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ALVIN INSTRUMENTATION

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Woods Hole, Massachusetts

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by

W. M. Marquet

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TECHNICAL REPORT

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Scott C. Daubin, Department Chairman
Department of Ocean Engineering

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ALVIN Instrumentation

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THIS PAPER DESCRIBES the equipments used to establish the relative position of ALVIN from her mother ship, the R/V LULU. Operating procedures used at sea are also discussed.

A recent review within the Deep Submergence Research Vehicle Program at WHOI established a set of conclusions and guidelines, for internal use, governing the ALVIN locating equipments and procedures. Our guidelines include, in part, the following:

a) Both surfaced and submerged ALVIN locating systems are required. Priority will be given to the submerged systems.
b) The submerged tracking system should have a reliable range of at least 3000 yards. More is obviously preferred. Five nautical miles is viewed as a comfortable margin.
c) The submerged tracking system should be sufficiently secure that tracking can be maintained after any single equipment or power failure aboard either ALVIN or LULU.
d) The tracking system must answer the obvious question of which way should LULU steam to close ALVIN for recovery. Direct indications are preferable to those which must be deduced or calculated.
e) Built-in blunder-checking features are desirable.
f) The responsibility of tracking ALVIN when submerged shall be held by the Surface Controller aboard LULU, who in turn must be a qualified ALVIN pilot.
g) Loss of submerged communication is sufficient cause to abort a dive. It is understood that ALVIN will surface if her UQC becomes inoperative or if she loses contact with LULU (who is equipped with two UWC's) for more than half an hour.

The R/V LULU is equipped with a U.S. Navy provided, five-foot JT Line Hydrophone. This hydrophone is housed in a WHOI designed baffle and horizontally mounted on a tower which is lowered between the two hulls of LULU. The hydrophone is remotely trainable from the Surface Controller's station on the bridge. To obtain a bearing to ALVIN, the Surface Controller will, via the UQC, request CW. The ALVIN pilot switches his UQC to CW and holds the key down for 20 seconds. The Surface Controller sets his tunable amplifier to 10.0 kHz and by rotating the line hydrophone, peaks the 10-kHz signal being received. Immediately after the bearing is read a check is made at the determined bearing, plus 180 degrees. The air-filled baffle behind the hydrophone provides sufficient signal reduction that a clear indication of the bearing to ALVIN may be obtained. The horizontal beam pattern of the line hydrophone at 10.0 kHz is approximately five degrees at the −3 dB points. The directivity gain at 10 kHz is 13 dB. The 100-acoustic-watt level of ALVIN UQC makes this system suitable for use at ranges in excess of five nautical miles. The key information of which way to steer to close ALVIN is obtained directly.

The slant range between ALVIN and LULU is sometimes determined by using the UQC's in the voice mode. After requesting a range check to alert the ALVIN pilot, the Surface Controller begins a one-second-interval countdown: "5-4-3-2-1-MARK." By following the rhythm of the counts on his watch, the ALVIN pilot transmits the word "MARK" one second after he hears the "one" of the countdown. The Surface Controller records, using a stopwatch, the elapsed time between the two "marks." The time interval is converted to range with the aid of a graph. Stopwatches with a hand that makes a full sweep in 10 seconds are used aboard ALVIN and LULU for voice ranging. Normally three ranges are averaged. While very elemental, voice ranging has proven to be very valuable as a check on other systems, particularly under poor acoustic transmission conditions, and when at very great ranges. Voice ranging by itself does not constitute an effective vehicle locating system since a determination of the direction to the submersible can be determined only after many surface stations have been taken.

A special WHOI-designed-and-constructed tracking pinger has recently been installed on ALVIN. This pinger transmits a 20-ms, 4.00-kHz, 10-acoustic watt, pulse every two seconds. The pinger is controlled by an internal clock that has a drift of less than 1 ms per day. The battery powered pinger is attached to the pressure hull and remains fully operative in the extreme emergency condition of the pilot releasing the buoyant pressure hull from the rest of the vehicle. The 4.0-kHz signals transmitted from ALVIN are received on LULU and can be used to obtain the relative bearing to ALVIN, the opening or closing rate between LULU and ALVIN, and a direct reading of the slant range to ALVIN.

The relative bearing to the ALVIN pinger is obtained with the trainable-line hydrophone previously described. At 4.0-kHz the hydrophone has a horizontal beam pattern of approximately 13 degrees at the −3 dB points. The directivity gain at 4 kHz is 9 dB. Useful signals at slant ranges of 3000 yards have been obtained using a broadly tuned receiver. When a better receiver is installed, it is expected that much greater ranges will be obtained.

The opening or closing rate between LULU and ALVIN is obtained by printing the received 4-kHz signals from ALVIN on a graphic recorder operating at one sweep per second. By watching the slope of the recording, the changes in relative slant range may be quickly observed. This feature permits a rapid blunder-preventing check if LULU inadvertently steams away from, instead of toward, ALVIN for recovery. Additionally, in the event of the failure of the direction-determining-line hydrophone system, the range-rate presentation permits homing-in on ALVIN. This can be done by following any closure course until the rate goes to zero, then making a 90-degree turn to drive toward ALVIN. If the turn is made in the wrong direction, the relative ranges will start to increase instead of decrease. If this happens a 180° turn is ordered. The process is repeated until closure rates can no longer be obtained. This "boxing-in" technique has been used at WHOI to close submerged markers and has proven to be both workable and reliable. With this technique only a single omnidirectional hydrophone is needed for closure on a submerged object when it is equipped with a suitable pinger.

The one-way acoustic travel time between ALVIN and LULU may be read directly as follows: The 4-kHz clock pinger on ALVIN is turned on before ALVIN leaves LULU. A graphic recording of the 4-kHz pulses from ALVIN and time ticks from WWV, or a local time standard, is started and maintained. The time intervals obtained during the dive, corrected for the initial zero-range time interval, may be converted to slant range. If one-second local-time standard ticks are used, the lane width before ambiguity is 1600 yards (assuming C=4800 fps). This last utilization of the clock-controlled pinger on ALVIN has been successfully demonstrated but is not yet routinely operational. The pinger on ALVIN has performed without failure. The problems encountered have been assembling reliable surface readout equipments.

The ALVIN UQC has a modification to provide a transponding mode. When this mode is selected, normal voice receiving capabilities are maintained. If a moderate-duration, high-level 8.887-kHz pulse is received, the UQC will automatically transmit a single 10.0-kHz reply and then automatically switch back to the transponder/voice listening mode.

A UQC aboard LULU contains the modifications to interrogate the ALVIN UQC and receive the 10.0-kHz reply. LULU's UQC automatically starts and stops a time-interval counter which then displays the round-trip travel time. The sequence is initiated by the Surface Controller. By using the line hydrophone to listen to several 10-kHz replies, the bearing to ALVIN may be updated without the active participation of the ALVIN pilot.

ALVIN also carries a separate tracking transponder. When interrogated at 8.087-kHz, this unit will reply with a five-second train of 20-kHz pulses. The train consists of 15-ms pulses at 200-ms intervals. The transponder has a source level of 90+ dB/microbar/yard. LULU has two means of interrogating this transponder, a UQC modified to transmit its carrier frequency and a separate, manually keyed, interrogator.

The rotatable-line hydrophone on LULU is used to receive the train of 20-kHz reply pulses. If five seconds is insufficient to obtain a bearing to ALVIN, the transponder is re-interrogated. At 20-kHz, the five-foot-line hydrophone has a horizontal beam pattern of approximately two and one half degrees at the −3 dB points. At 20-kHz, the directivity gain is 16 dB.

The results that have been obtained with the two transponders on ALVIN have been only partially successful. Both work well at short ranges, but neither has worked well at ranges of 3000 yards. The primary problem is associated with the reliable triggering of the transponders when mounted on ALVIN. It is suspected that the cause of the problem is high vehicle noise. The self noise of ALVIN has not been quantitatively established, but it is known to be high. This is particularly true when the right-angle-gear driven, higher-rpm, side propellers are operating.

The equipment installed on LULU which could be used in searching for ALVIN on the surface includes a long-range radar and a radio direction finder.

For long horizontal tracking ranges to be maintained, the vehicle being tracked must be below the acoustic shadow zones often encountered. A surface controller and vehicle pilot should know the predicted shadow-zoning conditions in the area the submersible is working. If near the end of a dive there is a large horizontal separation between the DRV and the tracking ship, it is very desirable to close the DRV before she begins her ascent. It is not difficult to visualize conditions where it would even be desirable to request the DRV to stay deep (assuming she could safely do so), until the mother ship could regain a favorable recovery position. Failure to do this could result in losing all acoustic contact with the DRV during her ascent.

During a typical ALVIN dive, the R/V LULU maintains a position at a horizontal range approximately equal to the depth of ALVIN. This displacement is required because the rotatable, directional listening hydrophone on LULU is mounted horizontally and too steep a depression angle to ALVIN degrades the relative-bearing-angle determining capability. When ALVIN is operating on a slope, it has been found best for LULU to stay on the downhill side of ALVIN. This tends to minimize the conditions where the acoustic path between the two is blocked by topography.

Preparations for recovery are started as soon as ALVIN begins her ascent. During her ascent, ALVIN periodically reports her depth via the UQC. With this information and the slant range and bearings taken from LULU a course is maintained to close ALVIN. When ALVIN starts her ascent a CTFM transponder is lowered on a short line from LULU. When ALVIN reaches a depth of approximately 300 meters she begins searching for the transponder using her CTFM sonar. When ALVIN acquires the transponder she reports its ranges and bearing to LULU via the UQC. This is compared with the ranges and bearings to ALVIN taken from LULU. Assuming that a reasonable check is obtained, ALVIN ascends to approximately 30 meters and stops. The relative ranges and bearings are again checked. LULU makes a visual and radar search of the area ALVIN is known to be in. Simultaneously, ALVIN makes her own visual and sonar appraisal of the area overhead. When the projected surfacing area is judged to be clear by the Surface Controller, ALVIN is given permission to surface. A typical dive will end with ALVIN surfacing 200 to 400 yards on either the port or starboard side of LULU. When ALVIN surfaces, radio contact is immediately established and an auxiliary craft is dispatched, with swimmers aboard, to standby the surfaced vehicle.

ALVIN is a team effort of which the author is a member. This paper reports the collective effort of this team which is sponsored by the Office of Naval Research.

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3. Navigation

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