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[redacted]

NRL Memorandum Report 3025
Copy No. 117

A Review of NIDAR
[Unclassified Title]

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Radar Division

April 1975

NAVAL RESEARCH LABORATORY
Washington, D.C.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NRL Memorandum Report 3025	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A REVIEW OF NIDAR [Unclassified Title] A RADAR METHOD FOR THE DETECTION OF SUBMERGED SUBMARINES [[redacted] Title]		5. TYPE OF REPORT & PERIOD COVERED An exploratory study. 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Merrill I. Skolnik		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Research Laboratory Washington, D.C. 20375		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS N/A
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Department of the Navy Arlington, VA 22217		12. REPORT DATE April 1975 13. NUMBER OF PAGES 23
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) [redacted] 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE GDS-1983

16. DISTRIBUTION STATEMENT (of this Report)

None.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Radar
ASW
NIDAR
Submarine detection
Bernoulli hump
Atmospheric turbulence
Convective cells

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

([redacted]) Radar detections of submerged submarines have been reported sporadically from the Fleet ever since World War II. Under the project name of NIDAR, this was investigated by Destroyer Development Group Two from 1956 to 1959. Although the participants in NIDAR believed they successfully detected submerged submarines, their results were generally treated with skepticism by the scientific community. The reported results of NIDAR are briefly reviewed in this report and it is concluded that there was sufficient evidence to indicate that submarine detections were

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20. Abstract (Continued)

made under certain conditions. A sample of these observations are summarized. An explanation of the effect is offered which depends on the reported radar observations being like those due to reflections from elevated convective cells. These cells, it is speculated, might be due to the disturbance to the water-vapor gradient, just above the surface, caused by the passage of the Bernoulli hump generated by the passage of the submarine. Turbulent buoyant cells are formed which rise and are detectable by radar.

CONTENTS

A REVIEW OF NIDAR
[Unclassified Title]

A RADAR METHOD FOR THE DETECTION OF SUBMERGED SUBMARINES
[[redacted] Title]

1. INTRODUCTION

([redacted]) There have been continuing reports over the years from the operating units of the Fleet, both surface and air, regarding the detection by radar of submerged submarines. The first documented report of a radar sighting of a submerged submarine by a destroyer radar dates back to 1956[1], but "Spooks" on the radar scope in the vicinity of submerged submarines were reported back to World War II[2]. Since 1956 there have been a significant number of reports of detections by a variety of microwave radars. These reports, for the most part, have not been given much credibility outside of those who participated directly. In fact, some critics put them in the same category as Unidentified Flying Objects. This could be an unfortunate mistake. The purpose of this memorandum is to suggest that there have indeed been valid radar detections of submerged submarines, to summarize the nature of the reported observations, to offer a model for the radar observations, and to suggest a possible mechanism for describing the effect. This memorandum represents but a cursory study of the problem. The study has been sufficient, however, to indicate that completely submerged submarines are quite likely to be detectable by radar. Such a conclusion could have significant effect on our ASW and SSBN operations. The evidence is sufficient enough and the implications significant enough that the question of radar detection of submerged submarines cannot be lightly dismissed. It is a subject that bears wide discussion by all interested parties.

([redacted]) This is an old subject and it can be asked why it should be resurrected now. There are three basic reasons for doing so. First, reports of submerged submarine detections by radar continue to appear, usually by word of mouth. Second, an examination of previous documentation on the subject clearly indicates there is a submarine-related effect, that it was believed by many creditable witnesses to be a real effect, and that official interest in this subject died prematurely probably because of a lack of understanding. Third, there has been in recent years new knowledge of radar effects in the atmosphere that can contribute to the understanding of this phenomenon. This information was not known when the interest in these radar detections was at its highest, about fifteen years ago.

([redacted]) The bulk of the documented radar observations of submerged submarines was obtained by the Atlantic Fleet Destroyer Force, especially

Note: Manuscript submitted March 14, 1975.

[redacted] [redacted]

Destroyer Development Group Two and is reported under the project name of NIDAR. The NIDAR observations extend from March 1956 to February 1959. After that time the name of the project was changed to CUTWATER and it left the Des Group Two. In so doing, the original work was abandoned. All of the experimental findings in this report relating to the detection of submerged submarines by radar are based on the available NIDAR reports as documented in the References.

2. NIDAR

([redacted]) The February, 1959 NIDAR historical review[1] and the April, 1968 Naval War College Thesis[3] form the basis for the following summary of NIDAR radar observations:

1) Most of the observations were obtained with the Mk 25 and Mk 35 X-band gunfire control radars (Appendix lists their characteristics). Observations were also obtained with the SPS-10 C-band surface-search radar and the SPS-28 VHF air-search radar.

2) Radar detections were reported in many regions of the world, including Narragansett Bay, Virginia Capes, Guantanamo Bay, the Straits of Gibralter, and in the Mediterranean.

3) Positive indications were reported on all types of U. S. submarines.

4) Successful results were reported at various depths down to 700 ft. Changes in depth had little effect.

5) It seems that increased signal strength was obtained with increasing target speed.

6) There were no indications that the results were correlated with target course. The presence of a surface ship or an aircraft within 20-30 degrees of the submarine's bearing was found to interfere with the NIDAR response.

7) Positive indications have been reported under a variety of conditions varying from calm seas to sea state 5, and from clear skies to fog and solid overcast. There was no positive correlation with changes in sea state. However, rain and low clouds seriously affect NIDAR operation.

8) The radar operators reported that on the E-scope (Range-Height Indicator) the target had a cloud-like effect. The target width appeared to be greater than 500 yards and was much larger in size than would normally be received from a surfaced target.

[redacted] [redacted]

9) Detection ranges were as great as 32,000 yards.

10) Antenna elevations of 6 and 8 degrees produced the strongest signals (for ranges of 4-6 kyds.).

11) The target bearings drifted as if around an inverted conical field over the submarine. The size of the return appeared smallest near the surface and larger above the surface.

12) The effect has been described as positive, but sporadic and not reliably reproducible on demand for demonstration. Tracking up to two hours was reported.

13) When the ranges were close enough for a sonar contact, there was agreement between the radar and sonar information.

14) Success was reported in using NIDAR radar tracking in operations, to aid in classification, to assist in holding contact, and to regain contact, to augment spiral search plans, to set up barriers and to adjust the search front on approach to a datum.

([redacted]) As an example of the kind of results that were reported, the following information is extracted from a report of an experiment carried out by DESDEVGRU 2 in January 1959.[5]

([redacted]) A Mk 25 X-band gunfire control radar was used aboard the USS GLENNON (DD 840) on 15 January 1959 to track the USS CREVALLE (SS 291). The destroyer and the submarine both sailed on a 000T course with a nominal separation of 9,600 yards. The actual DR track of the destroyer is shown on the left hand side of Fig. 1. (Figures 1-7 were taken from Reference 5). Note that the destroyer was forced to change course due to the presence of another surface vessel. The submarine also made a course change. The submarine was at a keel depth of 150 feet and had a speed of 2 knots. The destroyer maintained a speed of 5 knots. The sea state was 2 and the wind was from 210° at 17 knots.

([redacted]) The report summarizes its results as follows:

"1. During a 1.5-hour period, some sort of return was usually discernible on the remote A-scope in the general direction and at the general range of the submerged submarine.

2. On the whole, the ranges were slightly less than those predicted by the DR plot.

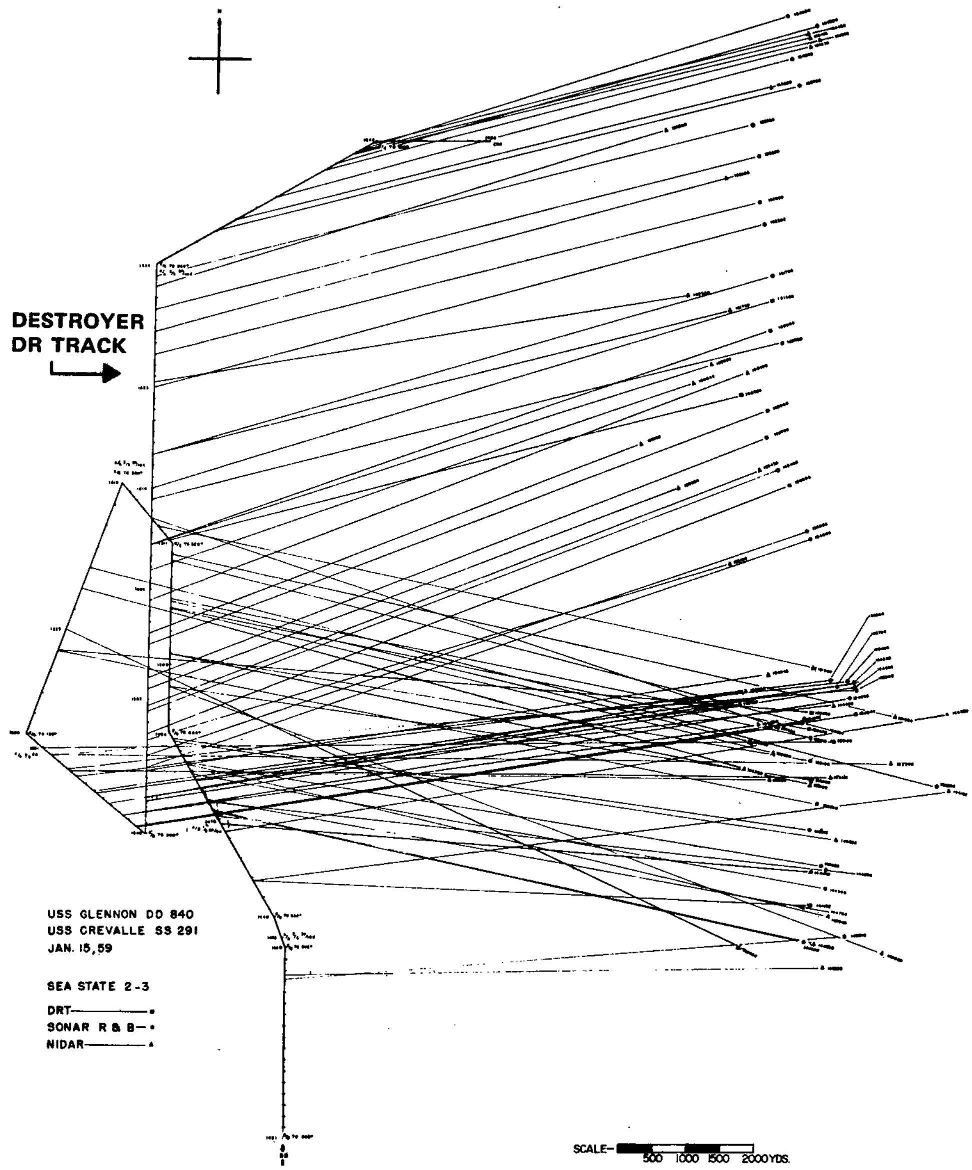
3. This return was held even though the destroyer itself performed an intricate maneuver and the submarine left its straight-line course (unknown to the destroyer).

4. At times multiple targets appeared and the operator was unable to determine the cause for this multiplicity."

([redacted]) The position data is shown in Fig. 1. NIDAR (radar) positions are shown by the triangles, sonar positions by the circles, and the submarine DRT by the squares. A few reports were also obtained from the SPS-10, a C-band radar. The numbers on the plot are the times. (Some of the details have been lost in the reproduction of this figure.) The correlation between the NIDAR radar range and bearing (ordinate) with the sonar range and bearing (abscissa) is shown in Figs. 2 and 3. At the end of the run (at 1646:00) the submarine raised its periscope to mark its position. It was detected by both the Mark 25 and the AN/SPS-10 surface search radars. Its location on Fig. 1 at that time is at the bottom of the D in NIDAR at the top right hand corner of the figure. A-scope presentations are shown in Figs. 4-7. The bottom trace is that of the normal Mark 25 external gated video. (The negative deflection is the range gate.) The upper trace shows the video output of the SLR-2 receiver that was connected to the output of the Mark 25 IF. The SLR-2 was connected to the IF output of the Mk 25 receiver. Figure 7 shows the type of multiple returns which were sometimes observed.

([redacted]) In order to ascertain whether the received signals were independent of the destroyer itself the power was turned off and on and the antenna azimuth and elevation were changed. It is stated that "When these three factors were changed the return signal should disappear and it is a true one; i.e., <u>the return is fixed in space above or in the vicinity of the submerged submarine</u>." (underline added) This is perhaps the most puzzling characteristic of the NIDAR phenomenon. The radar echo appears to originate from <u>above the surface</u>. <u>This observation is consistently reported throughout the available documents on NIDAR</u>. Figure 8, taken from another NIDAR document[4,6] unmistakably illustrates this fact. It is an important characteristic of the NIDAR observations and one which must be accounted for in any explanation or theory. This strange and unexpected observation is probably a major reason why NIDAR has been suspect. It is hard to imagine how a submerged submarine can give rise to an effect one or two thousand feet above the surface. It is indeed understandable why there might be skepticism. Nevertheless, it is an experimental observation reported on many occasions. It cannot be ignored simply because there is no satisfactory theory to explain how it occurred. (Later in this memo this problem will be addressed further.)

([redacted]) The above has been but a sample of the many similar observations that have been reported. There is certainly enough evidence to state that there is a radar observable effect associated with submerged submarines that is not on the surface.



(●) Fig. 1 — Range and bearing data

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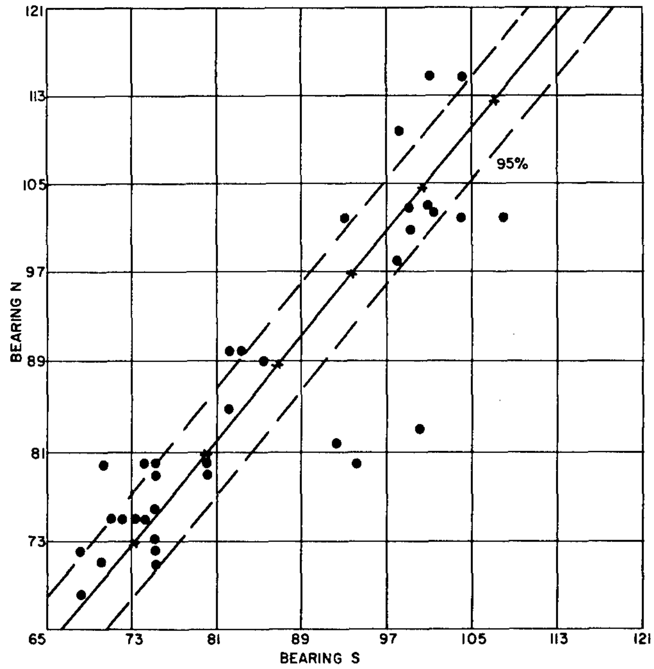
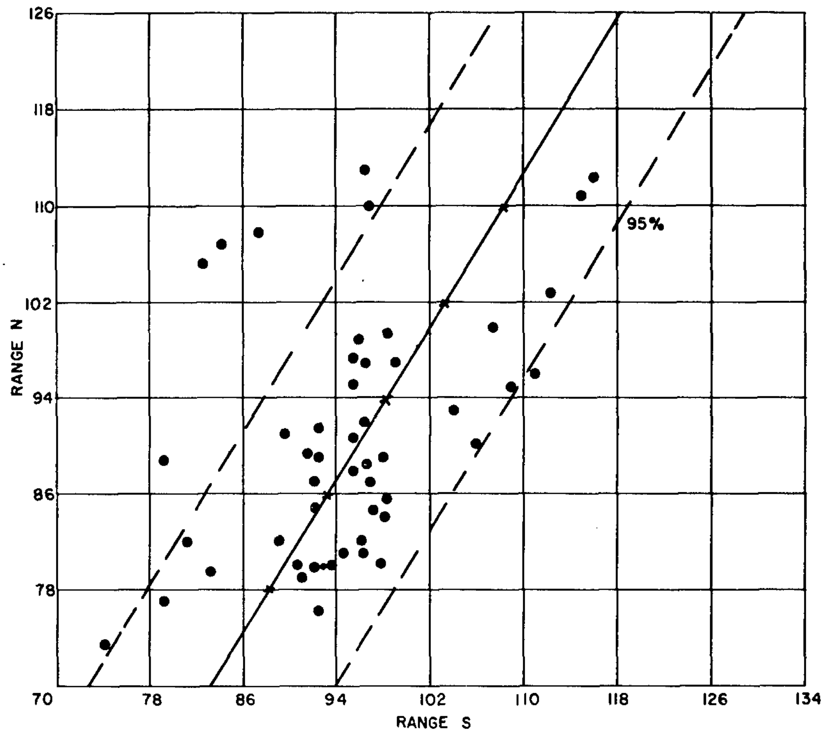


([redacted]) Fig. 2 — Bearing scatter diagram



([redacted]) Fig. 3 — Range scatter diagram

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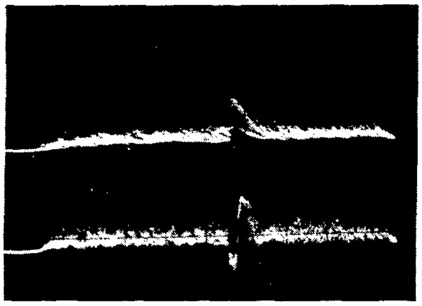
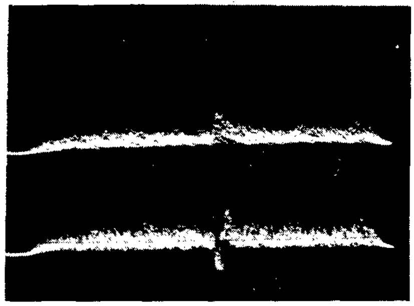
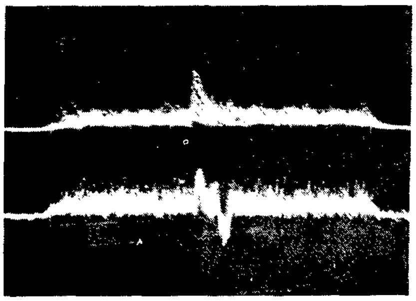


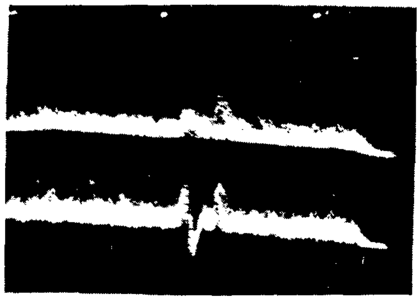
([redacted]) Fig. 4 — Typical A-scope presentation



([redacted]) Fig. 5 — Typical A-scope presentation



([redacted]) Fig. 6 — A-scope presentation — range gate off return



([redacted]) Fig. 7 — A-scope presentation — multiple returns

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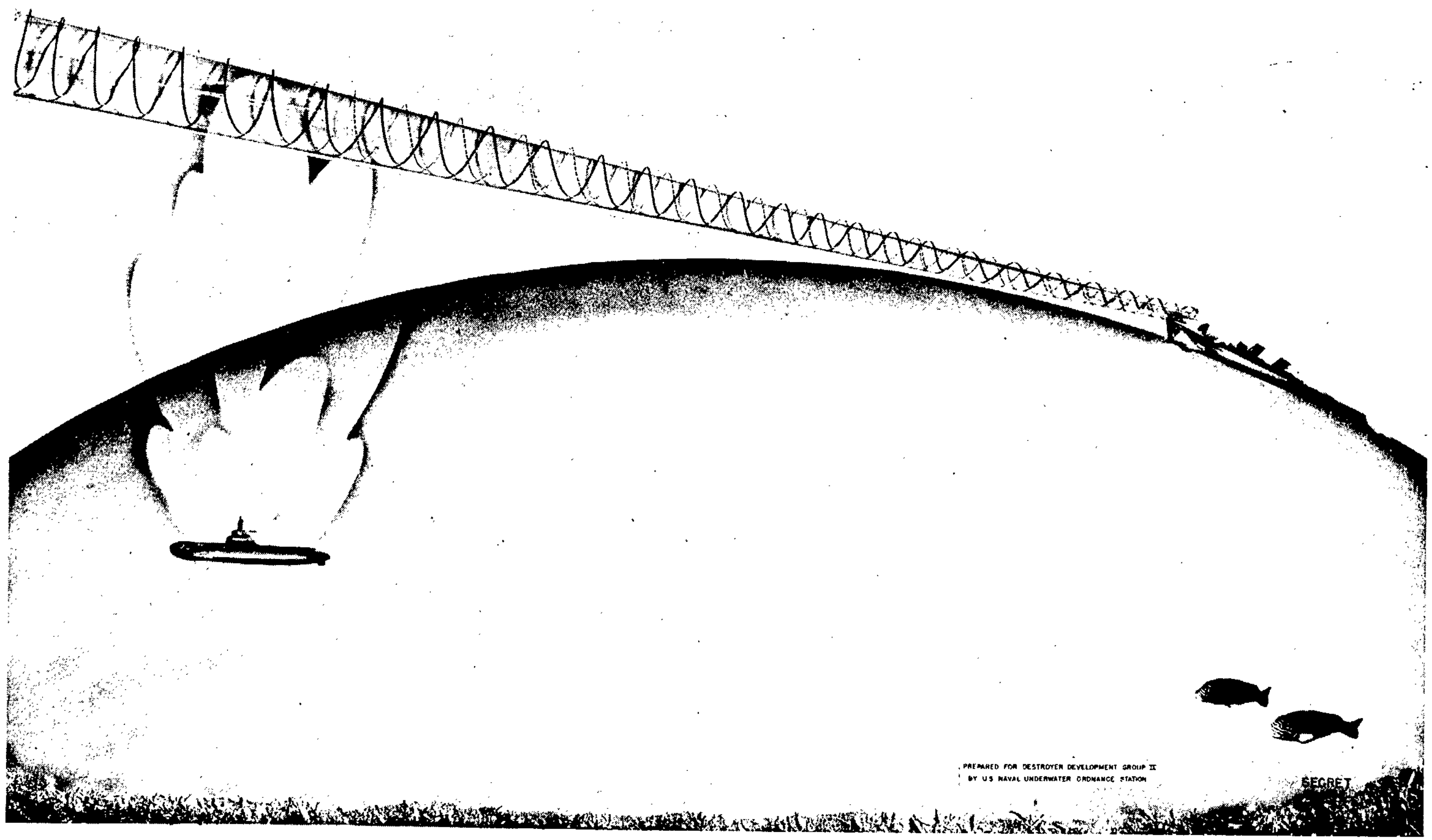
NIDAR



([redacted]) Figure 8

3. ATTEMPTS TO EXPLAIN NIDAR

([redacted]) There have been several attempts to explain NIDAR. However, the theories proposed generally have been refuted on basic grounds. In refuting these theories, the fact that observations were made at all seems to have been refuted as well. It was a case of "throwing out the baby with the wash water." It was apparently easy to disregard the reported observations since they were far different from what was normally expected. Submarines were below the surface so it was "inconceivable" that the radar could be detecting an effect well above the surface. Yet the fact that the NIDAR target is above the surface cannot be ignored. Also, the lack of a satisfactory theory is no justification to declare the experimental observations false. Another difficulty in establishing the validity of the effect has been its sporadic nature.

([redacted]) NIDAR stands for Nuclear Induction Detection and Ranging. Its name was derived from one of the proposed theories. At that time there was much interest in the subject of nuclear induction resonances in the microwave region of the electromagnetic spectrum and it is easy to understand why there was an attempt to apply this theory to this phenomenon. From the existing information it is not clear just what the details of the theory were, other than it apparently dealt with nuclear induction spins of the atmosphere and the magnetic field of the submarine, as well as the earth's magnetic field. It is probably not too important to understand this theory since a November 1958 report[7] states that "everybody admits -- even the inventor of the word by now -- that nuclear induction spin echoes have nothing to do with these radar returns." Many other mechanisms have been proposed[2,3], but none seem to have met with any favor.

4. CLEAR AIR TURBULENCE MODEL

([redacted]) Since the NIDAR observations over fifteen years ago, there has been considerable work in other areas that was not known to those experimenters. The chief area of interest that was not known is the work on the radar detection of atmospheric turbulence, conducted during the last five years. The reported observations of NIDAR are distinctly similar to the reported observations of the radar detections of clear air turbulence, in particular the clear air turbulence known as convective cells[8,9]. The radar echoes from naturally occurring convective cells could account for the size of the NIDAR echoes, their shape, duration, the height of the echo above the surface, the errors in radar position, the drift of the echo, and the sporadic nature of the echo. There is no doubt in the writer's mind regarding the close relationship between the radar observations of the convective cell and the reported radar observations of NIDAR. There are no other radar targets whose properties are as close to those of the NIDAR observations

[redacted]

as is the convective cell, and this includes targets such as aircraft, ships, birds, insects, sea clutter, clouds, weather, chaff, ionized media, dielectric objects, periscopes, Kelvin wakes, surface effects, or whatever.

([redacted]) If the NIDAR echo is from something like that of a convective cell, the connection between it and the submerged submarine must be explained. The writer cannot provide a quantitative theoretical explanation for this effect, but a qualitative model can be hypothesized which is plausible and which is consistent with the known effects produced by submarines and what is known about the formation of convective cells.

([redacted]) We shall work backwards in constructing the model. That is, we start with the presence of a convective cell and ask how is it generated by the submarine. There will be an intermediary stage in the process, as provided by the sea-air interface.

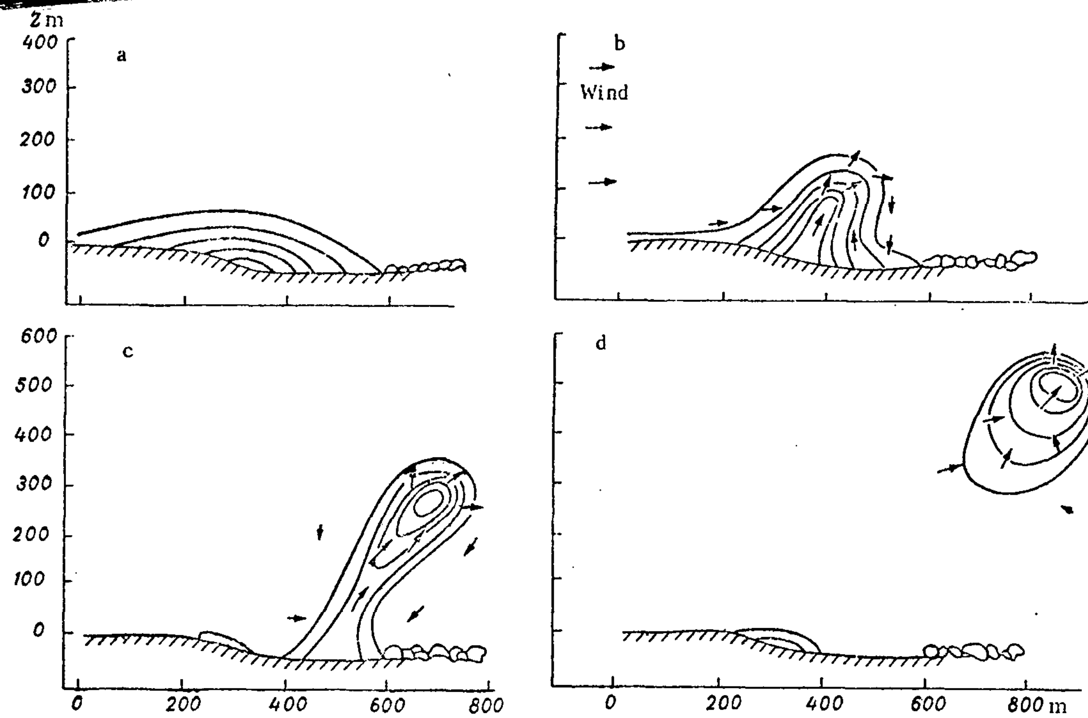
(U) Convective cells over land are often formed by the localized heating of the surface. The heating of the air above the surface results in the warmer air being less dense than its surroundings. If there is a wind shear there will be a mixing of air from one height to another. The hotter, lighter parcels of air that find themselves at a lower height due to the effects of turbulent mixing are in the midst of a denser (cooler) environment. Thus they will be buoyant and will rise. These parcels of air are small near the surface, but grow as they rise in altitude and act like bubbles. Several bubbles may merge to form a larger one. The cell diameter near the ground might be several meters in diameter. At an altitude of one km, the diameter might be from 0.5 to 2 km. The cells rise to a height where they are no longer buoyant or where the temperature results in condensation of the moisture.

(U) When the source of the surface heat is constant, the buoyant parcels might rise in the form of a jet, or convective column. If the wind near the ground increases, the convective jets are first inclined in the direction of the wind and then are separated from the ground to become a freely floating cell, or bubble.

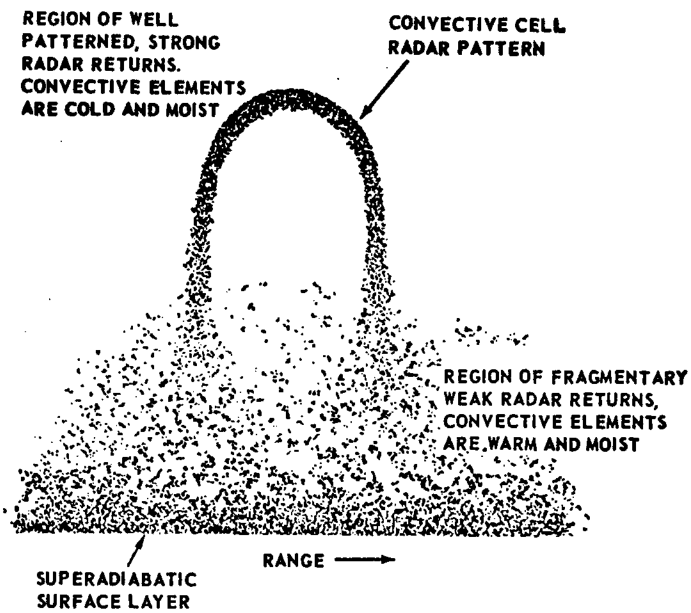
(U) An example of how the bubble, or thermal, might be formed is shown in Fig. 9, taken from Ref. 10. Figure 10, from Ref. 9, shows a sketch of a convective cell as derived from radar observations.

(U) From investigations with gliders, one cell is formed every 5 to 15 minutes above sections of heated ground of area about 2 sq. km.[10] Radar measurements of convective cells from Wallops Island indicate they can have a life of 15 to 20 minutes. (These two observations from two different sources might not be related.)

[redacted]



(U) Fig. 9 — Ascent of a thermal in a light wind (after Woodward). From Ref. 10.



(U) Fig. 10 — Sketch showing convective cell radar pattern in vertical section ([redacted]) The reported descriptions of the target behavior in NIDAR, the descriptions of the radar echo from convective cells, as well as the atmospheric physics literature relating to convective cells all give credence to the hypothesis that the target observed in NIDAR was like a convective cell. This might be hard to accept because (1) the convective cell is elevated and (2) a source of "heat" that gives rise to a cell is not identified in the submarine problem. The first objection can be dismissed since the radar reports consistently mention an elevated target. It is an experimental fact. The second objection is indeed a valid one since there is no obvious manner by which thermal energy in sufficient quantity can be transferred from the submarine to the surface. However, thermal sources are not needed for convection and for convective cells.[11] Over the ocean, the moisture gradients could fulfill the same role as thermal gradients.

(U) It is well known that there exists over the surface of the ocean a strong gradient of moisture due to evaporation. It extends 10 to 20 m above the surface and is known to give rise to super-refraction and extended propagation due to trapping of the electromagnetic waves[12]. This is known as the evaporative duct. Moist air is lighter than dry air, just as heated air is lighter than cool air. If a wind shear exists at the surface of the water, turbulent mixing can occur with the result that less dense parcels of moist air will find themselves in the presence of heavier dry air and, being buoyant, they will rise just as if they were caused by temperature gradients.

([redacted]) Convective cells, which are a form of clear air turbulence, produced in this manner by a submarine would be different than thermal jets or convective cells over land. Their buoyancy would be due to the moisture content rather than due to differences in temperature. Moisture gradients result in greater radar reflectivity than do thermal gradients. Another significant difference is that the source (the submarine) generating the buoyancy in the atmosphere is in motion, as contrasted to stationary sources over land.

(U) In the absence of a submarine there is a continual interaction between the wind and the water. This is what gives rise to waves. The air-sea interaction has been the subject of much study, primarily to determine how waves are generated. Just as wind gives rise to waves, so does a wave give rise to a wind.[13-15] In one set of experiments[13] in a wave tank with mechanically generated water waves it was found that smoke introduced into the air above the waves drifted slowly in the direction of wave propagation over the troughs and took a quick jump up, backwards, and over the wave crests. There was "clear evidence of organized air motion due to the waves that is detectable at an elevation seven times the wave height." In experiments reported by the Russians[14], a similar effect was observed. It was found that near the water, the turbulent momentum flux was directed from the water to the air. (That there should be a momentum transfer follows from the continuity of the Reynolds stress at the surface.) In the near-water air laye , there is an orbital motion of air particles that is similar to the motion of water particles in a wave. Thus a wave passing through the water gives rise to a motion in the air above it that could conceivably be the mechanism whereby the air is mixed and convection takes place. Next, the mechanism by which the submarine can generate a wave needs to be examined.

[redacted] In order for the submarine to affect the atmosphere over the sea surface, it is reasonable to expect that there be a pronounced surface effect caused by the submerged submarine. There are at least four effects that a submarine can cause:

1. Internal waves - These are generated by the passage of a submarine through the water. Their effect on the surface would appear relatively far behind the submarine. Although there has been much work on this subject, the writer is not aware of any significant results which would indicate that submarine-generated internal waves can produce a detectable surface effect. Slicks caused by natural internal waves can be detected by properly designed radar, but there have never been reports of radar observations of internal waves generated by submerged submarines. Until more encouraging information is available, a more positive surface effect should be sought.

2. Kelvin Wake - The production of a Kelvin wake from a submerged submarine is well known. It can be seen visually as well as by high resolution microwave imaging radar. It has also been detected by HF radar. Under certain conditions the Kelvin wake is a fine mechanism for the radar detection of submerged submarines. However, the amplitude of the Kelvin waves decreases exponentially with increasing depth and decreasing speed. A slow moving boat or one too deep will not be detected. An analysis of the Kelvin wake effect indicates that detection of submarines below about 200 ft by this means is highly unlikely[16]. Since NIDAR detections have been made at greater depths, it does not seem too encouraging to expect that the Kelvin wake is the cause of a significant atmospheric disturbance. (The only reservation to this is that the wake is a two dimensional effect whereas the wave height is one dimensional. Restriction to the one-dimensional wave height might mask the effect that the large area encompassed by the wake might have on the atmosphere. This possibility, however, does not appear too promising.)

3. Centerline Wake - Both visual and high resolution radar observations indicate the presence of a turbulent wake trailing behind, along the centerline of the submarine's path. This is due to the

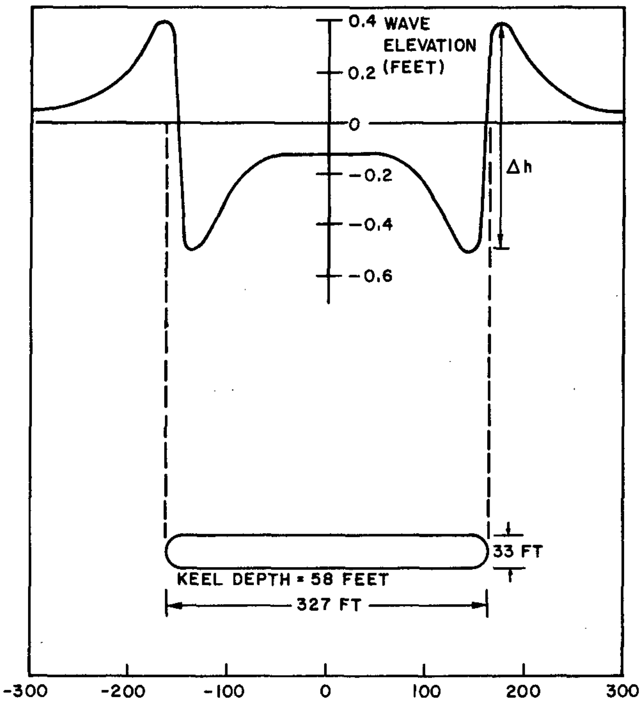
[redacted]

action of the propeller. Less seems to be known about it than about the Kelvin wake, but it cannot at this time be considered to be a suitable candidate for explaining this phenomenon.

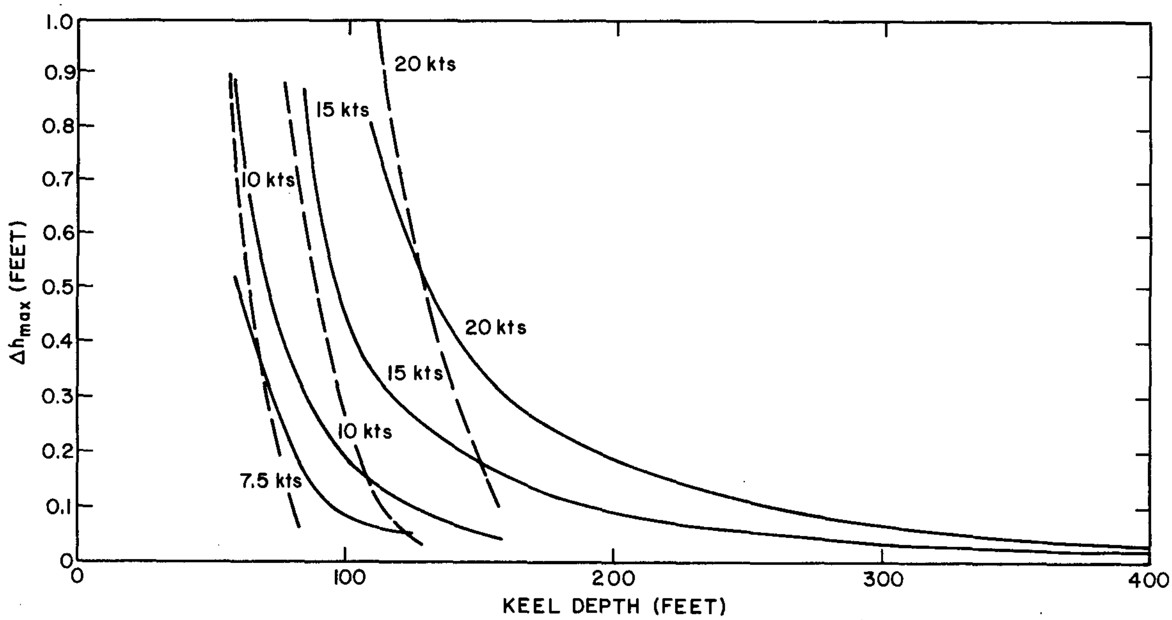
4. Bernoulli Hump - The pressure wave from a submerged body produces a pronounced disturbance of the surface just above the boat[17]. This has been called the local disturbance or the Bernoulli hump (although it is more of a depression rather than a hump). The pressure wave causes a disturbance that is a welling up of the water at the surface directly over the bow and the stern, and a depression in between. There is no appreciable time lag in the generation of this effect. The disturbance in the dimension transverse to the longitudinal axis of the submarine is almost as wide as the submarine is long. An example of the disturbance is shown in Fig. 11[18]. The variation with depth is shown in Fig. 12. There are two things of interest regarding the Bernoulli hump. First, the amplitude of the disturbance (solid curves of Fig. 12) does not fall off with depth as fast as does the Kelvin wake (dashed curves). Second, there is a considerable area of water surface that is disturbed. There exists more than just a displacement of the surface. Water flowing over an obstacle such as a submarine is forced to move faster since the streamlines are constricted[19]. This might be transferred to the air-water interface to cause a speedup of the water just above the submarine. Reports from observers in small craft above a submarine indicate a significant disturbance caused by the passage of the submarine. It has been observed visually that there seems to be a smoothing action of the surface just above the submarine[20]. The water appears black, as it might be if the normal wave structure on the surface of the sea were drastically smoothed. Although the phenomena associated with the surface effect caused by the pressure wave may not be fully understood, it appears to be a viable candidate for the type of disturbance that can give rise to an atmospheric effect and the convective cell.

([redacted]) Although the theory of the air-sea interaction due to submarine surface effects is not as fully developed as one might like, there is enough information to suggest a possible mechanism. In brief, the passage of a submerged submarine through the water creates a surface effect that disturbs the moisture-laden air above it. The surface effect that appears to be the most likely candidate is the Bernoulli hump, although the Kelvin wake or the surface penetration of internal waves cannot be fully eliminated as other possible mechanisms. The motion of the surface effect causes a mixing of the relatively strong moisture gradient that lies just above the surface. The mixing gives rise to buoyant parcels of moist air that ascend and form "clear air turbulence" in a manner similar to a thermal plume or a convective bubble that form over land. The location of the bubble, or convective

[redacted]



([redacted]) Fig. 11 — Profile of the Bernoulli hump due to a submerged body moving at a speed of 10 knots



([redacted]) Fig. 12 — Height of surface disturbance as a function of keel depth. The dashed curve is the regular wake height, and the solid curve is the local wave differential height.

[redacted]

cell, is affected by the direction and speed of the submarine and by the winds (which can vary significantly in direction and speed). The bubble rises until it comes to equilibrium with its surroundings. After 15 to 20 minutes it disappears. Other bubbles are formed at regular intervals to produce a near-continuous target effect. Because of the motion of the submarine and the winds, the location of the radar echo might not coincide with that of the submarine. Since the formation of a convective cell depends on the meteorological conditions and the sea conditions, it might not always be reproducible on demand. Finally, the scale sizes of the phenomenon are so large that it might be difficult to produce this effect in scaled laboratory experiments (i.e., the Reynolds numbers are too large to achieve in a laboratory-scale experiment).

([redacted]) The above model is offered as a plausible hypothesis for explaining the reported NIDAR observations. Much of it is based on qualitative arguments. The existing knowledge makes quantitative analysis difficult, yet it needs to be attempted. It might be completely incorrect, but it is a good place to begin. Nonacoustic ASW projects like NIDAR seem to suffer by "outlandish" theories that are grossly inconsistent with the facts of Nature. The present model, under further examination, might turn out as fitting this category. If it does, the accumulated experimental facts associated with NIDAR should not be discarded along with the theory, as unfortunately they seem to have in the past.

5. DISCUSSION

([redacted]) The overall impression on reviewing the existing documents on NIDAR is that the military personnel involved believed they had a positive effect that was useful for the detection of submerged submarines. It was recognized, however, to be sporadic and not always reproducible on demand. In 1959 the name of the project was changed from NIDAR to CUTWATER and responsibility for its further pursuit was assigned to the Naval Research Laboratory. NRL was skeptical about the NIDAR detections. They witnessed at-sea tests but concluded the operations were locking onto sea clutter rather than a valid target[21]. They diverted the program to the exploration of surface effects (primarily the Kelvin Wake) and periscope detection, using high resolution radar.

([redacted]) The writer is personally convinced that the reported observations of the NIDAR phenomenon are real and have not been fully exploited. Ship weapon control radars such as the Mk-92 (based on the Dutch M-20 series of radars) that will be on the PF are more powerful than the earlier Mk-25 radar used in NIDAR (see Appendix). It is predicted that reports of submarine detections will continue when the PF escorts are used in future ASW exercises. It should also be noted that the radars installed on Soviet BPK ships (large anti-submarine ships) are far larger than they need be for AAW, and would make fine radars for the detection of the NIDAR effect[22]. If they were not originally designed with that purpose in mind, it is quite likely that the Soviet Navy is receiving reports from their radar operators of strange submarine detections, just as our own Navy operators have reported. Since the Soviets have more of a vital interest in ASW than we do, it is reasonable to believe they might have exploited the NIDAR effect better than we have.

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Appendix

COMPARISON OF RADARS

PARAMETER	MK 92 SEARCH	MK 92 STIR	MK 68 SPG-53	MK 25 MOD 0	OWL SCREECH	HEAD LIGHTS
FREQUENCY	8900-9400	8900-9400	8300-9600	8500-9600	8020-8145	4930-6745
POWER:						
PEAK	1 MW	1 MW	250 KW	70 KW	250 KW	1 MW
AVERAGE	1 KW	1 KW	70 W			
ANTENNA SIZE	5' by 1.7'	7' DIAM	5'	5'	8'	11.5'
PULSE WIDTH	0.4 μSEC	0.75 μSEC	0.25 μSEC	0.25 μSEC	0.2-0.6 μSEC	0.4-0.7 sec
NOISE FIGURE	7.2 DB	9 DB	11 DB	16 DB		8 DB
POLARIZATION	HOR or CIR	HOR	VERT	VERT	45°	HOR and VERT
PULSE REP RATE	2500 HZ	1350 HZ	1000 HZ	1800-2200 HZ	1640-3150 HZ	1450-1725 HZ
BEAMWIDTH	1.4° by 4.7°	1.1°	1.6°	1.5°	1°	1°
ANTENNA GAIN	35 DB	40 DB	39 DB	38 DB	42 DB	45 DB

[redacted]