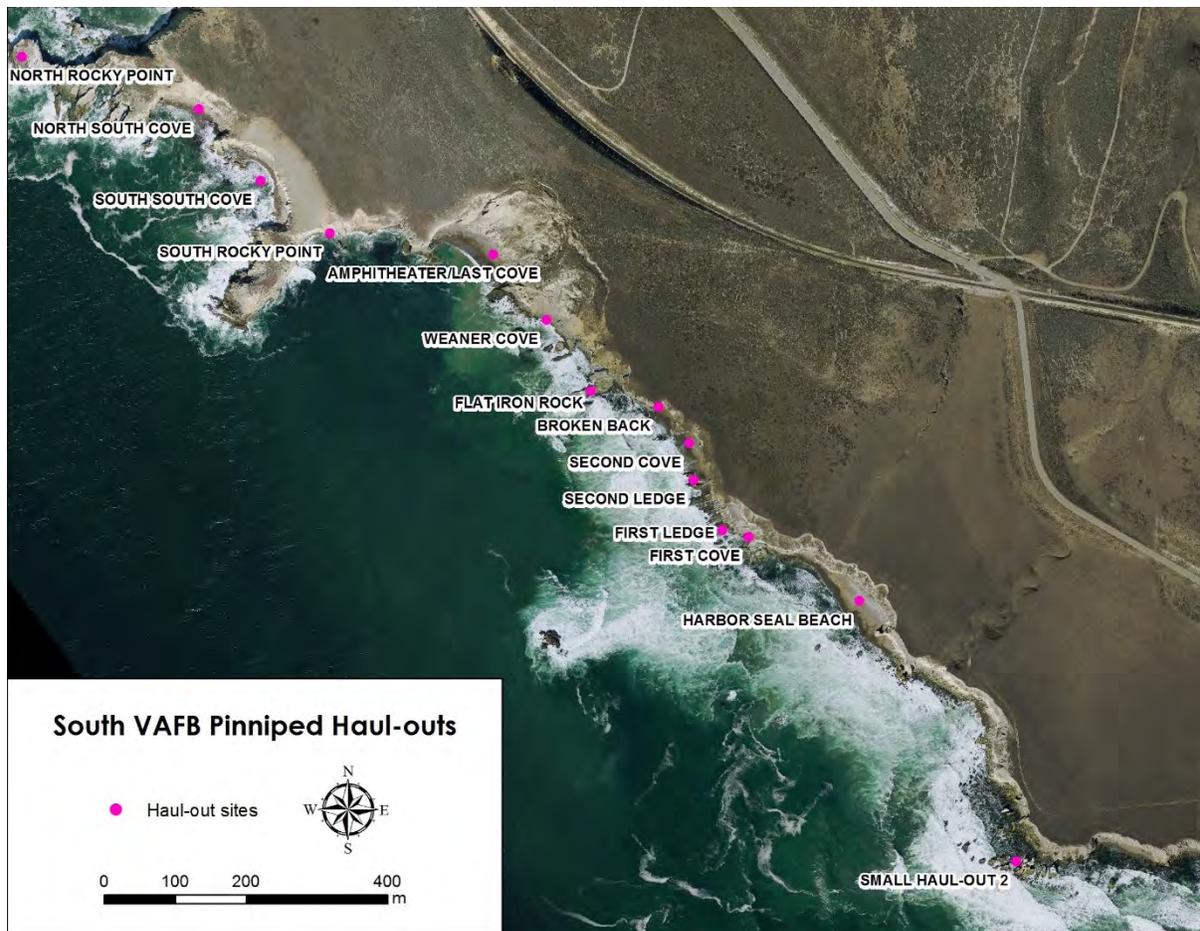


Figure 1-2. Primary South VAFB Pinniped Haul-outs.

2.0 Sonic Boom Monitoring

2.1 Sonic Boom Modeling

In accordance with the LOA issued to VAFB, ManTech SRS Technologies, Inc. (MSRS) performed sonic boom modeling using PCBoom3 to determine the potential impact location of a sonic boom generated by the SpaceX Falcon 9 launch from SLC-4E. Pre-launch sonic boom modeling used nominal flight trajectory information and multiple daily meteorological profiles to generate potential sonic boom footprints and levels. These were then analyzed to determine the likelihood of a sonic boom impacting the NCI during the launch and whether pinniped monitoring would be required on the NCI. The results revealed that no sonic booms would impact the surface of the earth as a result of the launch; therefore, there no pinniped monitoring was required on the NCI for launch related impacts.

In addition, Wyle Laboratories performed sonic boom modeling using PCBoom 6.6 to estimate the “far-field” sonic boom footprint associated with the return flight to the ASDS off the coast of VAFB. The results predicted that the maximum overpressure impacting the NCI would be approximately 0.2 psf (Figure 2-1). However a boom predicted to exceed 1.0 psf was modeled to possibly impact the mainland, requiring pinniped monitoring on south VAFB (Figure 2-1).



Figure 2-1. Far-field sonic boom modeling results of Falcon 9 SSO-A landing flight using PCBoom model.

2.2 Sonic Boom Monitoring

The overpressure generated during the return flight of the Falcon 9 first stage was recorded at the pinniped monitoring location on South VAFB, as was required by the IHA (Figure 2-2). A Larson Davis SLM Model 831 recording unit was deployed with a PCB 377A12 1/4- inch microphone and PCB PRM831 pre-amplifier. The unit was deployed on a sturdy tripod so that the microphone was greater than six feet (ft) from the ground. The microphone was equipped with a wind sock and programmed to begin recording 30 minutes prior to the launch and landing event and cease recording 20 minutes after the event.

The time wave forms were extracted from the recordings and analyzed to estimate overpressure levels (Figures 2-3 and 2-4). The landing created two sonic booms impacting the pinniped acoustic monitoring location approximately three seconds apart. Although the sonic boom modeling had predicted that an overpressure as great as 2.0 psf might impact the mainland monitoring area, the first sonic boom was calculated at only 0.0075 psf and the second was calculated at 0.011 psf. Therefore, the received overpressure levels at this location were significantly less than what was predicted by the PCBoom model (Figure 2-1).

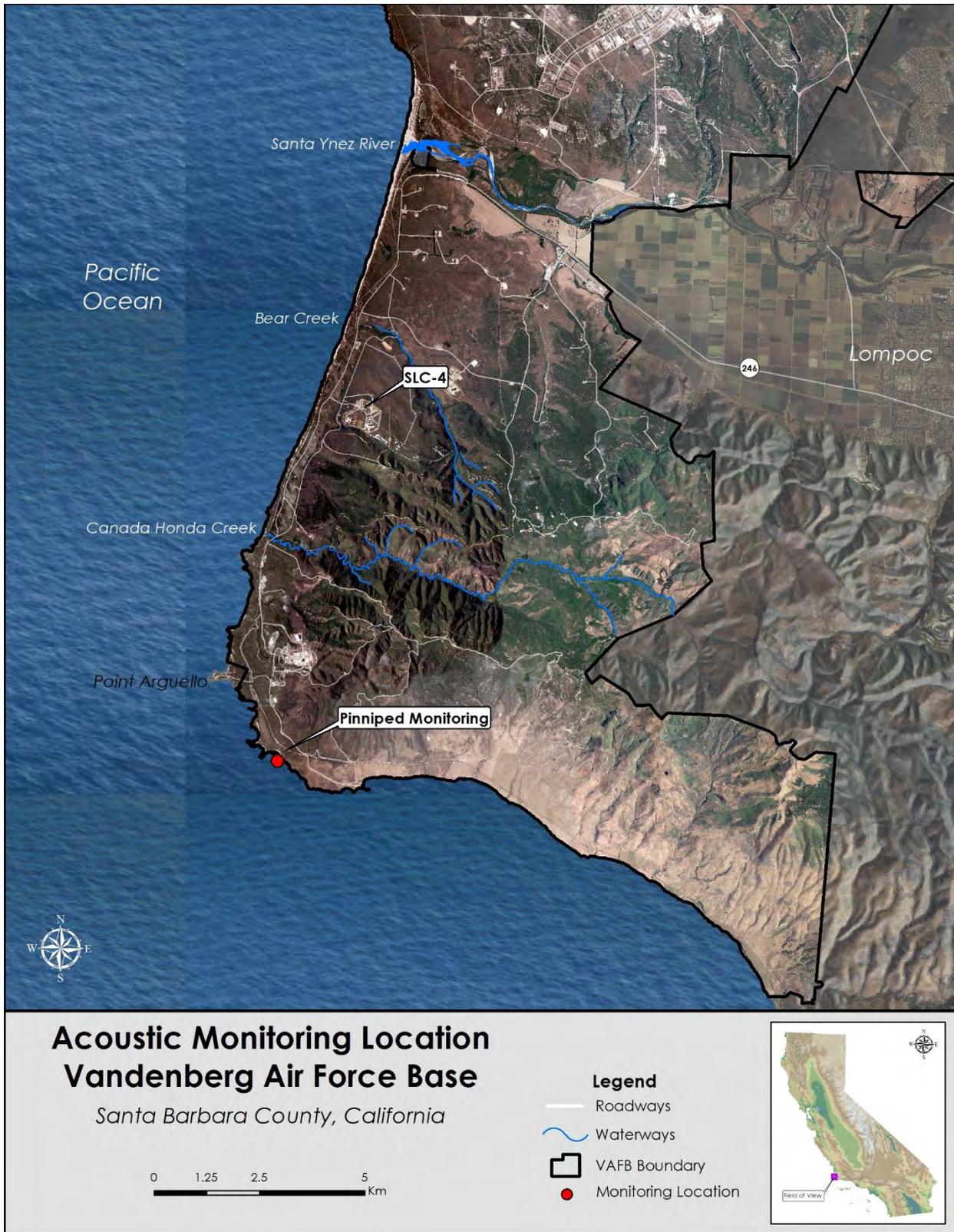


Figure 2-2. Acoustic monitoring locations for SpaceX Falcon 9 SSO-A.

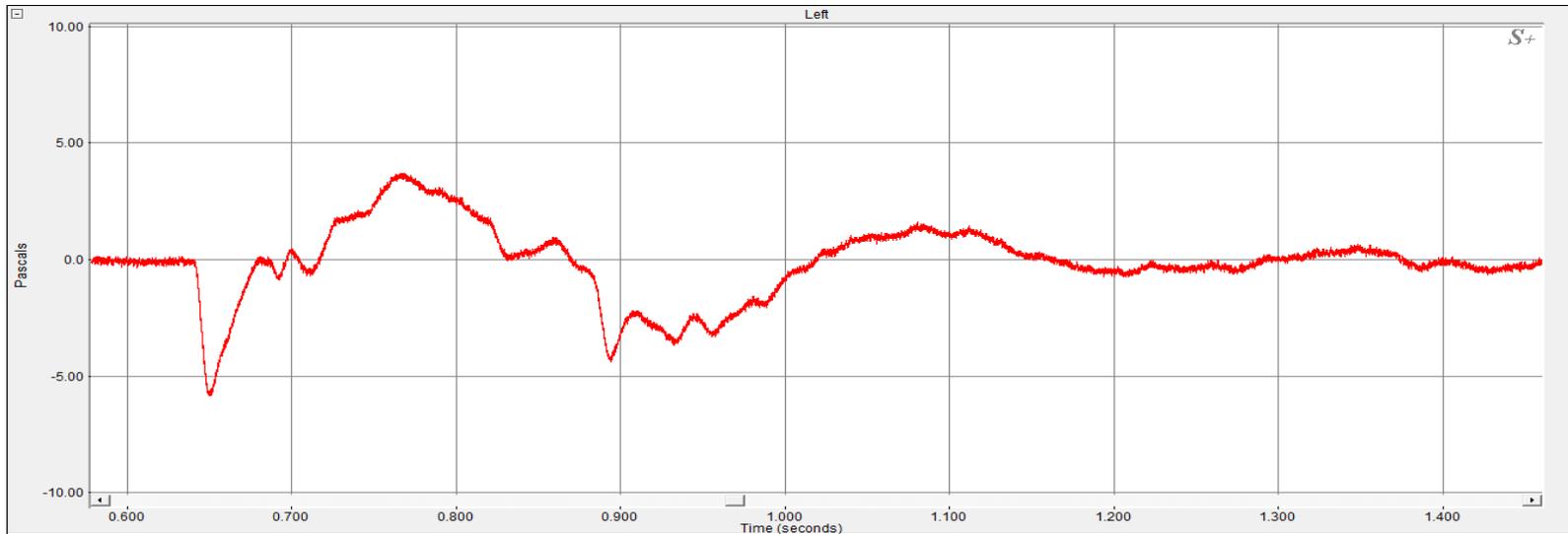


Figure 2-3. Time wave form of the first sonic boom at the pinniped monitoring location.

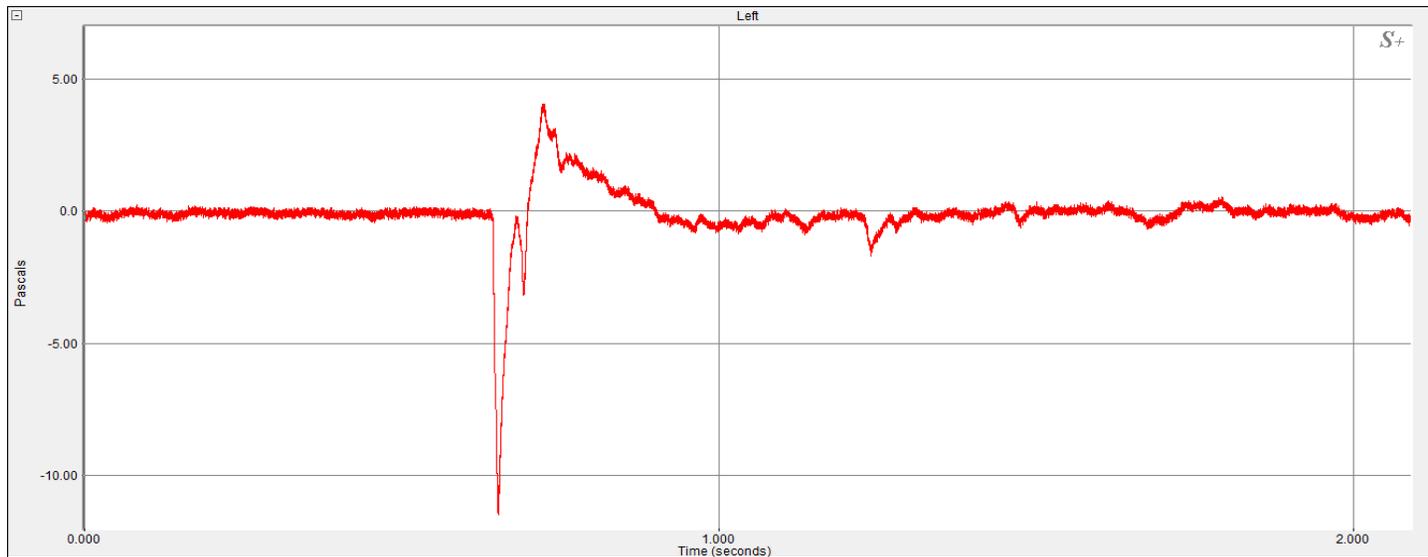


Figure 2-4. Time wave form of the second sonic boom at the pinniped monitoring location. Note: The top graph (Figure 2-3) is approximately 3 seconds before this graph.

3.0 Pinniped Monitoring

3.1 Methods

Pinniped monitoring on VAFB followed the protocols outlined in the IHA, which requires multiple daily counts beginning 72 hours prior to launch and continuing to 48 hours after launch. Safety related closures on south VAFB for launch preparations prevented monitors from performing counts on the day of the launch. In lieu of monitoring during the launch, a remote video camera was deployed to record the pinniped's reactions to the launch.

Pre-launch monitoring counts for pinnipeds on south VAFB were first initiated on 25 November 2018 with an expected launch on 28 November 2018. However, the launch slipped multiple times, finally occurring on 3 December 2018. The final delay was announced too late to enable monitors to perform counts on 2 December, which should have been the final count 24 hours prior to launch. However, MSRS had cumulative days of pinniped data with sufficient information on haul-out numbers and species during different tide levels and weather conditions from 29 November 2018 to 1 December 2018. Post-launch pinniped counts were conducted on 4 December 2018 and 5 December 2018. A two-week follow-up count was not required. Pre-launch and post-launch counts were bracketed around the tide levels at the time of launch. Counts were made using 10 x 42 power binoculars and an 82-mm SWIFT® Sport Optics spotting scope at the primary count sites.

The counts were conducted at four hourly intervals between South Rocky Point and Weaner Cove. Haul-out locations from Flat Iron Rock and Small Haul-out 2 were counted during the first and last hour counts because of the distance between each location and fewer animals being hauled out. Animals were primarily distributed between South Rocky Point and Weaner Cove, with occasional harbor seals at Small Haul-out 2 (Figures 1-1 and 1-2). Each count included all pinnipeds hauled out at a site (not including animals in the water) at the time the count was made. Species, number of animals, and age classes were recorded. Because elephant seal bulls, sub-adult males (SAM), and young of year juveniles are easily distinguishable, they were counted separately. Since undetermined age juveniles (i.e. 2 to 5 years) and adult female elephant seals were grouped together because they are indistinguishable. Juvenile elephant seal and animals that were in the range of young of last year were considered juveniles, and young of the year were considered pups. However, due to the similarities of weaned elephant seal pups (weaners) and young of last year, all weaned elephant seals that were not adults or nursing pups were considered juveniles. For all other species observed, adult-sized animals were considered adults, sub-adults to young of last year were consider juveniles, and young of the year were consider either weaner or pups.

In addition, data on natural or human-caused disturbances and any unusual pinniped behavior was recorded. Environmental conditions were recorded at the monitoring site with a Kestrel 3000 hand-held wind gauge with a built-in thermometer. Tide data was obtained from NOAA Tides and Currents website (NOAA National Ocean Service 2018).

3.2 Results

Pre-launch and post-launch temperatures, as recorded at the haul-out site during monitoring hours, were similar and ranged from 58.2 to 61.5 degrees Fahrenheit (°F). Both average and maximum wind speeds were higher during post-launch monitoring, with average post-launch wind speed being 12.6 miles per hour (mpg) versus 4.9 mph prior to the launch. Maximum wind speed ranged from 2.2 to 18.9 mph during pre-launch counts and from 17.4 to 26.4 mph post-launch.

Video Monitoring

Video footage indicated that nearly 45 of the 180 elephant seals, mostly juveniles, reacted to the initial launch by raising their heads but remaining in place. The remaining 135 elephant seals, adults and SAM's, showed no reaction and continued their current behavior of either sleeping or mock battling. On the other hand, 14 of the 15 harbor seals reacted to the initial launch by quickly moving into the water from their hauled-out location (Figure 3-1). The remaining harbor seal was alert but did not flush to the water. Over the next few minutes after the launch, seven harbor seals returned to the beach, but remained alert. However, at approximately 8 minutes 44 seconds after the launch, the sonic boom of the landing caused two of those seven harbor seals to retreat back into the water; the remaining five harbor seals moved toward but did not re-enter the water. Screen shots of the reaction to the launch and sonic boom are available for review; however, the video was inadvertently lost.

Pacific Harbor Seal (*Phoca vitulina*)

Pre-launch harbor seal counts, ranged from 1 to 46 adults and 1 to 15 juveniles (Figure 3-2). No pups were observed since they are not present at this time of year. Post-launch pinniped counts ranged between 4 and 50 adults and 2 to 5 juveniles (Figure 3-2). Pacific harbor seal numbers varied throughout the monitoring period based mainly on tide levels and weather conditions. At the time of the launch, the tide was approximately 2.5 feet. Overall, post-launch count totals were within range of pre-launch totals and the activity did not appear to affect this population.

Northern Elephant Seal (*Mirounga angustirostris*)

Elephant seal numbers ranged from 33 to 47 adults, 36 to 49 SAM's, and 97 to 113 juveniles prior to the launch (Figure 3-3). Post-launch, elephant seals ranged from 19 to 40 adults, 42 to 60 SAM's, and 92 to 112 juveniles (Figure 3-3). Although the start of elephant seal pupping season typically starts in mid-December, no elephant seal pups were present during the early December time of monitoring. Pre- and post-launch totals were similar and the activity did not appear to have any impact on this species.

California Sea Lion (*Zalophus californianus*)

A single juvenile California sea lion was observed only on the two days prior to launch (Figure 3-5). The animal was observed coming and going at Amphitheater Cove throughout the hourly counts. Given that only a single animal was observed, it is difficult to infer any impacts from the launch on this species.

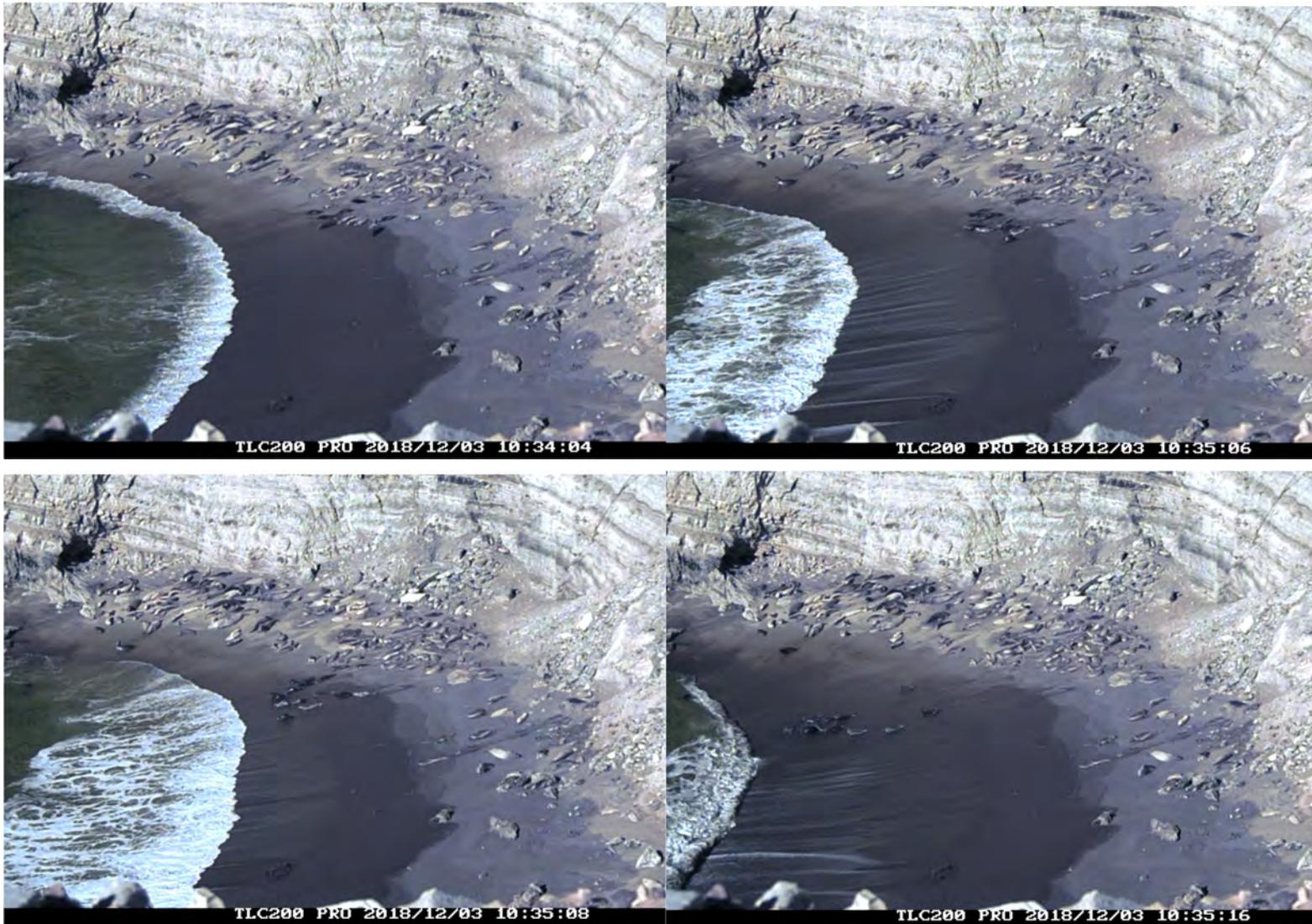


Figure 3-1. Stills from video recording show Pacific harbor seals reacting to the launch by retreating into the water.

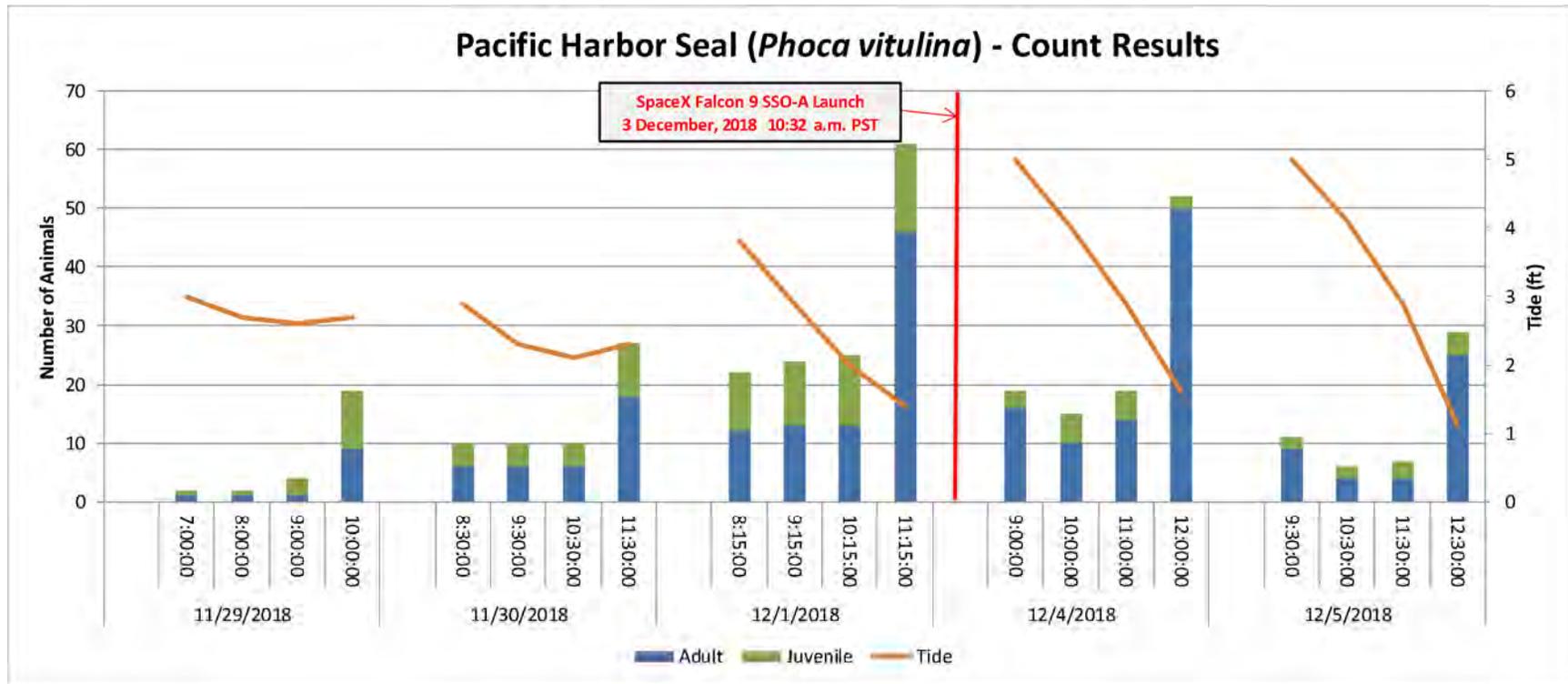


Figure 3-2. Harbor seal count results.

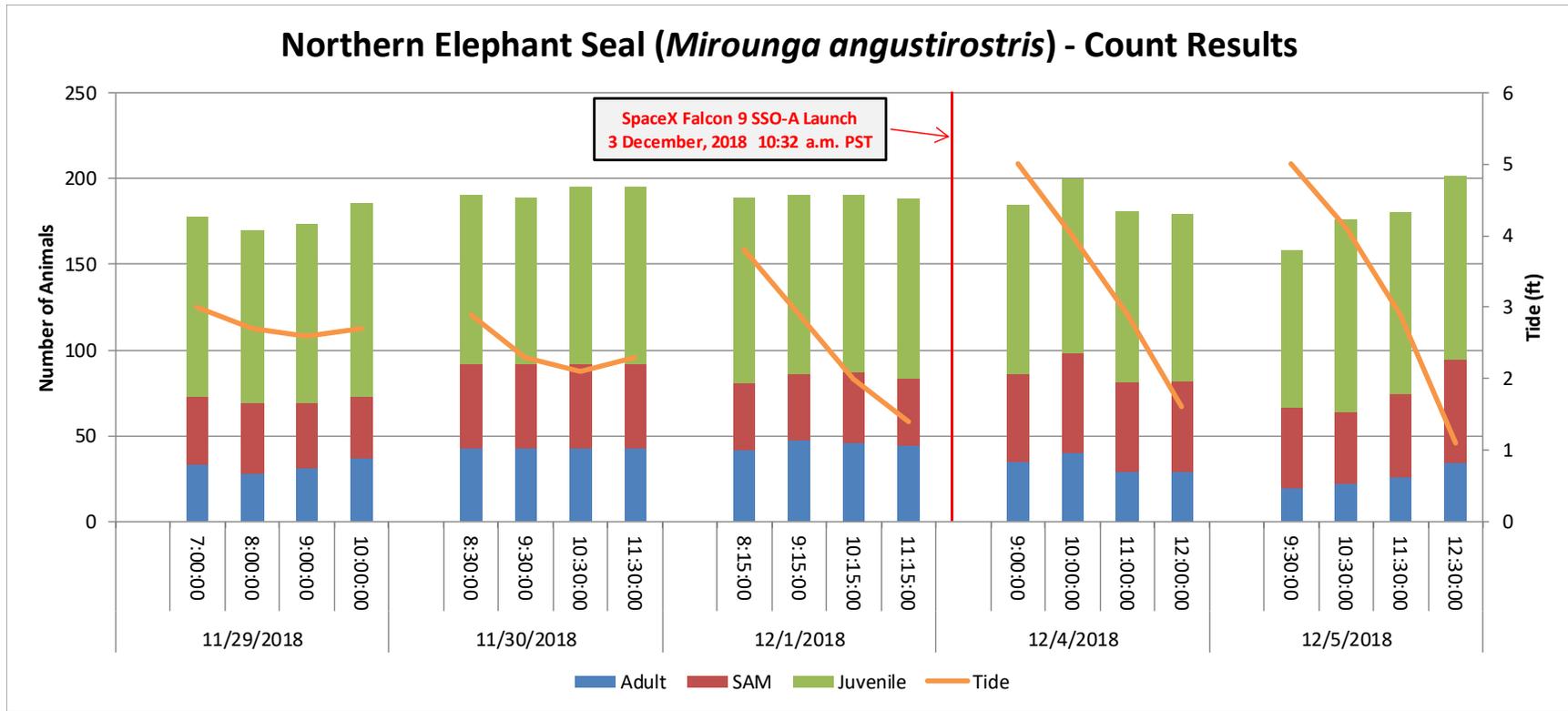


Figure 3-3. Northern elephant seal count results.

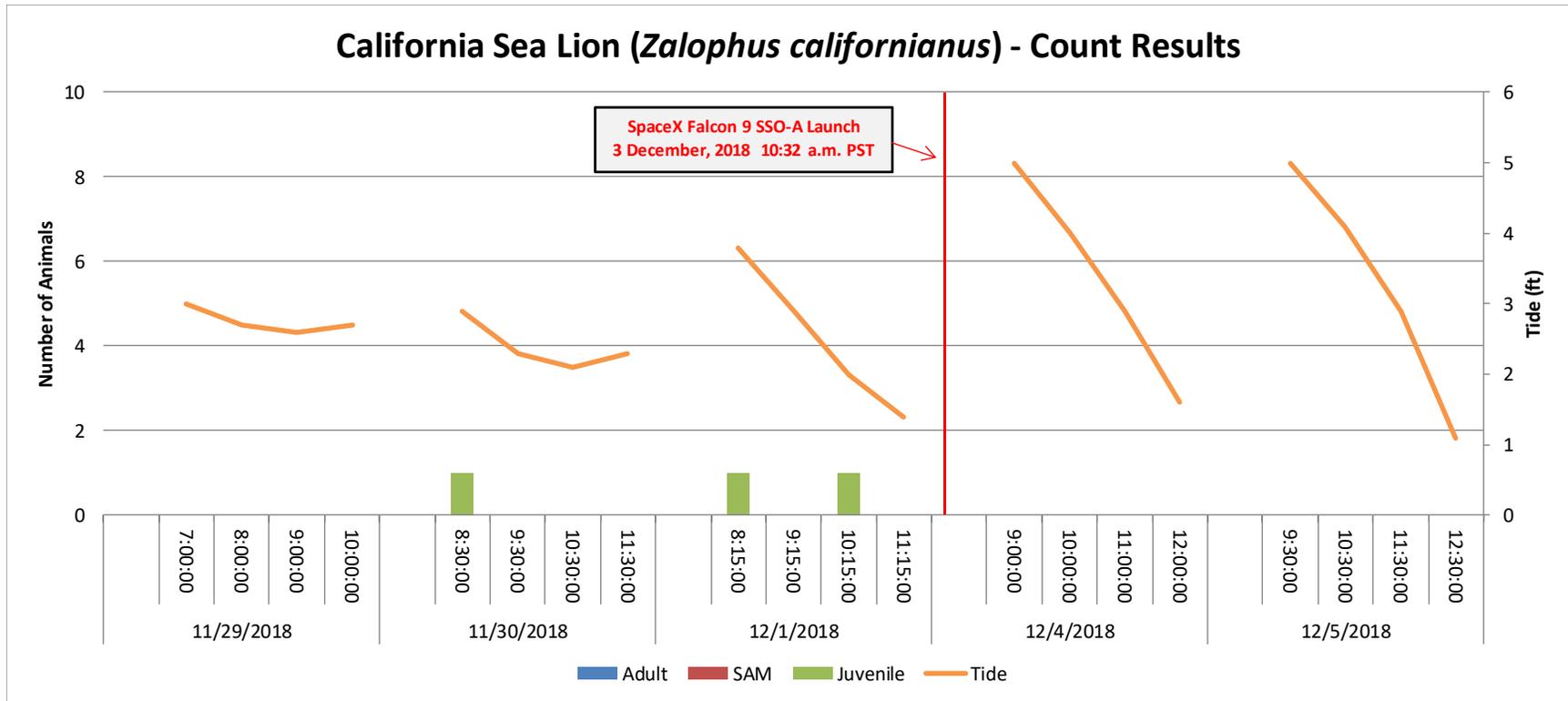


Figure 3-4. California sea lion count results.

4.0 Discussion

Daily pinniped counts did not indicate any negative impacts as a result of the launch and landing. Harbor seal numbers appeared to be more influenced by tide levels and weather conditions than by the launch or landing of the Falcon 9. Northern elephant seal numbers were observed to remain fairly constant over the monitoring period, regardless of conditions. On average 187 elephant seals were hauled-out between South Rocky and Amphitheater Cove. California sea lion numbers were not present in sufficient numbers to infer potential impacts.

No evidence of mortality, injury, or abnormal behavior was observed during the post-launch counts. Based on the results of monitoring, the 3 December 2018 launch of the SpaceX Falcon 9 SSO-A did not appear to have a significant effect on pinnipeds present at the south VAFB haul-out sites.

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