Pre Cruise Plan for Lamont Acoustic Calibration
Cruise: plan-C, no tagging or CEE

The activities of this cruise either require no permit or will be conducted under the IHA issued to Lamont Doherty Earth Observatory. Should the permit for tagging and CEEs become available, we will end the cruise covered under this cruise plan and switch to the cruise described by SWSS plan A, involving tagging and CEEs, for which a separate cruise plan is being prepared.

Goals:

- Calibrate the sound field around an airgun array in the Gulf of Mexico. Should be performed in deep water sperm whale habitats. Ideally would also include several shallower sites as well.
- Track the movements and dive patterns of sperm whales (Teloni lead on acoustic, Quero/Podesta lead on visual) both near seismic survey and far from them, to build data on effects of exposure using gross measures of vocalization and dive pattern.
- Improve 3D acoustic tracking methods for sperm whales (Thode lead).
- Work towards near real-time geographical display of ship-gathered whale track information. This display is being developed as a general tool for monitoring and mitigation, and will also help in CEE planning should we move to Plan A.
- Continuous acoustic monitoring and daylight visual monitoring for use as survey data. Once calibration of seismic arrays is completed, ship can cover whatever areas are highest priority to MMS.
- CTD deployments adjacent to sperm whales to examine physical oceanographic features of habitat.

- Optional goal depending on availability of D. Engelhaupt: Tissue sampling effort in the relatively under-sampled areas west of 90°W or east of 88°W. For this to be accommodated under plan C, Engelhaupt and his equipment would have to be transferred from the Gyre to the Ewing after the Gyre moves east to the delta area.

The primary objective for this leg is to calibrate all R/V Ewing acoustics sources. These are various configurations of the airgun array (20, 12, 10 and 6 guns), 2 GI guns, and the 3.5, 12 & 15.5 kHz sonars. Calibration runs will be conducted at 3 sites distinguished by three different water depth regimes: Shallow (< 100m), Slope (~1000m), and Deep (>2000m). The primary calibration tool will be a specially adapted Spar Buoy with two hydrophones hung at 18 m and 500 m (except for shallow site). Note this buoy has been constructed in a very short time period, and final assembly and testing is still underway. Therefore we expect some ‘shake-down’ time to iron out any wrinkles in the buoy operations. At this point we also anticipate that we will be deploying the EARS buoy at
the beginning of the cruise at the shelf site. We will also conduct “Sea Cat” CTDs and XBTs at each of the 3 sites to provide accurate velocity depth profiles.

We will be leaving Gulfport ~ 8am on May 27, and will transit to the EARS buoy deployment site (slope site). A direct transit would take ~ 10 hours, but we will stop midway to do several hours (adjustable as needed) of buoy testing in day light, and so will arrive at the Shelf site after dark. During transit both the Visual Team and the Acoustic team will be:

1. setting up tools
2. testing and calibrating both the old and new data logging system
3. training observers

We will then deploy the EARS buoy and do a CTD and XBT, and transit overnight to the deep water site. We will take two days at the deep water site to do calibration runs using the GI-guns and sonar systems one day and various airgun arrays the other day. Acoustic monitoring will be on-going through out this process to ensure that whales are not nearby when shooting is underway. In addition small-boat testing can be on-going during breaks in calibration activity, and in particular may be quite useful in initial buoy test work to aid in adjusting the radio transmitters. Small-boat testing could be used for further visual/acoustic calibration, testing and training.

Night-time will be occupied with acoustic monitoring, CTDs, buoy recovery/deployments, and transiting between sites. In particular it would be useful to arrive at sites several hours before dawn so that acoustic monitoring can identify areas with whales that need to be avoided. If feasible the buoy can be deployed near sunrise and recovered near sunset to maximize operational time in day light hours.

Following the deep water work, we will transit to the slope area (anticipated Friday May 30), and conducted airgun calibration work there (note, no gi-gun or sonar calibration work will be done in the slope area). Saturday May 31 and Sunday June 1 will be spent doing airgun, gi-gun and sonar calibration at the shallow site, and we will transit back to port Sunday evening to arrive in Gulfport by 8 am on June 2.

This schedule provides some slack but not a lot. Delays may be possible due to weather problems, technical problems with the buoy, the need to relocate due to presence of whales in the calibration areas and/or the need to extend the lines to cover range out to 160 dB. In the event we finish early we may be able to come into port on Sunday evening, or can use the time to conduct more acoustic monitoring for SWSS goals. In the event we are significantly delayed and are unable to achieve primary calibration objectives we would delay returning to port to as late as the morning of June 3.

However, for planning purposes we anticipate and are relatively confident of a return to port on the morning of June 2.

**Schedule:**

23 May  Ewing arrives Gulfport
26 May  2100 All plan c personnel aboard Ewing/ training session for mitigation
27 May – 8am – leave Gulfport, transit to slope site with stop mid-way for buoy testing. 
Evening – deploy EARS buoy, conduct CTD and XBT and transit to deep site. 
28–29 May  Deep site calibration of guns and sonar sources. 
30 May  Slope site calibration of guns 
31 May – 1June  Shallow site calibration of guns and sonar sources. ~Midnight – if Tyack permit is available, begin transit to port. 
2June  8 am – arrive Gulfport, transfer personnel and begin leg b of EW0303. 
Potential switch to plan A. may require port call. disembark airgun personnel, Thode, embark tagging/CEE personnel. This switch may be moved back a few days to accommodate permit timing. 
Contingency schedule if Tyack permit is delayed 
3-4 June: Decision day to cancel a Plan A if permit is not likely to be issued 
4-7 June: Possible transfer of Engelhaupt to RV Ewing from RV Gyre 
10 June: Possible early stop date of cruise in case of permit not having been issued 

Field Party Chiefs 

LDEO chief scientist: Dr. John Diebold, 
Mitigation coordinators: Alessandro Bocconcelli, Michela Podesta 

Captain's name on the cruise will be Jim O'Loughlin. He replaces Mark Landow during the port stop.

Email addresses on board Ewing: First initial then last name@ewing.ldeo.columbia.edu 
If longer than 8 letters, truncate last name to 7 letters. 
For example, Patrick Miller would be: pmiller@ewing.ldeo.columbia.edu 

EWING Cel phone: 914 329 1770 

Inmarsat B 
Voice 330 370 650 
Fax 330 370 651 

Inmarsat F 
Voice 763 198 624 

All Inmarsat calls are dialed: 011 [ocean code] number Atlantic West = 874 

Iridium 
8816 3183 0186 

Shipping address for equipment: 

P & O Ports Stevedoring 
East Pier 
Port of Gulfport 
Gulfport, Ms. 39501
Science Crew for Plan C:

Alex Bocconcelli  mitigation coordinator
Michela Podesta  visual coordinator Team A
Maria Elena Quero  visual coordinator Team B
Valeria Teloni  acoustic coordinator
Aaron Thode  leader for 3-D acoustic tracking of sperm whales

Todd Pusser  visual/ acoustic observer
Dee Allen  visual/ acoustic observer
Irene Brigga  visual/ acoustic observer
Kara Buckstaff  visual/ acoustic observer
Suzanne Yin  visual/ acoustic observer
Meike Holst (LGL)  visual observer

WHOI will provide 9 staff for this phase of the cruise, and Aaron Thode from SIO will bring the total biology science staff to 12. The 9 from WHOI will consist of Alex Bocconcelli as a coordinator between LDEO and WHOI staff. Michela Podesta will be the WHOI lead for monitoring and mitigation. Maria Elena Quero will be WHOI lead for visual data collection, with Michela Podesta as primary assistant. Teloni will be the lead on acoustic monitoring. Aaron Thode will conduct focused trials of data-collection for 3-D tracking of sperm whales.

In addition to Bocconcelli, Podesta, Teloni, and Quero, WHOI will provide five people trained in visual observation and monitoring vocalizations of marine mammals. This is enough to rotate two sets of four visual observers (2hON/2hOFF), maintain two sets of two acoustic monitors, and have a mitigation coordinator during all times of Ewing transmissions.

Mitigation coordinator: Bocconcelli
Acoustic Monitor team A: Thode, Buckstaff
Acoustic Monitor team B: Teloni, Yin
Visual monitor team A: Podesta` (team leader), Pusser, Allen, Buckstaff
Visual monitoring team B: Quero (team leader), Brigga, Yin, Holst

Some of the visual observers will be inserted into the acoustic rotation during their turn OFF.
The rotations of observers may vary depending upon the primary activity. The trained visual observers and acoustic monitors will train Ewing personnel who will then assist in monitoring when available during times with no Ewing sound transmissions.

Outline of Cruise Plan with options depending upon status of permits and authorizations
The RV Ewing will arrive in Gulfport on 23 May 2003. This provides four days to rig deployment system for rhibs and to load equipment. TAMU will ship the reconditioned R2 and 500 gal tank by 23 May to the shoreside site decided by Paul Lundgren of Lamont. WHOI ship Balaena to same site by 24 May. WHOI will provide its leased SEAMAP array for towed acoustic monitoring to arrive at the ship no later than 25 May. A second array (the ‘WHOI Array’) will also be shipped as a backup and to assist with the Thode 3-D tracking project. Thode will provide autonomous acoustic recorders. Alex Bocconcelli will work with Ewing crew 23-26 May to rig deployment system for rhibs and hydrophone arrays, and to implement a safety protocol for on-board re-fueling of the RHIBs. Three ‘big eye’ binoculars will be mounted on the flying bridge at this time.

In order to provide for planning logistics, the primary cruise plan assumes LDEO has an IHA for acoustic transmission. However, the cruise will take place regardless of the status of any permits, and would default to recording of ongoing commercial seismic surveys if necessary. Assuming the Tyack permit becomes available in time, the first start date for the plan A Dtagging and CEE cruise is planned for June 2, with a port call and crew change. In this crew change, Thode will disembark while Johnson, Miller, Grund, Aguilar, and Shorter from WHOI and another acoustic monitor will board the Ewing.

Source Calibration and Opportunistic Response Assessment

If the Ewing receives its IHA in time for 27 May the Ewing could conduct its calibration 28 May – 1 June. This will take place away from marine mammals. Since beaked whales may be of particular concern, this calibration will be conducted more than 50 km from sightings of beaked whales, as reported in the NMFS 2002 Gulf of Mexico Stock Assessments, and as per the sighting database collated by Joel Ortega (Appendix 1) will be conducted 20 km (deeper, preferably) from the 2000 m depth contour, as this is reported in the stock assessments to be the most common depth for beaked whale sightings in the Gulf. WHOI will provide an ARCVIEW GIS layer including all sighting data collected for beaked whales in the northern Gulf of Mexico since 1990. Figure 1 shows a preliminary plot of the Ortega sightings. Teloni will manage GIS data on the cruise. Once this is provided, the plan C science team will work with Lamont to identify sites for calibration At each of three depths: shallow, 1000 m and >2000 m.
Figure 1. Sightings of beaked whales from Ortega database (Appendix 1).

For more detail on monitoring and mitigation, see the following section. During the first days of this period the visual and acoustic monitors will set up equipment, test at sea, and start training Ewing personnel. No transmissions will take place until both acoustic and visual monitoring teams are fully functional. During monitoring and mitigation associated with any sound transmissions, Valeria Teloni will be responsible for acoustic monitoring, Maria Elena Quero will be responsible for visual monitoring, and Michela Podesta will receive information from Quero and Teloni and coordinate with the ship to implement the mitigation protocol. Podesta, Quero, and Teloni will have complete authority and control over the monitoring and request for source shutdown. Bocconcelli and/or the WHOI team leader will ensure that communication regarding vessel maneuvering and mitigation decisions is clear.
If neither IHA nor Tyack permit are available by 27 May, then the Ewing will coordinate with a commercial seismic vessel and perform an acoustic calibration of an ongoing seismic survey. This will require industry cooperation both for rendezvous and for the survey vessel to provide the precise times and locations of all shots. Before the cruise date, we request the IAGC to provide us with a prospectus of locations and times of survey activity in the northern Gulf between May 27 and June 23. Periodic updates by email of changes in planned survey locations or timing should be sent to the field party chief on the Ewing. When the Ewing is monitoring ongoing seismic surveys, there is no need for following the monitoring and mitigation specified in the IHA for Ewing transmissions. Instead we will monitor visually and acoustically throughout the survey pass to collect opportunistic response data in tandem with the calibration effort. Ideally, we will adopt a position several hours ahead of a survey path to establish pre-exposure population density of marine mammals, especially sperm whales and beaked whales, in the area.

If sperm whales are present in vicinity of the commercial seismic vessel selected for calibration, then after the calibration of the commercial airgun array, the Ewing will attempt to follow the group of whales using visual and acoustic monitoring. Every effort will be made to localize individual whales and determine their diving behavior. We also will develop and implement a protocol to measure the synchrony of fluke-outs by the
different individuals in the group using 360 degree all-event sampling of fluke-outs. All such observations should be accompanied by acoustic measurements of airgun signals, with a specific focus on estimating received level and signature at the location and depth of localized diving whales. This may require some additional calibration of the seismic survey to cover the probable exposure levels for a distant whale. It is very unlikely that a sperm whale will happen to be closer than about 5-10 nmi. Based upon last year’s results, this would correspond to received levels no higher than 143-148 dB rms re 1 µPa. This is not the highest priority exposure range for controlled-exposure studies, but would be a useful augmentation to our existing dataset of visual and acoustic observations of sperm whales near ongoing seismic surveys.

Post-calibration marine mammal survey and dedicated follows

Once calibration has been completed, if the permit for the next cruise is not available, the RV Ewing should follow survey lines designed to cover areas of maximum interest to MMS. Quero and Podesta will lead the visual monitoring team and be in charge of the rotation of observers. Whenever sperm whales are detected, the ship should attempt to follow the whale(s) using visual and acoustic monitoring. Effort should be divided between 3-D tracking (Thode), acoustic tracking of individuals (Teloni) and visual observations of surface behavior and diving synchrony (Quero). Visual monitoring will be useful for both of the acoustic tasks, but developing and testing new methods for 3D acoustic tracking may require a different pattern for maneuvering the ship than would be chosen for acoustic tracking of an individual. If an individual whale can be tracked using standard methods, these should take priority. When these methods do not allow individuals to be tracked easily, such as when the ship is following a group of whales, this would provide the best opportunities to test new methods for 3D tracking. As the ship nears a new group of whales, the acoustic monitors and FPC should coordinate to decide which activity takes priority for decisions about maneuvering the vessel.

Teloni will take the lead on tracking individual whales, and will be responsible for helping coordinate ship’s maneuvering to optimize tracking, collecting and organizing tracking data, analyzing and reporting data on these tracks. Teloni will use these data as part of her PhD thesis. Thode will be responsible for testing different configurations for 3D tracking, and will be responsible for deciding which configuration of hydrophones to use, collecting all data required for this task, analyzing and reporting data on techniques for 3D tracking. These data will be collected by Thode throughout the cruise when the opportunity arises. Deployment of equipment for 3-D tracking will have to be approved by the FPC. Decisions on vessel maneuvering to deploy equipment or make ship steering or speed changes to optimize 3-D tracking geometries can be made only when such maneuvers do not impact the risk of following the group or collecting acoustic or visual data. Quero will lead the effort to develop and test a protocol for acquiring fluking synchrony of whales in visual range of the vessel.

For follows of the diving behavior of individuals, the Ewing will work primarily in the de Soto canyon area where whales tend to be more isolated. For 3-D tracking and the diving synchrony study, the larger groups off the delta area may be followed. If Dan
Engelhaupt is transferred to the Ewing from the Gyre, additional effort to biopsy sample animals West of 90 W or East of 88 W could be added as a primary goal of this cruise.

Whenever possible without impacting the above higher priority activity, we will make CTD measurements in the vicinity of sperm whales. Ideally the CTD drops will be both temporally and spatially spread with the goal of providing a fine scale physical description of the deep-water environment chosen by sperm whales. The CTD data is also important for establishing sound speed and propagation for 3-D tracking and source calibration and so should be seen as an integral part of these activities. If available, XBT drops will supplement the less-frequent CTD measurements.

Transfer from plan C cruise to plan A cruise:
If Tyack permit is issued in time, the personnel transfer will take place on June 2. The tagging team and additional acoustic monitors will meet the ship at a port selected for proximity to the ship’s location, probably Gulfport. This may entail higher air travel costs than anticipated, given the need for last minute ticketing. This team will be prepared for rapid deployment. Their equipment will be limited to that which can be taken as luggage (all other equipment will be loaded before 27 May), and can quickly be loaded on the ship.

During this same time, the seismic source ship should be rigged for departure ex Texas City, Galveston, on June 4. Doug Nowacek, Jason Gedamke, Aaron Thode, and MMS observers will board the seismic vessel in Texas City. If the Ewing arrives at the end of this cruise on 2 June, then Thode will have several days to travel to the source ship. Rendezvous between the Ewing and source boat will take place at sea on the evening of June 5. June 6 will be the first day that a CEE might be conducted.

In the case that issuance of the Tyack permit is slightly delayed from June 1, the crew transfer date (and source boat departure) will be moved back by the appropriate number of days.

Options for continued plan C after June 4

If by June 4, there is no certainty that the Tyack permit will be available for the plan A cruise, the Ewing team will enter its second phase of plan C activities. By this point, most of the calibration work should be completed, and the primary options for this longer phase are 1.) continued acoustic and visual survey in an area of interest to MMS; or 2.) a dedicated biopsy effort focused on areas outside of 88-90° W. Option 2 will only be possible if Dan Engelhaupt is transferred from the Gyre to the Ewing after the Gyre moves east into the Delta area. Clearly this transfer may not be feasible for logistical reasons so we must remain flexible as to the tasks for an extended plan C. If it is not possible for Engelhaupt to transfer to the Ewing, we suggest that the cruise be terminated early with June 10 as a possible end-date. The exact timing of an early end-date will be dependent on having obtained sufficient acoustic data to satisfy the goals of plan C.
Coordination with R/V Gyre

We plan to be in email contact at least once daily with the R/V Gyre. In our daily update we will provide our location and activities for the day, as well as a prospectus for the next 24 hours. Summaries of locations and diving depths of sperm whales may also be provided as appropriate. In the event of continued plan-C activities, greater coordination may be needed either to transfer Engelhaupt from the Gyre to the Ewing or for Dr. Thode to provide dive-depth information to guide targeted trawls by the Gyre.

Equipment List

LDEO
- airgun source equipment
- calibration buoy
- bimini for cover on the flying bridge
- Laser range finder

WHOI
- Balaena rhib
- 3 bigeye binocs and stands
- 3 pair hand-held binoculars
- 2 laptops for logging visual data
- arrange shipment of leased Seamap array, provide WHOI array
- direct to disk recorder for acoustic data (5 ch needed)
- 2 TASCAM 8 track recorders for backup
- 2 acoustic analysis computers + acoustic GIS computer
- Laptop for GIS display on flying bridge
- Head set radios for intra-visuals communication
- Talkabouts for visual-acoustic communication and coordination

TAMU
- R2 rhib
- 500 gal gas tank
- 2 cases of oil from 2002 Dtag cruise

Detailed Plan for Visual Monitoring

Visual observers will use high-power ‘big-eye’ binoculars, hand-held binoculars and naked eye to spot whales. Three sets of big-eyes will be mounted upon shock-mounts on the flying-bridge: one port, one starboard, and the third in a central position to provide broad viewing of both sides of the ship and any areas that are blocked to the port or starboard big-eyes. The flying bridge will be outfitted with a weather-protecting canopy that will be provided by LDEO and two data-recorder stations will be created using equipment provided by WHOI. Visual observations will be made whenever the light and
weather conditions permit. For safety reasons, the flying bridge will be vacated during high winds or strong rain. A waterproof case will be required on the flying bridge for storing computers and other sensitive equipment. This will be provided by LDEO?

The top priority for combined visual and acoustic follows will be isolated whales, as they are easiest to follow. The primary data collected by the visual team during follows of relatively isolated whales will be: range to whale, bearing of whale, and the heading of the whale (called ‘aspect’). Range from the ship to each surfacing whale will be determined by measuring the declination from the horizon using big-eye binoculars, and bearing will be determined using relative bearing (with respect to ships heading) to the whale. The ship’s heading will be automatically logged from the gyro compass string in the ship’s NMEA stream. Visual sightings data will be entered into Logger or similar system for real-time plotting and display.

When a single individual whale cannot be followed, due to large group sizes, our visual efforts will focus on design and execution of a protocol to measure the dive-synchrony of sperm whales within visual range of the Ewing. In this case, teams of visual observers will undertake all-event sampling of fluke-outs within visual range of the ship. Fluke-out locations and times of non-focal whales are already recorded under the visual protocol, but to measure synchrony in an unbiased fashion we must assure that ALL fluke-outs in a given area can be observed. The 360° field will be broken into quadrants and visual teams will intensively survey quadrants to record all fluke-outs. The key to this sampling is to assure that all fluke-out can be observed within the sample area, and it is foreseen that some modification to the protocol will be required once in the field. This sampling method will work best with eight visual observers, two to each quadrant. Such a large group will only occasionally be available, and the team will work to develop a workable protocol for fewer observers if necessary.

Visual observers will communicate regularly with the acoustic team using handheld radios to ensure near continuous observation of diving whales. Navigation of the ship in the vicinity of whales will be by consensus between acoustic and visual teams.

**Detailed plan for calibration procedures**

Calibration of Ewing sources
Calibration of Commercial Seismic Survey sources (need industry input re mechanics of the coordination to find and rendezvous with seismic survey)

**Detailed Plans for Acoustic Monitoring**

Search / Survey Phase (typically when in route or on pre-determined survey track
Focal follow phase (ship will break off survey once animals are detected; will attempt to follow, linking acoustic and visual information.)
2 main goals
Teloni project: Bio-acoustic studies following the dive and acoustic behavior of individual sperm whales.

**General Scope:** The aim of Teloni’s study is to contribute with new information to the understanding of the functionality of sperm whale clicks during deep foraging dives. Acoustic research in the last 40 years have significantly improved our knowledge on this species and but the production of regular clicks still remains one of the most controversial questions. Sound production will be correlated with the dive status, in order to characterize different phases of a dive with the type of clicking. Studies on sperm whales are conducted in Norway (University of Aarhus) and in the Gulf of Mexico (WHOI). Recorded sounds from these two populations appear useful to find out possible regional variations in the click production.

**GoM03 Contribution:** During passive acoustic tracking operations, we will have the chance to record several dives of single sperm whales. The protocol will refer to previous operations conducted both in the Gulf of Mexico and in the Ligurian Sea. The aim is to record complete dives from the same animal as from different animals. This task is usually reached by coordinate with the bridge for track changes and the visual team for tracking the animal movements when they are at the surface. When many animals are present in the area (typical GoM situation) and their clicking overlap on the same direction, it becomes difficult to concentrate on single dives and carefully describe the acoustic behavior of a specific animal. Teloni’s project requires selection and follow of isolated sperm whales or at least those animals that are not within a group.

Once a sperm whale is chosen to be suitable for a focal follow, the new Logger software will allow a detailed logging of its dives. This Logger provides text output files easy to manage so preliminary results can be issued shortly after the experiment. Further information can be obtained with the replay of interesting cuts.

The available information for each (complete) dive will be: dive time (time between the first and the last click); the inter-dive time (time between the last click of a dive and the first click of the following one); the dive cycle time (time between the first click of a dive and the first click of the following one); the occurrence of sperm whale sound categories such as trumpets and codas; the occurrence and duration (if possible) of pauses and its correlation with creaks and other sounds. If visual information is available, a more detailed analysis on the tracked animal can be done adding results on the surface behavior, the estimate length to be compared with the acoustic IPI, times between the last/first click and the first blow/fluke-up.

In summary, the analysis goals of this passive acoustic tracking are:

- To outline basic statistical parameters of sperm whale diving behavior (dive times, inter-dive times and dive cycle times).

- To detect, locate and identify the sound categories of the generally accepted sound classification for sperm whales (regular clicks, creaks, codas, slow clicks and trumpets)

- To characterize in detail the different phases of a dive, using the inter-click intervals (ICI) variation. This analysis is focused on regular click sequences in which the temporal variation of ICI can be used to describe the dive status.
• To study, once a baseline behavior for the GoM population is described, any possible reaction of sperm whales to anthropogenic noise.

Thode project: development and testing of novel methods for 3D localization

3-D acoustic tracking: A separate pre-cruise plan is being composed for the 3-D passive tracking portion of the cruise by Aaron Thode. A brief summary is given here. The use of widely separated (>300 m) acoustic arrays may permit more precise localization of sperm whales beyond bearings. This information can be used to determine the effective detection ranges of the acoustic arrays, as well as determine “rules of thumb” for estimating whale range from received sound levels on a single array.

When the ships are within 2 km of the animals, and the arrays are deployed below 50 m depth, surface reflections may be separated in time from the direct paths, permitting full 3D localization, which provides additional information about what portion of a dive cycle a particular whale is involved in at a given moment. By using two widely-separated hydrophones the horizontal range and depth of acoustically active whales can be determined. The method does not require the use of returns off the ocean bottom.

Description of 3D tracking concept

On Sept. 5, 2002, a feasibility test of the method was conducted during the DTAG cruise on the R/V Gyre. Two arrays were deployed simultaneously, and the signals from one hydrophone on each array were recorded. The arrays were spaced about 150 m apart.

Using two spatially separated arrays each ‘click’ an animal makes provide three pieces of information: the difference between the arrival times of the direct and surface-reflected paths($P_{ds,x}$) on the forward ($F$) and rear ($R$) hydrophones, and the arrival time difference between the direct paths on both hydrophones ($P_{dd}$). From geometric considerations the following expression can be derived relating slant range from the forward array($P_d$) to these three parameters, assuming straight-line ray propagation:

$$ \frac{z_{a,F}}{z_{a,R}} = \frac{P_{d,F} (2P_d + P_{ds,F})}{P_{ds,R}(2P_d + 2P_{dd} + P_{ds,R})} $$

(1)

The ratio on the left-hand side is the ratio between the two hydrophone depths. Thus if the array depths are known, the slant range can be determined, from which the whale depth ($z_w$) can be computed using the formula

$$ z_w = \frac{P_{ds,F} (2P_d + P_{ds,F})}{4z_{a,F}} $$

(2)

The horizontal range can then be computed from Eq. (2) and the slant range. Note that the separation between the two hydrophones does not have to be known, if only whale depth and range are desired. Indeed, Eqs. (1) and (2) are equally valid for a vertical array.
deployment. However, if the animal’s azimuth is also needed, then either the hydrophone separation needs to be measured, or one of the two locations must be occupied by a two-element hydrophone array, instead of the single hydrophone previously assumed.

Examination of Eq. (1) indicates that the algorithm will only be effective out to slant ranges of about 5 times the path difference between the direct arrivals $P_{dd}$. In addition, the algorithm performance will be poor whenever the animals are broadside of the arrays (when $P_{dd}$ is effectively zero), and will perform best whenever the animals are directly ahead or behind the assembly.

In summary, the method requirements and restrictions are as follows:

1. Two hydrophones must be spaced at least 200 m apart, preferably 500 m apart, to work on whales out to 1 to 2 km range. Ideally, two towed arrays should be available, so that the animals’ azimuths can also be obtained.

2. The best resolution is achieved if the animals are either directly ahead or behind the vessel towing the hydrophones, in other words, *endfire*. This orientation is completely different than what is desired for measuring bearings from a towed array. In that case, the best bearing resolution is obtained when the animal is *broadside* of the array.

3. Each hydrophone must be at least 60 m deep, to obtain large values of $P_{ds}$. Consequently, if arrays are used, the array tow speeds generally must be low, less than 2 knots, unless the hydrophone cable is attached to a dive wing.

4. The hydrophone depths must be recorded accurately and continuously. The deeper the array, the less precise the measurement needs to be, but 1 m accuracy seems to be a good rule of thumb.

5. The change in water sound speed with depth should be sufficiently low such that the straight-line travel time approximation assumed in Eq. (1) is valid. Generally, studies evaluating the effect of ray curvature on travel time have concluded that the extra time delay is small for target ranges less than 1 km$^{1,2}$, but the results of Eqs. (1) and (2) would have to be compared with a full-scale acoustic propagation model, such as SCOOTER or BELLHOP$^3$, in order to validate the straight-line assumption. In general, it is expected that the deeper the array, the less impact ray-refraction effects will have on the result.

6. At present no software is available to perform the analysis real-time. However, in 2002 about 2/3 of the effort required to arrange the various software components was completed.

**Deployment configurations.**

Two possible deployment configurations are available for collecting such data under Plan A. Neither is expected to interfere with calibration activities.
(1) Recording time-synched data from a dual-deployment of the WHOI and SEAMAP array on the Ewing, a procedure nearly identical to that attempted in the 2002 SWSS cruise on the Gyre, which was described above.

(2) Limited deployment of autonomous recorders from Ewing in the early evening in conjunction with towed array, when calibration and visual operations are not active. The recorders would be lowered 60-100 m beneath the surface using 100-300 m of 300 lb. strength spectra fishing line. The recorder would be time-synched with the SEAMAP towed array upon recovery, by playing an FM sweep over a speaker onto both the Alesis 2424 HD drive while holding the recorder next to the speaker as well.

Transition to Plan A

If the permit application for WHOI DTAG is approved then Thode will transfer to the Kondor, where he will continue to work on deployment option (2), described above. In addition, he will attempt to time-synch data recorded on both the Ewing and Kondor towed arrays to help create an effective single large-aperture array. While on the Ewing Thode will install acoustic software to prepare for the latter possibility.

Detailed Plan for Monitoring and Mitigation associated with Ewing sound transmissions

This plan annotates sections of the LDEO IHA application. Once the IHA is issued, this will need to be checked against the actual IHA. A final mitigation plan will be agreed upon prior to the cruise based on the following considerations.

Marine Mammal Monitoring

Vessel-based observers will monitor marine mammals near the source vessel starting one half hour [Plan C will plan on a minimum of 1 hour of preexposure observations] before all airgun operations. Airguns will be operated only during daylight; they will not be operated or started up during nighttime. Airgun operations will be suspended when marine mammals are observed within, or about to enter, designated safety zones (see below) where there is a possibility of significant effects on hearing or other physical effects. Vessel-based observers will watch for marine mammals near the seismic vessel during daylight periods with shooting, and for at least 30 [plan C will double this to 60] min prior to the planned start of airgun operations.

The *Maurice Ewing* is a suitable platform for marine mammal observations. The observer’s eye level will be approximately 11 m (36 ft) above see level when stationed on the flying bridge, allowing for good visibility within a 210º arc for each observer. During acoustic transmission, it will be essential to have 360º of visibility, with special focus aft near the airgun arrays. It may be necessary to establish a second visual observer site to accomplish this. In addition to visual observations, a towed hydrophone array will be used to detect and locate marine mammals. This will increase the likelihood of detecting and identifying any marine mammals that are present during airgun operations. The proposed monitoring plan is summarized in § XIII.

We plan to have three visual observers + one recorder watching at all times from 60 min prior to transmissions, continuously until 60 minutes after transmissions cease. If a visual observer sights an animal close enough for concern s/he will notify the team leader (Podesta’ or Quero). If the team leader confirms animal near 180 dB safety zone, she will contact Bocconcelli who will receive information from visual and acoustic monitors and
will be in continuous contact with airgun operators. Estimation of the 180 dB safety zone will be made with conservative acoustic modeling, which will be validated by empirical measurements as soon as possible. This range will be converted into a reticle count, so that operators of the big eyes do not need to wait for calculation of distance measurements.

**Proposed Safety Radii**

Received sound levels have been modeled by LDEO for the 2, 6, 10, 12, and 20 airgun arrays and are depicted in Figures 7-11, respectively, in § I of the IHA application. Based on the modeling, estimates of the 190, 180, 170, and 160 dB re 1 µPa (rms) distances (safety radii) for these arrays are shown in Table 1 in § I. Acoustic measurements in shallow (<100 m), mid-depths (100-2000, but probably about 1000 m), and deep (>2000) water will be taken during the proposed cruise, in order to check the modeled received sound levels during operation of these airgun arrays in a wide variety of water depths. Because the safety radii will not be confirmed before the cruise, conservative safety radii will be used during the proposed Gulf of Mexico surveys. Conservative radii will be 1.5 times the distances shown in Table 1 for the 2 GI [what are these?] guns and the 20 airgun array. Thus, during the Gulf of Mexico cruise the proposed conservative safety radii for cetaceans are 75 and 1425 m for the 2 GI guns and 20-gun arrays, respectively, and the proposed conservative safety radii for pinnipeds are 23 and 600 m, respectively.

**I. Operations to be Conducted**

For each of these configurations of the airgun array, the sound pressure field has been modeled in relation to distance and direction from the airguns. Received sound levels for the 2-, 6-, 10-, 12-, and 20-gun arrays are depicted in Figures 7-11, respectively. Table 1 shows the maximum distances from those arrays where sound levels of 190, 180, 170 and 160 dB re 1 µPa (rms) are predicted to be received. Here the rms (root-mean-square) pressure is an average over the pulse duration. The calibration measurements to be obtained during the proposed program will confirm the actual radii corresponding to each sound. When airgun operations commence after a period without airgun operations, the number of guns firing will be increased gradually ("ramped up", also described as a "soft start" in some jurisdictions. Operations will begin with the smallest gun in the array that is being used (80 in³). Guns will be added in a sequence such that the source level on the vertical axis of the array (i.e., vertically below the array) will increase in steps not exceeding 6 dB per 5-minute period over a total duration of ~14 min (6 gun array). During the calibration program, no streamer (hydrophone array) will be towed behind the source to receive the echoes of airgun signals. However, a different kind of hydrophone array will be towed throughout this period to monitor for sounds of marine mammals A spar buoy will receive the seismic signals from the various airgun arrays and will transfer the data via radio to the on-board processing system.

**TABLE 1. Distances to which sound levels =190, 180, 170 and 160 dB re 1 µPa (rms) might be received from the 2, 6, 10, 12, and 20 airgun arrays that are proposed to be used in 2003.**

<table>
<thead>
<tr>
<th>Airgun Array Volume (m)</th>
<th>Airgun Depth (m)</th>
<th>RMS Radii (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>190 dB</td>
</tr>
<tr>
<td>210 in ³ (2 GI guns)</td>
<td>6.0</td>
<td>15</td>
</tr>
<tr>
<td>1350 in ³ (6 airguns)</td>
<td>7.5</td>
<td>50</td>
</tr>
<tr>
<td>3005 in ³ (10 airguns)</td>
<td>7.5</td>
<td>250</td>
</tr>
</tbody>
</table>
Airgun operations will be suspended immediately when cetaceans are detected within or about to enter a zone 1.5 times the appropriate 180-dB (rms) radius. This 180 dB criterion is consistent with guidelines listed for cetaceans by NMFS (2000) and other guidance by NMFS.

**Mitigation During Operations**
The following mitigation measures, as well as marine mammal monitoring, will be adopted during the Gulf of Mexico acoustic verification program, provided that doing so will not compromise operational safety requirements:
1. Course alteration;
2. Shut-down procedures;
3. Ramp-up procedures; and
4. Avoidance of areas with concentrations of cetaceans.

**Course alteration**
If a marine mammal is detected outside the safety radius and, based on its position and the relative motion, is likely to enter the safety radius, alternative ship tracks will be plotted against anticipated mammal locations. If practical, the vessel’s course and/or speed will be changed in a manner that avoids approaching within the safety radius while also minimizing the effect to the planned science objectives. The marine mammal activities and movements relative to the seismic vessel will be closely monitored to ensure that the marine mammal does not approach within the safety radius. If the mammal appears likely to enter the safety radius, further mitigative actions will be taken, i.e., either further course alterations or shutdown of the airguns.

The WHOI GIS tool will be used if possible to plot acoustic and visual marine mammal locations. This will be made available on the bridge, where Podesta or Quero will coordinate with the bridge watch to plan course alterations. The marine mammal mitigation coordinator on the bridge, Alex Bocconcelli, will also have alternate methods for instantaneous communication with acoustic monitors and visual observers. Any such course corrections will be taken with input from both visual and acoustic teams to assure that the course change will be effective to move away from animals.

**Shutdown procedures**
Airgun operations will be suspended immediately when marine mammals are observed or otherwise detected within, or about to enter, the designated safety zone. Michela Podesta will be in real-time contact with visual and acoustic monitors, and with the Lamont personnel operating the airguns to enable rapid shutdown. Podesta will have unquestioned command authority for shutdown. The shutdown procedure should be accomplished within several seconds (or a “one shot” period) of the determination that a marine mammal is within or about to enter the safety zone. Airgun operations will not resume until the marine mammal is outside the safety radius. Once the safety zone is clear of marine mammals, the observers will advise when seismic surveys can re-commence. The “ramp-up” procedure will then be followed.

**Ramp-up procedure**
A “ramp-up” procedure will be followed when the airgun arrays begin operating after a specified-duration period without airgun operations. Under normal operational conditions (vessel speed 4-5 knots), a ramp-up would be required after a “no shooting” period lasting 2 minutes or longer. At 4 knots, the source vessel would travel 247 m (810 ft) during a 2-minute period. If the towing speed is reduced to 3 knots or less, as sometimes required when maneuvering in shallow water, it is proposed that a ramp-up would be required after a “no shooting” period lasting 3 minutes or longer. At towing speeds not exceeding 3 knots, the source vessel would travel no more than 277 m (909 ft) in 3 minutes. These guidelines would require modification if the normal shot interval were more than 2 or 3 min, respectively, but that is not expected to occur during the Gulf of Mexico project. Lamont personnel will be responsible for following the correct ramp up procedure.

Avoidance of Cetacean Concentrations
The Maurice Ewing will be involved in a different cruise, involving separately-permitted studies of sperm whales during June near the period when the proposed acoustical measurements will be obtained. A separate cruise with the RV Gyre will also survey for marine mammals, especially sperm whales, and will be in daily contact with the RV Ewing. In addition, cruise planners will utilize a GIS system mapping the locations of all beaked whales sighting in since 1990 in the Gulf of Mexico. Thus the scientists in charge of this program will have knowledge of the locations of concentrations of sperm whales and other cetaceans. The proposed acoustical measurements will not be conducted near known concentrations of marine mammals. TAMU will provide an Arcview GIS layer including all information on recent sighting data of beaked whales, and Podesta, Quero, and Teloni will integrate monitoring data collected by the Ewing. They will be responsible for ensuring that no sound transmissions are conducted near concentrations of these species, and they will have the final call on appropriateness of a site in terms of avoiding cetacean concentrations.

MONITORING AND REPORTING PLAN
LDEO’s proposed 2003 Monitoring Plan is described below. LDEO understands that this Monitoring Plan will be subject to review by NMFS, and that refinements may be required. The monitoring work described here has been planned as a self-contained project independent of any other related monitoring projects that may be occurring simultaneously in the same regions. LDEO is prepared to discuss coordination of its monitoring program with any related work that might be done by other groups insofar as this is practical and desirable.

As soon as the IHA is issued by NMFS, the science crew will carefully review this plan, to verify that it meets the full requirements of the actual IHA. If necessary, the plan will be modified to ensure that it completely and fully meets all IHA requirements.

Vessel-based Visual Monitoring
A team of six or more observers dedicated to marine mammal observations will be stationed aboard LDEO’s seismic survey vessel during the acoustical measurement program in the Gulf of Mexico. In addition, several other qualified observers will be present as part of other activities being conducted by the Maurice Ewing during this cruise. It is proposed that three marine mammal observers (MMOs) aboard the seismic vessel will search for and observe marine mammals whenever airgun operations are in progress. Airgun operations will be restricted to periods with good visibility during daylight hours. Three observers will be on duty for at least 60 minutes prior to the start of airgun operations and during ramp-up procedures. The observers will watch for marine mammals from the highest practical vantage point on the vessel, which is the
bridge, or flying bridge. The observer's eye level will be approximately 11 m (36 ft) above sea level when stationed on the bridge, allowing for good visibility within a 210º arc. The observer(s) will systematically scan the area around the vessel with 7 × 50 Fujinon reticle binoculars or with the naked eye during the daytime. “Bigeye” (25 × 150) binoculars will be available during this cruise to assist with species identification of marine mammals that are sighted. Laser rangefinding binoculars (Bushnell Lytespeed 800 laser rangefinder with 4x optics or equivalent) will be available to assist with distance estimation. (These are useful in training observers to estimate distances visually, but are generally not useful in measuring distances to marine mammals directly.) If a marine mammal is detected well outside the safety radius, the vessel may be maneuvered to avoid having the mammal come within the safety radius (see section XI, “Mitigation”, above). When mammals are detected within or about to enter the designated safety radii, the airguns will be shut down immediately. The observer(s) will continue to maintain watch to determine when the animal is outside the safety radius. Airgun operations will not resume until the animal is outside the safety radius.

The vessel-based monitoring will provide data required to estimate the numbers of marine mammals exposed to various received sound levels, to document any apparent disturbance reactions, and thus to estimate the numbers of mammals potentially “taken” by harassment. It will also provide the information needed in order to shut down the airguns at times when mammals are present in or near the safety zone. When a mammal sighting is made, the following information about the sighting will be recorded:

1. Species, group size, age/size/sex categories (if determinable), behavior when first sighted and after initial sighting, heading (if consistent), bearing and distance from seismic vessel, sighting cue, apparent reaction to seismic vessel (e.g., none, avoidance, approach, paralleling, etc.), and behavioral pace.
2. Time, location, heading, speed, activity of the vessel (shooting or not), sea state, visibility, cloud cover, and sun glare.

The data listed under (2) will also be recorded at the start and end of each observation watch and during a watch, whenever there is a change in one or more of the variables. All mammal observations and airgun shutdowns will be recorded in a standardized format. At least three experienced marine mammal observers (with several years of marine mammal observation experience) will be on duty aboard the seismic vessel. The visual observation team will have enough personnel to field two sets of three visual observers for rotations, along with coordinators with acoustic monitoring and with the bridge and airgun operations.

Prior to the start of the project, the primary observers will participate in a one-day meeting and training or refresher course on the specific marine mammal monitoring procedures required for this project. The primary objectives of this session will include the following:

1. Review of the marine mammal monitoring and mitigation requirements and procedures,
2. Review of operation of specialized equipment (reticle binoculars, night vision devices),
3. Review of, and practice with, the data recording and data entry systems, including procedures for recording data on mammal sightings, seismic and monitoring operations, environmental conditions, data entry, and error checking,
4. Familiarization with reporting requirements that may need to be met during or immediately after the cruise.

This will take place on the Ewing on May 26, the day before the ship sails. Allen, Podesta, Quero, and Teloni will be primary observers and responsible for review and overseeing reporting.
Three observers will be on duty in shifts of duration no longer than 4 hours. Use of three simultaneous observers will increase the proportion of the marine mammals present near the source vessel that are detected. Bridge personnel additional to the dedicated marine mammal observers will also assist in detecting marine mammals and implementing mitigation requirements, and before the start of the seismic survey will be given instruction in how to do so. Results from the vessel-based observations will provide
1. The basis for real-time mitigation (airgun shutdown).
2. Information needed to estimate the number of marine mammals potentially taken by harassment, which must be reported to NMFS.
3. Data on the occurrence, distribution, and activities of marine mammals in the area where the seismic study is conducted.
4. Information to compare the distance and distribution of marine mammals relative to the source vessel at times with and without seismic activity.
5. Data on the behavior and movement patterns of marine mammals seen at times with and without seismic activity.

**Vessel-based Passive Acoustic Monitoring**
A towed hydrophone array will be deployed during the airgun measurements in the Gulf of Mexico. The array will be provided by WHOI as part of other studies being conducted by the Maurice Ewing during a separate cruise. The acoustical array will be monitored during airgun operations to detect, locate and identify marine mammals near the Maurice Ewing, insofar as this is possible via passive acoustic methods. The acoustical array will provide additional ability to detect, locate and identify marine mammals over and above that provided by visual observations. The acoustical data will be integrated, in real time, with the visual observations to ensure that marine mammals do not enter the 180 dB safety radius. Teloni will be responsible for communicating any relevant acoustic data to Podesta, who will be in contact with airgun operators.

**Outstanding tasks:**

<table>
<thead>
<tr>
<th>TAMU</th>
<th>1. Arrange for delivery of R2 and fuel tanks, also 2 cases of oil left over from 2002 Dtag cruise.</th>
</tr>
</thead>
<tbody>
<tr>
<td>IAGC</td>
<td>2. Provide prospective dates and locations of survey activity in the Northern Gulf</td>
</tr>
</tbody>
</table>