Scientific Solutions, Inc.
INNOVATIVE RESEARCH & ENGINEERING
SINCE 1992

APPLICATION FOR A PERMIT FOR SCIENTIFIC RESEARCH UNDER THE MARINE MAMMAL PROTECTION ACT

DATE: 15 May 2003

Permit Submitted To:
Chief, Permits Division, F/PR1
Office of Protected Resources
National Marine Fisheries Service
1315 East-West Highway, Room 13705
Silver Spring, MD 20910-3226

APPLICANT HOLDER / PRINCIPLE INVESTIGATOR
DR. PETER J. STEIN, President / PI Scientific Solutions, Inc. 99 Perimeter Road Nashua, NH 03063-1325 Tel: (603) 880-3784 , Fax: (603) 598-1803 Email: pstein@scisol.com, cc: kgilbert@scisol.com
OTHER CO-INVESTIGATORS (CI) & RESEARCH ASSISTANTS (RA) (included but not limited to)
1. Dr. Adam S. Frankel, Marine Acoustics Inc. – CI 2. Dr. Christopher W. Clark, Cornell University – CI 3. Mr. Michael R. Birmann, SSI – RA 4. Mr. Michael G. Fitzgerald, SSI – RA 5. Mr. Douglas W. Andersen, SSI - RA

III. APPLICANT'S QUALIFICATIONS AND EXPERIENCE

Dr. Peter J. Stein will be the principal investigator for the project. Dr. Stein received his Ph.D. in Oceanographic Engineering from the Massachusetts Institute of Technology (MIT) and the Woods Hole Oceanographic Institution (WHOI) Joint Program in 1986. He has a great deal of experience as a researcher and system developer and over the past 15 years has managed a wide variety of projects. The content of these projects has spanned a wide gamut, but recently they have focus on developing active acoustic systems for the detection of marine mammals. The primary purpose of these systems is to protect marine mammals by making operators aware of their presences. In this fashion harmful military or industrial activities can be halted or altered so as to avoid a marine mammal take. Dr. Stein is currently the president of Scientific Solutions, Inc. (SSI). SSI is the principle developer of the Integrated Marine Mammal Monitoring and Protection System (IMAPS). The long term goal of IMAPS is to provide a solution to marine mammal monitoring that integrates statistical data bases, sonic dosage monitoring, passive acoustic detection, active acoustic detection, and possibly other detection means.

<u>Selected Publications and Patents</u>

"Non-Invasive Low Frequency Elastic Wave Fluid Level Sensing System for Sludge Laden Environments", with Steven E. Euerle (U.S. Patent No. 6,192,751 B1, dated February 27, 2001)

"Communication Buoy with Ice Penetrating Capabilities", with Armen Bahlavouni, and Douglas W. Andersen (U.S. Patent No. 6,183,326 B1, dated February 6, 2001)

"Hydrophone Arrangement and Bunker for Housing Same", with Steven E. Euerle (U.S. Approved Patent No. 5,920,524 dated July 6, 1999)

"Weatherproof Sensing Apparatus with Rotatable Sensor", with Armen Bahlavouni, Douglas W. Andersen and Michael G. Fitzgerald (U.S. Approved Patent No. 5,591,907 dated January 7, 1997)

"Ice-Penetrating Communication Buoy for AUV Operating in the Arctic", with Armen Bahlavouni, and Douglas W. Andersen (Proceedings of the Tenth International Offshore and Polar Engineering Conference, Seattle, WA; May 28-June 2, 2000)

"Intelligent Sensor Protection System for Polar Environments", with Armen Bahlavouni and Douglas W. Andersen (*Sea Technology*; February 2000)

"Inversion of Pack Ice Elastic Wave Data to Obtain Ice Physical Properties", with Steven E. Euerle and James C. Parinella (*Journal of Geophysical Research*, 103:C10; September 1998)

Dr. Christopher W. Clark will provide technical oversight to the passive component of the IMAPS system. Dr. Clark received his Ph.D. in Biology from the State University of New York at Stony Brook in 1980. He also has a M.S. in electrical engineering and a double B.S. in Engineering and Biology. Dr. Clark is the I. P. Johnson Director of Cornell's Bioacoustics Research Program (an endowed chair) and is also on the Faculty in the Department of Neurobiology and Behavior. Dr. Clark's primary strength comes from his advanced training and research experiences in electrical engineering and biological systems. His background in electrical engineering is in digital signal processing with an emphasis on development and implementation of systems for transient signal detection, recognition and classification. His background in biology is in animal acoustics with particular emphasis on underwater sounds of marine mammals. In 1987 he was selected as the Director for Cornell University's Bioacoustics Research Program where he leads an interdisciplinary team of engineers, computer scientists, and bioacoustians. In 1992 he was chosen to be the Chief Marine Mammal Scientist for the Navy's Dual-Uses IUSS program to evaluate and develop digital signal processing systems for automatic detection, location and tracking of biological transients. For that program he installed and operated real-time passive array tracking systems in NavFacs covering the western North Atlantic. Another real-time version of the system, Popeye, was successfully modified for rapid deployment aboard the RV Cory Chouest during several Low Frequency Active test.

In 1983 Clark teamed with Dr. William T. Ellison to design and implement a portable acoustic transient location system for positioning vocalizing whales as they moved under the arctic ice. Versions of this system have been used since 1984 to census the whales, and the results have led to dramatic improvements in the way marine mammal populations are counted. In 1996 the International Whaling Commission's Scientific Committee formally recognized the critical value of the passive acoustic transient detection techniques pioneered by Clark, and it has now initiated an acoustic census program for the Southern Oceans. The techniques pioneered during these earlier arctic studies have been adapted and further modified for detecting and tracking transient signals via the Navy's IUSS. From 1996-2000 Clark was co-PI for the LFA Scientific Research Program investigating the potential impacts of LFA on marine mammals. He also served as an expert consultant in the LFA OEIS.

Throughout the past fifteen years Clark has received numerous grants from NSF, NRL, and ONR to design, build, test, and make operational software/hardware systems for transient signal recognition and classification; with an emphasis on biological transients. All projects have involved combining off-the-shelf components with customized state-of-the-art electronics and software into an applied, field-tested system. Such systems have been utilized off the coasts of South America, North Slope Alaska, central and southern California, Kauai and Big Island Hawaii, North Carolina, and Massachusetts.

Clark is recognized as one of the foremost authorities in the world on marine biologic transient detection, classification and tracking. He has served as a U.S. Delegate to the International Whaling Commission's Scientific Committee since 1984. In 1983-84 he served as principle investigator for research with BBN to investigate the potential effects of industrial noises on whales off California and Alaska. From 1992-1997 he served as the director of the Marine Mammal Research Program associated with ARPA's Acoustic Thermometry of Ocean Climate project.

Related Recent Publications

Clark, C.W. 1995. Application of US Navy underwater hydrophone arrays for scientific research on whales. Annex M, Rep. Int. Whal. Commn. 45:210-212.

Clark, C. W., R. Charif, S. Mitchell, and J. Colby. 1996. Distribution and Behavior of the Bowhead Whale, *Balaena mysticetus*, Based on Analysis of Acoustic Data Collected During the 1993 Spring Migration off Point Barrow, Alaska. Rep. int. Whal. Commn. 46: 541-552.

Clark, C.W. and N. S. Altman. in press. Acoustic Detections of blue whale (*Balaenoptera musculus*) and fin whale (*B. physalus*) sounds during a SURTASS LFA exercise. Journal of Ocean Engineering.

Clark, C.W. and W. T. Ellison, 2000. Calibration and comparison of the acoustic location methods used during the spring migration of the bowhead whale, *Balaena mysticetus* off Pt. Barrow, Alaska, 1984-1993. J. Acoust. Soc. Am. 107(6):3509-3517.
Clark, C.W., and W.T. Ellison. in press. Potential use of low-frequency sounds by baleen whales for probing the environment: evidence from models and empirical measurements. In *Echolocation in Bats and Dolphins* (J. Thomas, C. Moss and M. Vater, eds.). The University of Chicago Press.
Frankel, A. S. and C. W. Clark. 2000. Behavioral Responses of Humpback Whales *Megaptera novaeangliae* to full-scale ATOC signals. J. Acoust. Soc. Am. 108 (4):1930-1937.
Mellinger, D. K. and C. W. Clark. 2000. Recognizing transient low-frequency whale sounds by spectrogram correlation. J. Acoust. Soc. Am. 107(6):3518-3529.
Potter, J. R., D. K. Mellinger, and C. W. Clark. 1994. Marine mammal call discrimination using artificial neural networks. J. Acoust. Soc. Am. 96(3):1255-1262.
Tyack, P. L., and C. W. Clark. 2000. Communication and Acoustical behavior in dolphins and whales. Pp. 156-224, in *Hearing by Whales and Dolphins*. *Springer Handbook of Auditory Research* (W. W. L. Au, A. N. Popper, and R. R. Fay, eds.). Springer-Verlag, New York, 485 pp.

Dr. Adam S. Frankel has been conducting whale research since 1985. His research efforts include the 1985-1988 playback experiments with humpback whales and natural sounds (Frankel 1987 (master's thesis), Mobley et al. 1988). The next phase of research focused on passive acoustic location and tracking in conjunction with visual observation (Frankel 1994 (doctoral thesis), Frankel et al. 1995). During Dr. Frankel's post-doctoral work these techniques were applied to the study of anthropogenic sounds in both a playback experiment (Frankel and Clark, 1998) and with a full-scale source (Frankel and Clark 2000, 2001). In addition to these humpback research efforts, Dr. Frankel has participated in the bowhead whale census, the LFA-SRP research programs, and sperm whale research in New Zealand.

Related Recent Publications

Au WWL, Frankel AS, Helweg DA, Cato DH (2001) Against the Humpback Whale Sonar Hypothesis. IEEE Journal of Oceanic Engineering 26:295-300
Frankel AS (1994) Acoustic and Visual Tracking reveals distribution, song variability and social roles of humpback whales in Hawaiian waters. In. University of Hawaii at Manoa
Frankel AS (2002) Sound Production. In: Encyclopedia of Marine Mammals
Frankel AS, Clark CW (1998) Results of low-frequency m-sequence noise playbacks to humpback whales in Hawai'i. Can. J. Zool. 76:521-535
Frankel AS, Clark CW (2000) Behavioral responses of humpback whales (*Megaptera novaeangliae*) to full-scale ATOC signals. Journal of the Acoustical Society of America 108:1930-1937
Frankel AS, Clark CW (2002) Factors affecting the distribution and abundance of humpback whales off the North Shore of Kaua'i. Marine Mammal Science
Frankel AS, Clark CW, Herman LM, Gabriele CM (1995a) Spatial Distribution, Habitat Utilization, and Social Interactions of Humpback Whales, *Megaptera novaeangliae*, off Hawai'i, determined using Acoustic and Visual Techniques. Can. J. Zool. 73:1134-1146
Frankel AS, Ellison WT, Buchanan J (2002) Application of the Acoustic Integration Model (AIM) to predict and minimize environmental impacts. Oceans 2002

Frankel AS, J.R. Mobley j, Herman LM (1995b) Estimation of auditory response thresholds in humpback whales using biologically meaningful sounds. In: Kastelein RA, J.A.Thomas, P.E. Nachtigall (ed) Sensory Systems of Aquatic Mammals. DeSpil Publishers, Woerden, The Netherlands, pp 55-70

Helweg DA, Frankel AS, Mobley JR, Jr., Herman LM (1992) Humpback whale song: our current understanding. In: Thomas J, Kastelein R, Supin A (eds) Sensory Systems of Marine Mammals. Plenum Press, New York, pp 459-483

Mobley JRJ, Herman LM, Frankel AS (1988) Responses of Wintering Humpback Whales *Megaptera novaeangliae* to Playback of Recordings of Winter and Summer Vocalizations and of Synthetic Sound. Behavioral Ecology and Sociobiology 23:211-224

IV. DESCRIPTION OF MARINE MAMMALS TO BE TAKEN AND THE PROPOSED ACTIVITY

A. ABSTRACT

The purposed of this research is to develop, validate, and improve low-power and high frequency sonar systems designed to detect marine mammals. These systems are needed because there are military and industrial activities that pose a risk of injuring animals that come too close. These include high-powered military sonar systems; the operation of air-gun arrays to conduct seismic surveys; commercial shipping; detonation of explosives for the removal of offshore structures, shock testing, and excavation; and research using underwater sound. The zone of potential injury surrounding these operations may measure hundreds of meters (Richardson et al. 1995). This creates a monitoring need to ensure that no animals are in this potential zone of injury. It has been increasingly recognized that current visual and passive acoustic monitoring techniques are not 100% effective for this task. This recognition has lead to considerable recent efforts by Scientific Solutions, Inc. (SSI) to develop "whale-friendly" sonar systems that reliably detect marine mammals. One system is known as the Integrated Marine Mammal Monitoring and Protection System (IMAPS). It will eventually integrate passive acoustic detection, active acoustic detection, a statistical database of marine mammal distributions, and sonic dosage modeling. In this fashion it will provide a versatile tool to monitor and protect marine mammals from potentially harmful industrial and military operations. The active acoustic systems being developed must be validated with marine mammals in order to determine their performance. Also, in order to optimize the systems, data must be acquired to determine the characteristics of the sound that reflects off marine mammals. All scientific evidence indicates that marine mammals will not be harmed by these active systems. The frequency range of operation used and applied for under this permit is greater than 20 kHz, with a source level no higher than 220 dB re 1 μPa at 1 m, and a duty cycle no higher then 10%. During testing, visual monitoring and other safeguards will be in place to ensure that a marine mammal is not exposed to levels higher then 180 dB re 1 μPa. Testing will be halted if there is an overt avoidance to the sound. We seek a permit to intentionally ensonify only non-endangered species.

B. SUMMARY OF MARINE MAMMALS TO BE TAKEN

1. SPECIES NAME(S):

TABLE 1. List of Species that may be taken

SCIENTIFIC NAME	COMMON NAME	NUMBER OF TAKES (per year)	TYPE OF TAKE (Acoustic Insonification)	MMPA, ESA Status / CITES App.
Eschrichtius Robustus	Gray Whale (Eastern Pacific)	3600	Intentional	R / I
Arctocephalus townsendi	Guadalupe fur seal	30	Unintentional	T / I
Balaenoptera musculus	Blue Whale	30	Unintentional	E / I
Callorhinus ursinus	Northern fur seal	Unlimited	Unintentional	None / None
Lissodelphis borealis	Northern right whale dolphin	1200	Unintentional	None / II
Mirounga angustirostris	Northern elephant seal	Unlimited	Unintentional	None / None
Phoca vitulina	Harbor seal	Unlimited	Unintentional	None / None
Phocoena phocoena	Harbor Porpoise	150	Unintentional	None / II
Phocoenoides dalli	Dall's Porpoise	150	Unintentional	None / II
Zalophus californianus	California sea lion	Unlimited	Unintentional	None / None
Balaenoptera physalus	Finback Whale	400	Unintentional	E / I
Balaenoptera borealis	Sei Whale	400	Unintentional	E / I
Balaenoptera acutorostrata	Minke Whale	400	Unintentional	None / I
Physeter Carodon	Sperm Whale	800	Unintentional	E / I
Megaptera novaeangliae	Humpback Whale	400	Unintentional	E / I
Ziphius cavirostris	Cuvier's Beaked Whale	400	Unintentional	None / II
Berardius bairdii	Baird's Beaked Whale	400	Unintentional	None / I
Mesoplodon spp.	Mesoplodont Beaked Whale	400	Unintentional	None / II
Enhydra lutris	Sea Otter	Unlimited	Unintentional	T / I
Eumetopias jubatus	Stellar Sea Lion; Northern sea lion (Eastern Stock)	500	Unintentional	T / None
Orcinus Orca	Killer Whale (Eastern Pacific Offshore Stock)	2000	Unintentional	None / II
Lagenorhynchus obliquidens	Pacific White-Sided Dolphin	400	Unintentional	None / II
Tursiops truncates	Bottlenose Dolphin	2000	Unintentional	None / II
Grampus griseus	Risso's dolphin	2000	Unintentional	None / II
Delphinus delphis	Common Dolphin, Saddleback dolphin	2000	Unintentional	None / II
Globicephala macrorhybchus	Short-finned pilot whale	2000	Unintentional	None / II

2. PARTS OR SPECIMEN SAMPLES:

Not Applicable. SSI will not be taking any mammal parts or specimen samples in the research being proposed.

3. STATUS OF AFFECTED STOCK(S):

Gray whale (Eschrichtius robustus) **Stock: Eastern North Pacific**

The 1997/98 population estimate for this stock is 26,635 (Hobbs & Rugh 1999). The stock has been increasing over the past several decades, and it was delisted in 1994 from the list of endangered and threatened wildlife. The delisting was reviewed in 1999 by a NMFS workshop, and the recommendation was that the stock is not likely to become endangered within the foreseeable future. We have selected the gray whale as the primary subject of the new whale-finding sonar tests in order avoid working with a listed species, while field testing the sonar with a large baleen whale.

Guadalupe fur seal (Arctocephalus townsendi) **Stock: Isla Guadalupe**

The Guadalupe fur seal once ranged from Monterey Bay to the Revillagigedo Islands, but all living seals descend from a small colony from Isla Guadalupe. The rest were hunted to near extinction in 1894; two males were seen in 1928, but this species was not sighted again until 1954. The population size in 1993 was estimated at 7,408, with a minimum estimate of 3,028. The population is growing at an annual rate of about 13.7%. The Guadalupe fur seal is listed by the state of California as a threatened species and as a fully protected mammal. It is listed as a threatened species under the ESA, which automatically qualifies it as a depleted and strategic stock under the MMPA. The total US fishery take is <10% of the PBR (104). Individuals have been sighted as far N as 38 deg N, but are unlikely to occur near our proposed study site (Forney et al. 2000).

Blue whale (Balaenoptera musculus) **Stock: Eastern North Pacific**

The International Whaling Commission recognizes one stock in the North Pacific (Donovan 1991), but Forney et al. (2000) argue for more than one, including a eastern North Pacific stock. An average of line-transect and mark-recapture estimates suggests that there are 1,940 blue whales in California waters, with a minimum of 1,716. It is listed as an endangered species under the ESA, which automatically qualifies it as a depleted and strategic stock under the MMPA. The total human take reported in US waters (0) is less than the PBR (1.7). This population feeds in California waters in summer/fall and migrates to areas off Mexico south to Costa Rica in winter/spring. Since the proposed research will take place in California in January, there is a low chance of encountering blue whales.

Northern fur seal (Callorhinus ursinus) **Stock: San Miguel Island**

The San Miguel Island stock of fur seals numbers about 4,336 with a minimum estimate of 2,336 for 1999. The population has grown steadily since 1968 except for severe declines in 1983 and '98 associated with El Nino Southern Oscillation (ENSO) events. This stock is not listed as endangered or threatened under the ESA nor depleted under the MMPA. They are not considered a strategic stock under the MMPA because reported human-induced mortality (0) is less than the PBR (100) (Forney et al. 2000).

Northern right whale dolphin (Lissodelphis borealis) **Stock: CA / OR / WA**

The estimated abundance for Lissodelphis in California/Oregon/Washington waters from 1991-1996 is 13,705, with a minimum estimate of 10,060. This stock is not listed as endangered or threatened under the ESA nor depleted under the MMPA. They are not considered a strategic stock under the MMPA because the average annual human-induced mortality reported from 1994-98 (15) is less than the PBR (97) (Forney et al. 2000).

Northern elephant seal (Mirounga angustirostris) Stock: California Breeding

Populations of the northern elephant seal in the US and Mexico derive from a few tens or hundreds of individuals surviving in Mexico after being decimated by hunting. The entire population cannot be counted, so each year a pup count is made while all pups are ashore. The pup count for 1994-96 (24,000), yields a population estimate of 84,000 in 1996. The minimum population size of the US stock is 51,625 for 1996. This population has been growing well from 1955-1998. The maximum estimated net productivity rate for elephant seals is 8.3%. The net productivity appears to have declined in recent years in California. This stock is not listed as endangered or threatened under the ESA nor depleted under the MMPA. They are not considered a strategic stock under the MMPA because human-induced mortality (<100) is less than the PBR (2,142) (Forney et al. 2000).

Harbor seal (Phoca vitulina richardsi) Stock: California

The California population is estimated at 30,293, with a minimum estimate of 27,962. The population has a steady increase, except during ENSO events. This stock is not listed as endangered or threatened under the ESA nor depleted under the MMPA. They are not considered a strategic stock under the MMPA because reported human-induced mortality is estimated to be less than the PBR (1,678) (Forney et al. 2000).

Harbor porpoise (Phocoena phocoena) Stock: Central California

Harbor porpoise are found in coastal waters of the eastern North Pacific north of Point Conception California. The Central California stock is estimated from aerial surveys (1993-97) to number 5,732, with a minimum of 4,172. This stock is not listed as endangered or threatened under the ESA nor depleted under the MMPA. They are considered a strategic stock under the MMPA because human-induced annual mortality reported from gillnets alone during 1996-98 (63) is greater than the PBR (42) (Forney et al. 2000). The California Department of Fish and Game has restricted gillnet fishing in order to reduce this mortality.

Dall's porpoise (Phocoenoides dalli) Stock: California/Oregon/Washington

The estimated population size for the California/Oregon/Washington stock, combining estimates for inland Washington waters with shipboard surveys (1991-96) is 117,545, with a minimum estimate of 81,866. This stock is not listed as endangered or threatened under the ESA nor depleted under the MMPA. They are not considered a strategic stock under the MMPA because the average annual human-induced mortality from 1994-98 (12) is less than the PBR (737) (Forney et al. 2000).

California Sea Lion (Zalophus californianus) Stock: U.S.

The California sea lion includes 3 subspecies; this amendment addresses Z. c. californianus off the central California coast. The entire population cannot be counted, so each year a pup count is made while all pups are ashore. The pup count for 1999 (42,388) was adjusted to yield an estimate of 48,746 live births (Forney et al. 2000). Given the fraction of newborn pups in the population, this yields a population estimate ranging from 204,000 to 214, 000. The minimum population size of the US stock is 109,854. This population has been growing well from 1975-1999, with three major declines due to El Nino events in 1983, 1992-3, and 1998. Even including these declines, the annual rate of growth for this interval is 5%. This stock is not listed as endangered or threatened under the ESA nor depleted under the MMPA. They are not considered a strategic stock under the MMPA because human-induced mortality (1208 fishery related and 144 other) is less than the PBR (6,591).

C. DETAILED DESCRIPTION OF THE PROPOSED RESEARCH ACTIVITY

1. BACKGROUND

Over the past several years Scientific Solutions, Inc. (SSI) has been developing active sonar for the detection of marine mammals. The general goal is to very reliably detect the presence of a marine mammal out to a range of about 2 km (1 mile). This effort is motivated by the many military and industrial activities that might harm a marine mammal should they come to close. These include high-powered military sonar systems; the operation of air-gun arrays to conduct seismic surveys; commercial shipping; detonation of explosives for the removal of offshore structures, shock testing, and excavation; and research using underwater sound. Pictures of potentially harmful sources of underwater sound are depicted in Figure 1.

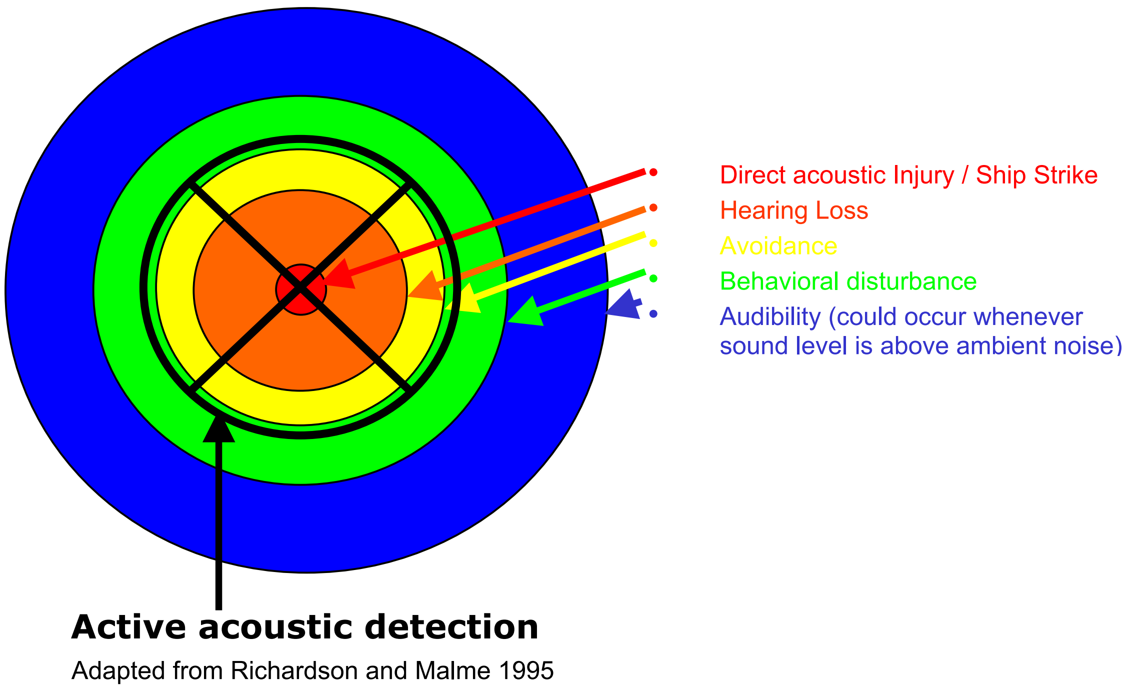
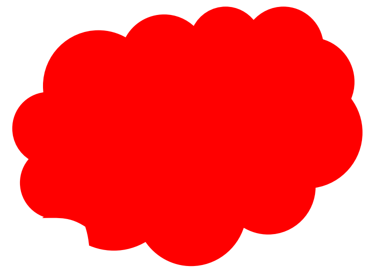


Figure 1 - Zones of influence for danger to marine mammals from military or industrial activates [adapted from Malme and Richardson, 1995]. The active sonar is expected to protect out and beyond the high danger area for marine mammals.

Current research indicates that there is a high danger zone surrounding these activities, out to several hundred meters, where there is a possibility of physiological damage. This is shown in Figure 1. If an animal could be detected prior to entering this zone an activity might be halted or otherwise changed so as to protect the animal. However, this relies on reliable detection. Current techniques for the detection of marine mammals include passive sonar (just listening for marine mammal vocalizations) and visual monitoring. But these are not reliable under all conditions. Figures 3, 4, and 5 depict the diving and vocalization behaviors of sperm whales and right whales. There are substantial portions of time for which both passive and visual monitoring would be ineffective. Further, even when vocalizing, it is difficult to get a range with passive techniques. Thus we are developing active sonar systems that transmit a sound pulse that is reflected off the animal and then received back at the sonar. In general, active sonar systems give the highest probability of detecting an object in the ocean environment with the most accurate localization. The protective zone for active acoustic monitoring is also depicted in Figure 1 with the goal of encompassing and extending well beyond the high danger zone.



Air Guns
230-260

Military Sonar
230+
dB re μPa at 1 meter

Explosives
280+

Figure 2 - Some of the intense sources of man-made underwater sound.

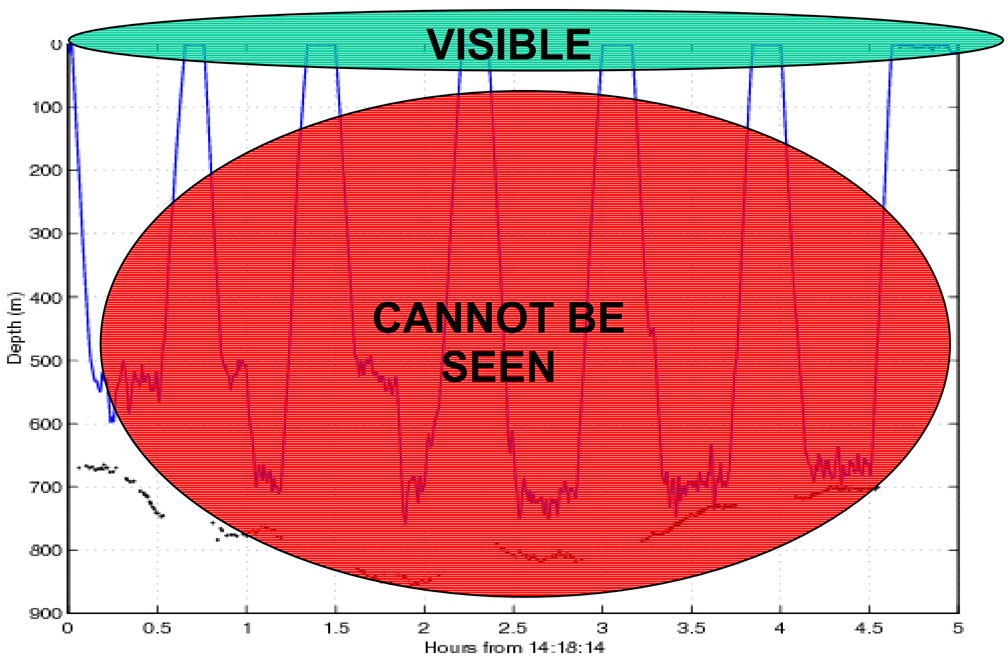


Figure 3 - Plot showing the dive behavior during time of deep diving sperm whales. Sperm whales are only on the service 5-10% of the time, making detection by visual monitoring highly unreliable [courtesy of P. Tyack].

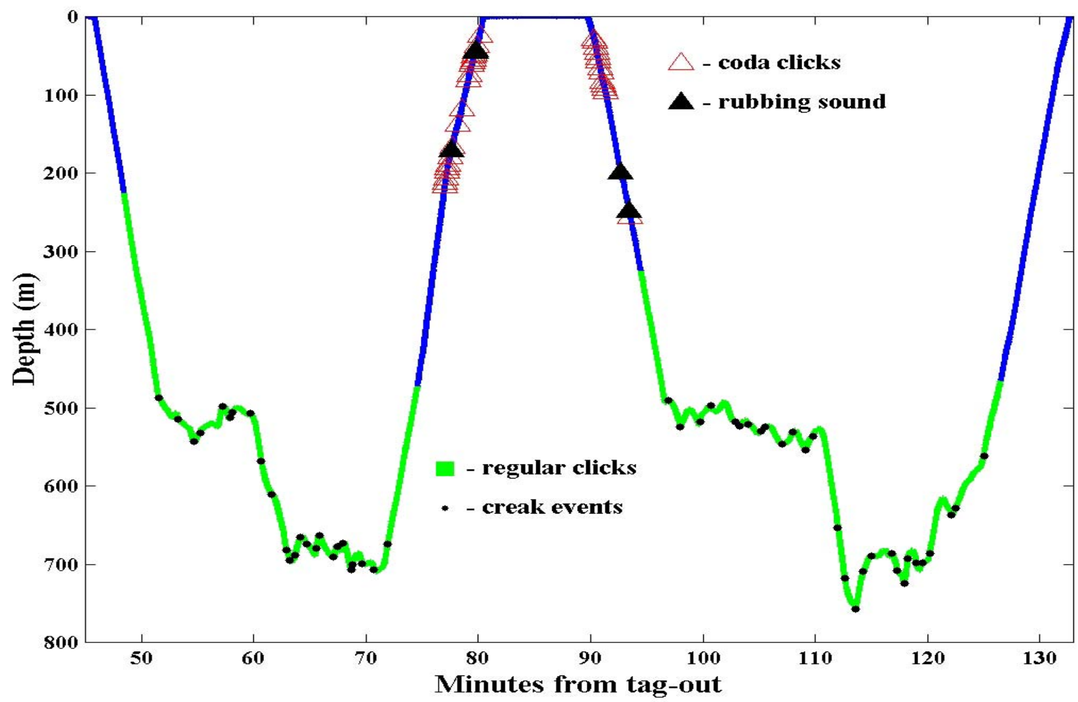


Figure 4 - Vocalization pattern of sperm whales through a dive. Although they vocalize for most of the dive, there is evidence to suggest that they stop vocalizing when exposed to sound making passive detection ineffective. Further, it is difficult to get a range from a single passive system [courtesy of P. Tyack].

At surface 20-30% of time; 1 vocalization in 3 hours

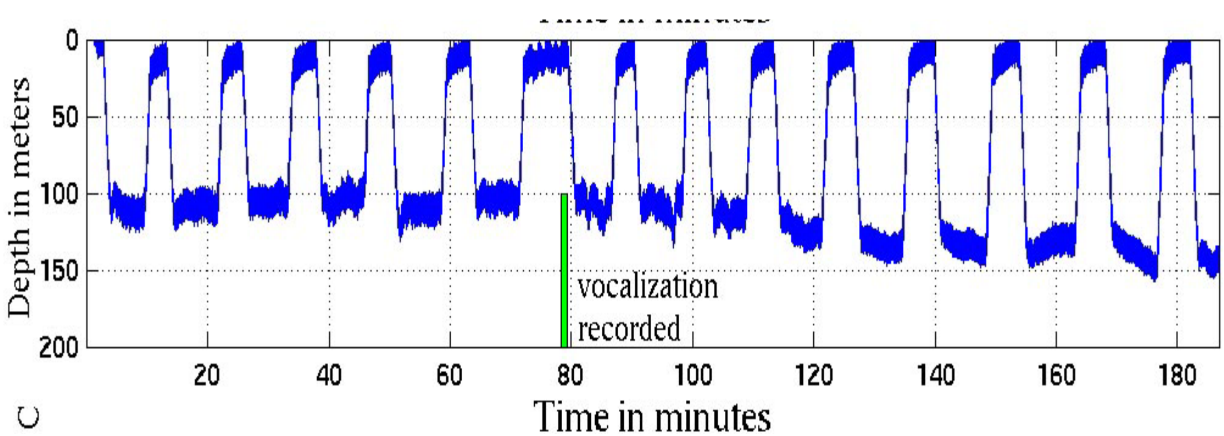
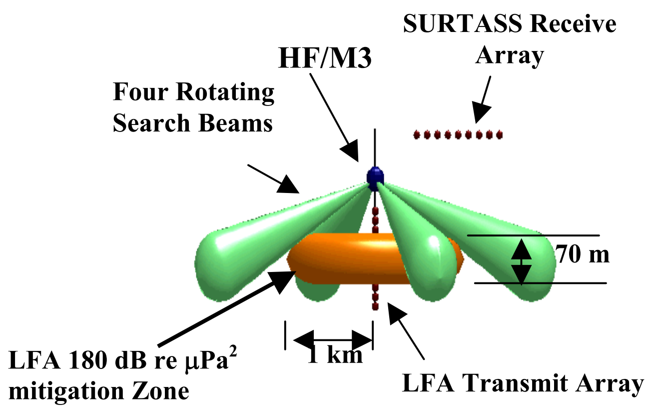


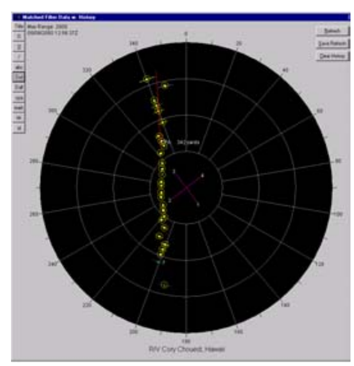
Figure 5 - Dive and vocalization pattern of the northern right whale. The animal spends very little time on the surface and even less time vocalizing. Clearly both passive detection and visual monitoring would not be sufficient.

One of the active sonars developed by SSI is called the High Frequency Marine Mammal Mitigation sonar (HF/M3). It is currently deployed as part of the SURTASS LFA (Surface Towed Array Surveillance System Low Frequency Active) sonar system. A significant and coordinated research effort determined that LFA transmissions might cause harm to a marine mammal should it come within about 500-800 m of the vertical source array. HF/M3 is deployed at the top of the LFA array. In this configuration HF/M3 should reliably detect a large marine mammal out to about 2 km, thus allowing shut down of this powerful sonar system before an animal enters the very high sound pressure zone near the transmit array. HF/M3 is a mechanically steered sonar system and is specifically designed for the SURTASS LFA application. The physical layout and operation of HF/M3 is shown in Figure 6. A version of HF/M3 has been developed to be used for development and testing of active sonar systems to protect marine mammals. We refer to this version as the MAST (Marine Mammal Active Sonar Test) Mechanical System and it is shown in Figure 7.



- **Transmit Frequency: 30-40 kHz**
- **Source Level: 180-220 dB**
- **Vertical Beamwidth: 10^0**
- **Horizontal Beamwidth: 8^0**
- **Reflector DI: 21 dB**
- **Sweeps azimuth in 45-60 sec at 2.5 km range setting**

HF/M3 Tow Body (with out fairing)



HF/M3 display showing test target track

Figure 6 - HF/M3 (High Frequency Marine Mammal Monitoring) system deployed on the SURTASS LFA vessel. The HF/M3 tow body (top right) is integrated at the top of the LFA array. Four parabolic transducers rotate to cover 360 degrees and protect the high pressure zone surrounding the array. The HF/M3 display with the boat passing a test target is also shown (lower right).

Figure 7 - The MAST (Marine Mammal Active Sonar Test) mechanical system. It is a version of HF/M3 that is not integrated in SURTASS LFA and is meant to be deployed from a stationary vessel.

SSI is also the lead developer of the Integrated Marine Mammal Monitoring and Protection System (IMAPS). IMAPS is a current Phase II Small Business Technology Transfer (STTR) project[1]. The long-term goal of IMAPS is to integrate active acoustic detection, passive acoustic detection, and a mitigation management and control module (MMCM). The MMCM would assimilate the available real time observations, and include a database of marine mammals and an estimation tool for predicting potential harm given the particulars of an operation (source strength, directivity, environmental conditions, etc). Once fully developed, IMAPS would provide a complete decision aid for the user to determine if an operation should continue or be altered.

To date work on IMAPS has focused on development of a more robust sonar system for the detection of marine mammals. The active component of IMAPS is a relatively expensive phased array system using a vertical line array source and 60 receive line arrays surrounding a cylindrical steel baffle. The line arrays can work as both active and passive receivers. The prototype IMAPS sonar head is shown in Figures 8 and 9 and has yet to be fully tested.

[1] An STTR is an SBIR (Small Business Innovative Research) that requires university participation. The SBIR program is a three phase program. Phase 1 is usually a feasibility study and Phase 2 is usually design, fabrication, and testing of a prototype. Phase 3 is full implementation supported by none-SBIR funds. Our university partner is Cornell University (Chris Clark) who is developing the passive detection component of IMAPS.

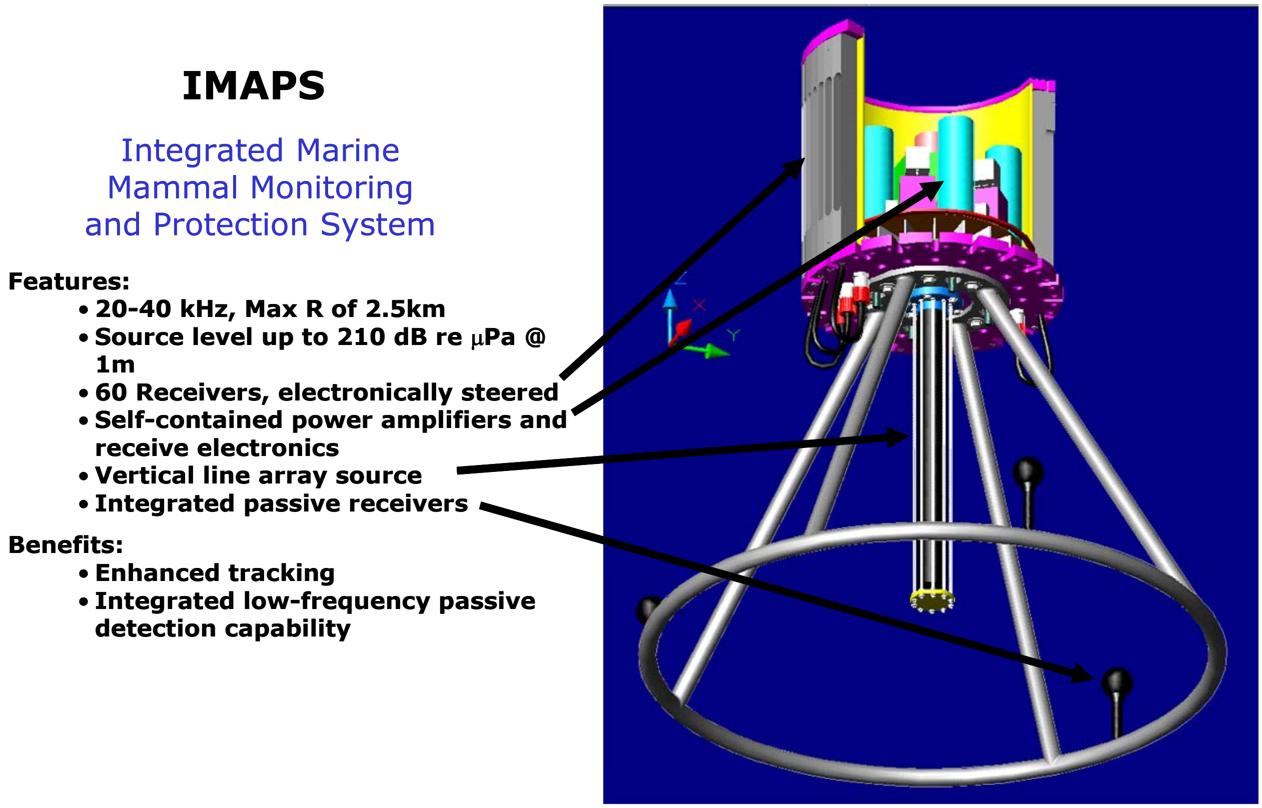


Figure 8 - The IMAPS Sonar head. The receive sensors are 60 vertical line arrays surrounding a steel baffle. The transmit line array is attached to the bottom of the baffle. Additional sensors would be attached for enhanced low frequency passive detection.

Figure 9 - Pictures of the IMAPS sonar head. The picture on the left shows it during preliminary testing when only 10 receive sensors were installed. The picture on the right is nearly fully assembled missing only the transmit line array.

IMAPS is meant to develop into a versatile tool for protecting marine mammals. For instance, it could be deployed during seismic survey operations to prevent animals from getting too close to large air-gun arrays. It could be deployed during explosives shock testing or explosive removal of offshore structures. It could be used to survey an area prior to a large military exercise to confirm that no marine mammals that might be harmed are present. It could also be deployed off of patrol boats that could survey the shipping lanes and warn ships of the potential for a whale strike.

2. GOALS OF THE PROPOSED RESEARCH

In general, active sonar systems for the detection of marine mammal require validation and performance data. SSI wishes to obtain a permit to conduct tests of what we will refer to as “whale finder” sonar systems using live animals in the wild. This includes the MAST Mechanical System and IMAPS, along with variations and improvements of these systems or other systems designed specifically to detect marine mammals. The data collected will be used to both evaluate the effectiveness of these systems to detect, and hence protect, marine mammals and to improve the systems. We are requesting a permit to intentionally insonify only non-endangered marine mammals with these whale-finding sonars.

The specific goals of the experimental program are to:

1. Determine the probability of detection for active sonars built specifically to detect marine mammals out to 1 mile.

2. Collect animal reflectivity data that can be used to improve these sonar systems.

3. Determine what, if any, reaction the animals have to high frequency (greater than 20 kHz) active sonars that are designed specifically to detect marine mammals.

3. CHARACTERISTICS OF THE WHALE FINDER SONAR SYSTEMS

Any sonar system that will be tested during this research activity, including both the MAST Mechanically Steered System and the IMAPS active component, will have the following characteristics:

1. Operating frequency greater than 20,000 Hz (20 kHz).

2. Maximum source level at or less than 220 dB re 1 μPa at 1 m.

3. Pulse length less than 1 second.

4. Duty cycle less than 10% (pulse duration divided by repetition interval).

5. Source level drop to 180 dB re 1 μPa at 1 m if an object with a target strength greater than –20 dB re 1 m is detected inside of 100 m.

6. A ramp-up procedure when first turned on whereas the source level starts no higher then 180 dB re 1 μPa at 1 m and increases no faster than 5 dB per minute.

The frequency range of the system is dictated by sonar system design fundamentals. A higher frequency is desirable because operating at higher frequency reduces the size of the sonar head. However, the absorption of sound in seawater as it propagates increases exponentially with increasing frequency. Lower frequencies are therefore desirable because the detection ranges are farther. Also, in general, the portion of incident sound energy that bounces back off an object (defined as the "target strength" of the object) increase with frequency. An operating frequency range of 20-40 kHz has been chosen through development of both the HF/M3 and IMAPS systems to optimize both sonar size, range performance, and detection of marine mammals.

The maximum source level of 220 dB re 1 μPa at 1 m was reached through the balancing of a variety of engineering issues such as maximum detection range, available power amplifier and transducer designs, and clutter versus ambient and electrical noise. Further, with this maximum source level we are assured that the sound level will drop to 180 dB re 1 μPa within 100 m. The system design and manner of operation strives to ensure that it is not operating at full power or is shut down if a marine mammal is detected within 100 m.

The current designed pulse length of both the MAST Mechanical System and IMAPS active component is less than 100 ms with a repetition rate greater than 2 seconds (duty cycle less than 5%). We would like to obtain a permit to transmit as long as 1 second with a 10% duty cycle in order to investigate the ability of different signal processing schemes to improve detection.

4. IMPACT OF THE WHALE FINDER SONAR SYSTEMS

Current research indicates that there will be little or no effect from SSI's whalefinder sonars on a marine mammal. There is perhaps a general confusion about using an active sonar system, itself a producer of sound, to protect marine mammals from sources of underwater sound. The difference is that the sonar systems developed by SSI operate at a relatively low power and high frequency. Figure 10 groups the existing sonar systems by source level and frequency. We see that the whale finder sonar systems being developed by SSI and others are grouped with commercially available depth sounders and fish finders. The potential sources of harm to marine mammals, such as high-powered military sonars and explosions, are at a much lower frequency and much higher source level. While these systems operate with output acoustic power in the megawatts, both HF/M3 and IMAPS operate with an acoustic output power less 3 kilowatts.

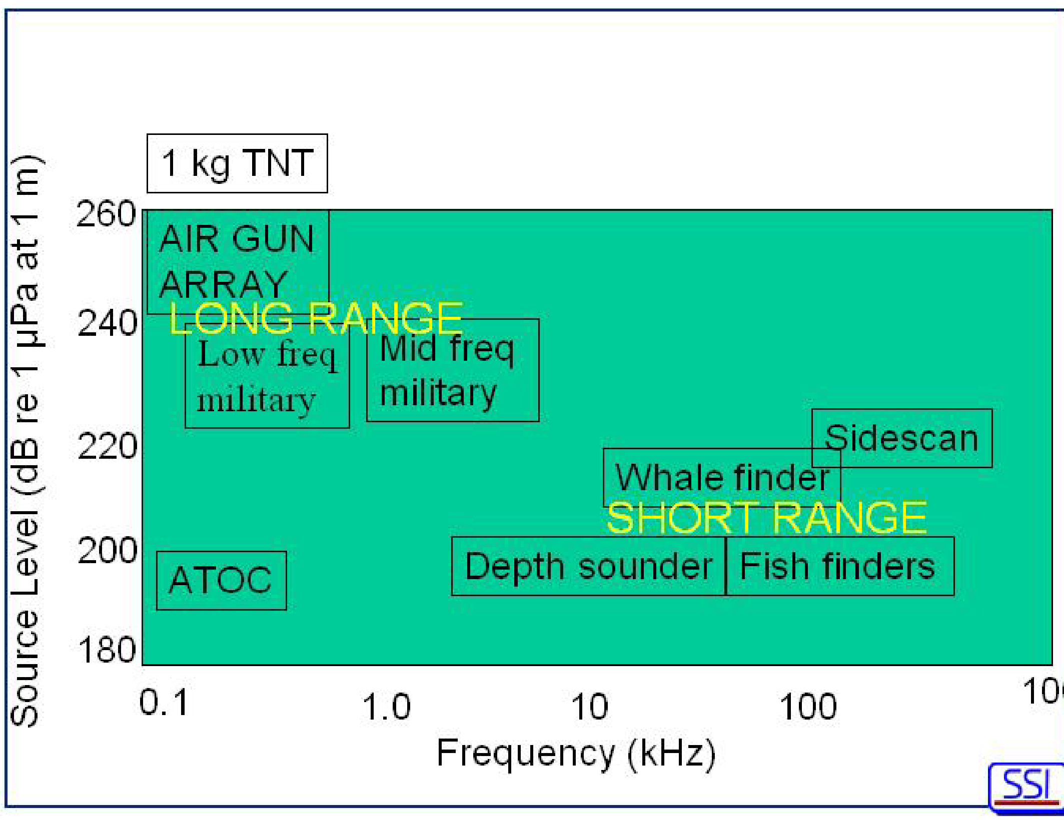


Figure 10 - Source level and frequency characteristics of different sources of man-made sound in the ocean. In general the sources that might be problematic are at low frequency and high source level, while those that are insignificant are at low power and high frequency. The whale-finding sonars being developed by SSI are most like fish finders, depth sounders, and side scan sonars.

Figure 11 shows the hearing sensitivity of various marine mammals and a few other marine species. Larger baleen whales are expected to have little to no hearing sensitivity above 20 kHz. This has been determined through studies conducted of the inner ear of marine mammals [ref??]. Thus, similar to a human during an ultrasound test, we expect no reaction at all from baleen whales. Toothed whales, such as sperm whales, and small odonocetes such as dolphins and porpoises do have good hearing in the frequency range of the whale-finding sonar. Figure 12 shows hearing tests conducted on captive dolphins. The whale-finding sonar might elicit an avoidance reaction from these animals. However, unless they get within about 30 m of the sonar head there will not even be a temporary threshold shift in their hearing.

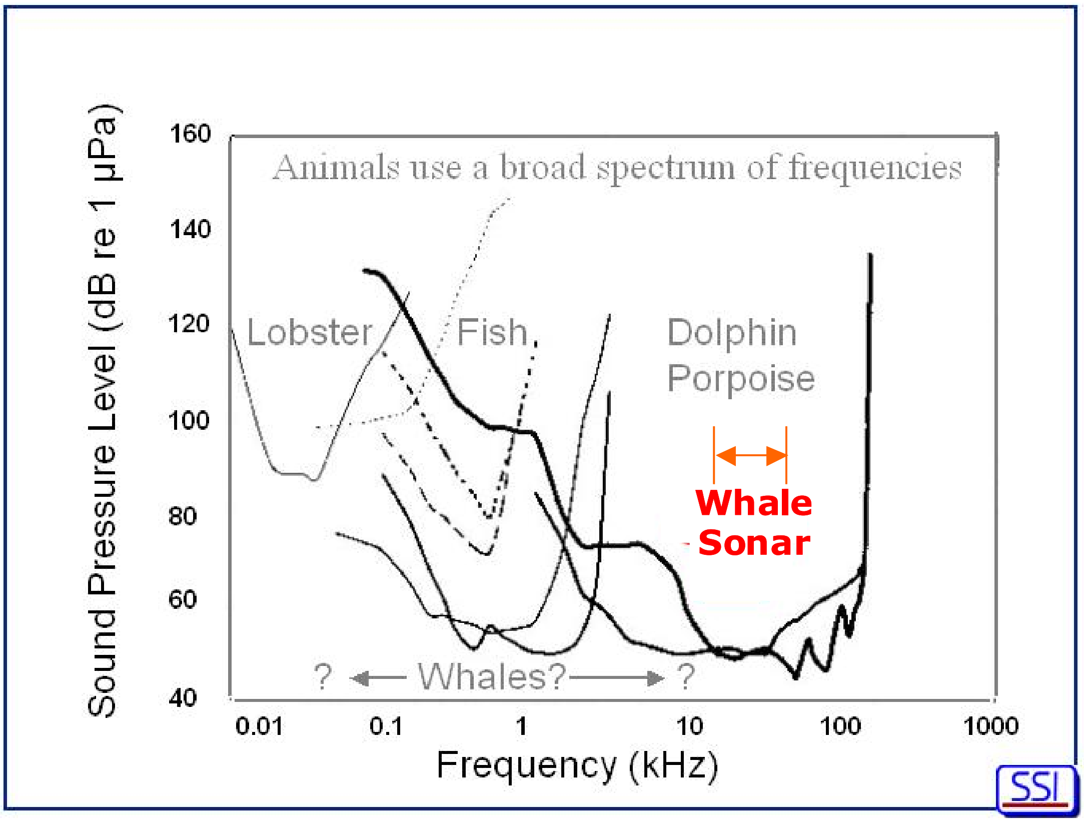


Figure 11 - Underwater audiograms of various marine life. That for the baleen whale was developed through studies of the inner ear anatomy. The larger baleen whales are not expected to hear the whale finding sonar. However, the toothed whales and smaller odonocetes will hear the sonar.

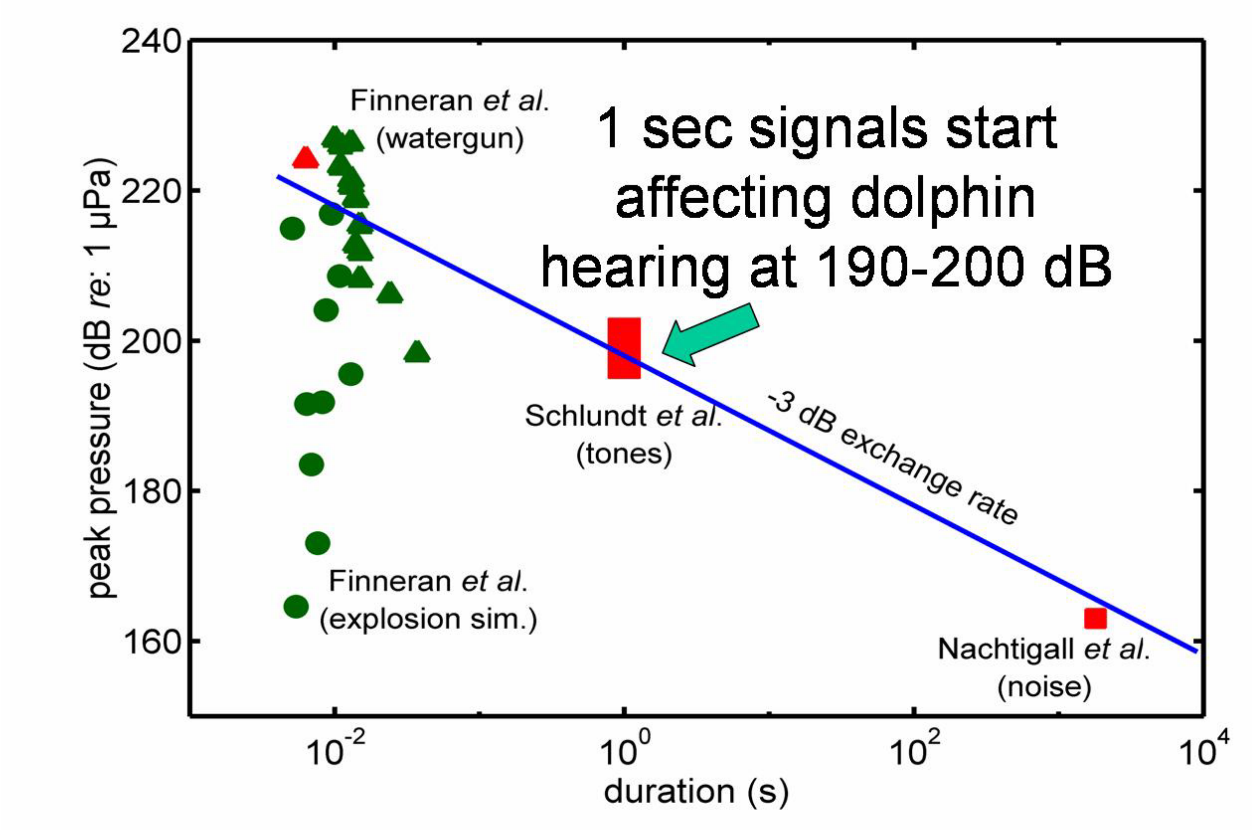


Figure 12 - Results of hearing tests on odontocetes. Pressures shown are that which will induce a temporary threshold shift in hearing. Tests on captive dolphins indicate that much higher exposure levels, and for a much longer duration, than what might occur with the whale finding sonar are required to induce even a temporary threshold shift. Although the system might annoy the odontocetes, unless they come much closer than 100 m they will not suffer any hearing damage.

Similar to dolphins, a large odontocete, such as a sperm whale, would hear the sonar system, perhaps generating an avoidance reaction. However, even though there have been no hearing tests conducted in this frequency range, the whale-finding sonars are unlikely to harm the animals. These animals generate sound in this frequency range while feeding and communicating. The sound levels they generate themselves would yield a tissue exposure greater than 180 dB re 1 μPa.

Another concern is the general increase in noise levels due to use of the marine mammal detection sonars. However, at these frequencies the absorption of sound in seawater is relatively high. Figure 13 shows the attenuation of sound in seawater versus range. Note how the sound levels drop off rapidly beyond a certain range that increases with frequency. The operational frequency of a sonar system is in general set by a requirement to achieve detections at this drop-off range. In any event, like depth sounders or fish finders, the cumulative effect of whale-finding sonars that operates at frequencies greater than 20 kHz is insignificant.

Figure 13 - Sound pressure level versus range for various frequencies and a source level of 220 dB re 1 µPa at 1 m. This assumes spherical (free-field) spreading plus absorption. In most realistic cases, scattering from the boundaries will increase absorption at the higher frequencies. At 20 kHz, the lowest frequency of operation of the whale finding sonar, the sound dies away rapidly beyond several km.

5. SAFEGUARDS DURING TESTING

Our tests are not expected to have any damaging effects on marine mammals. However, during any intentional insonification of marine mammals the following procedures will be in place:

1. NMFS approved marine mammal visual observers will be in place to both provide validation of the sonar performance and look for any avoidance reaction from the animals. A lead observer will be appointed and will have ultimate control as to whether it is safe to conduct or continue the testing.

2. The sonar will be shut down if any marine mammal is observed within 100 m.

3 The sonars will be shut down if any endangered species are observed in the vicinity at a range less than 2 km.

4. Tests will only be conducted during daylight hours and when adequate visual monitoring can be maintained as determined by the lead marine mammal observer.

6. TEST AREAS AND SPECIES

Possible locations for testing are the Northern Pacific, Gulf of Mexico, North Atlantic, or Mediterranean Sea. Only non-endangered species will be intentionally ensonified. At this point the only planned test is the Gray Whale Migration Test described below. Although no other specific tests are planned at this time, this experiment might be repeated in other locations using dolphins, sea lions, or other non-endangered species. We will conduct no more than five tests per year and all the above protocols will be maintained. Simultaneous testing at different locations will not be conducted under this permit.

7. GRAY WHALE MIGRATION TEST

The first experiment to be conducted under this permit will be a test off the central California Coast, near Diablo Canyon, using gray whales. The test will occur over an approximately 3 week period in the late December 2003 to early February 2004 time frame during the whale's southbound migration. Figure 14 shows the approximate area of operation for the test.

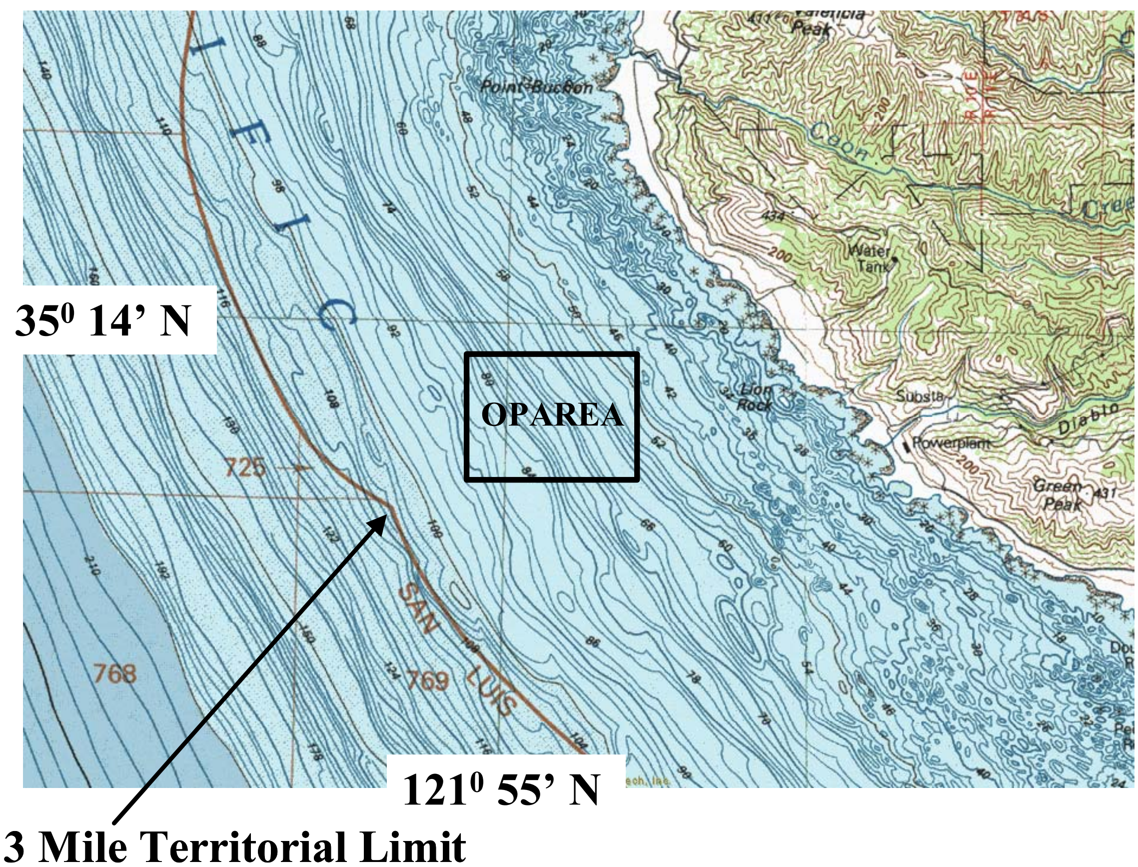


Figure 14 - OPAREA for January 2004 Gray Whale migration test.

A research vessel will be moored roughly 1 mile offshore near the center of the migration route. The whale-finding sonars will be deployed off the research vessel or moored nearby. Visual observers will be located at two separate stations on the bluffs overlooking the coast, pinpointing the gray whales positions using theodolites. Additional observers will be located on the research vessel. Although the experimental time frame may run for as much as 30 days, the sonar will be operated for no more than 120 hours (20 days at a maximum 6 hours/day). During the peak of the migration an average of 10 whales per hour pass by this location. Therefore, we estimate that we will intentionally insonify a maximum of 1200 gray whales, or an estimate of 5% of the gray whale population.

This test site provides what is likely the most ideal setting for collecting data related to the development of whale-finding sonars. The reasons are as follows:

1. As many as 100 whales per day pass through a narrow corridor ensuring many opportunities to detect and track the whales.
2. The animals will be ensonified at different aspect angles as they travel by allowing us to thoroughly analyze differences in animal reflectivity as a function of which way the animal is pointing.
3. There are high cliffs from where trained marine mammal observers can easily track the animals providing ground truth for the sonars.
4. Gray whales are not endangered.
5. This choice of sites maximizes our ability to study the large baleen whales while minimizing the probability of exposing endangered species to audible sounds. The water is cold enough that sea turtles are likely to not be present.

D. DESCRIBE THE ANTICIPATED EFFECTS OF THE PROPOSED ACTIVITY

See section C.4 above.

1. EFFECTS ON INDIVIDUAL ANIMALS:

Possible avoidance reaction to the sonar.

2. EFFECTS OF INCIDENTAL HARASSMENT:

Negligible.

3. EFFECTS ON STOCKS:

None.

4. STRESS, PAIN, AND SUFFERING:

None expected.

5. MEASURES TO MINIMIZE DISTURBANCE:

Protocols discussed in Section C.5 will be maintained during testing.

6. NATIONAL ENVIRONMENTAL POLICY ACT (NEPA) CONSIDERATIONS:

This research is likely to be controversial among the general public, as excited by the more radical environmental groups with help from the media. It is not likely to be controversial by those that would be considered experts in the field of sound and its effects on marine mammals.

E. PUBLICATION OF RESULTS

The results will be made available to the general public shortly after testing. Within 1 month after the test a quick look report will be written and distributed. Within several months following the test a full report will be written and distributed.

F. PROPOSAL AND PREVIOUS AND OTHER PERMITS

1. FORMAL RESEARCH PROPOSAL:

No formal proposal for this effort has been prepared at this time.

2. SPONSORS AND COOPERATING INSTITUTIONS:

A. Office of Naval Research – Dr. Ellen Livingston, Code: 321OA
Ballston Tower One
800 N. Quincy Street
Arlington, VA 22217-5660

B. Cornell University Lab of Ornithology - Dr. Christopher W. Clarke
Bioacoustics Research Program
159 Sapsucker Woods Road
Ithaca, NY 14850

C. Marine Acoustic, Inc. – Dr. Adam Frankel
Ballston Metro Center, Suite 708
901 North Stuart Street
Arlington, VA 22203-1821

3. PREVIOUS PERMITS:

None.

4. OTHER PERMITS:

None.

V. SPECIAL CONSIDERATIONS FOR APPLICANTS WORKING ABROAD (FOR EXPORTS OF PARTS/SAMPLES OR LIVE ANIMALS FROM THE U.S.)

Not Applicable.

VI. CERTIFICATION AND SIGNATURE

"I hereby certify that the foregoing information is complete, true, and correct to the best of my knowledge and belief. I understand that this information is submitted for the purpose of obtaining a permit under one or more of the following statutes and the regulations promulgated thereunder, as indicated in Section I. of this application:

- The Endangered Species Act of 1973 (16 U.S.C. 1531-1543) and regulations (50 CFR 222.23(b)); and/or
- The Marine Mammal Protection Act of 1972 (16 U.S.C. 1361-1407) and regulations (50 CFR Part 216); and/or
- The Fur Seal Act of 1966 (16 U.S.C. 1151-1175).

I also understand that any false statement may subject me to the criminal penalties of 18 U.S.C. 1001, or to penalties provided under the Endangered Species Act of 1973, the Marine Mammal Protection Act of 1972, or the Fur Seal Act of 1966, whichever are applicable."

APPLICANT: [signature]

PRINT NAME: Dr. Peter J. Stein

TITLE: President / PI

DATE: 15 May 2003