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U. S. NAVAL AIR DEVELOPMENT CENTER

JOHNSVILLE, PENNSYLVANIA

Anti-Submarine Warfare Laboratory

REPORT NO. NADC-AW-6383 31 JUL 1963

SUBMARINE WAKE DETECTION
FLIGHT TRIALS OF THE AN AAD-2 INFERRED
MAPPING SET IN A CESSNA 310-B AIRCRAFT (C)

PHASE REPORT
WEPTASK NO. RUDD/RCR/PCSI/PO01-06-02
(ATED Project AWC AW-43001)

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Anti-Submarine Warfare Laboratory

REPORT NO. NADC-AW-6303 SUBMARINE WAKE DETECTION, FLIGHT TRIALS OF THE AN/AAD-2 INFRARED MAPPING SET IN A CESSNA 310-B AIRCRAFT (C)

⑨ PHASE REPORT

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Ten overwater flight trials of the AN/AAD-2 infrared mapping set installed in a Cessna 310-B aircraft were performed from Sept 1960 to May 1961 to determine its capability for detecting surface effects produced by submarines. Night and day trials were conducted over waters of the eastern seaboard of northern U.S.A. Wakes generated by submarines operating on the surface and at keel depths of 55 (snorkel and/or periscope up), 80, 100, and 150 ft were recorded by the AN/AAD-2. (S)

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S U M M A R Y

TESTS AND RESULTS

From September 1960 to May 1961, 10 overwater flight trials of the AN/AAD-2 infrared mapping set installed in a Cessna 310-B aircraft were performed to determine its capability for detecting surface effects produced by submarines. Wakes generated by submarines operating on the surface and at keel depths of 55 (snorkel and/or periscope up), 80, 100, and 150 feet were recorded by the AN/AAD-2.

CONCLUSIONS

The value of a high-resolution, line-scanning, infrared mapping system for precise studies of submarine-generated thermal wakes has been demonstrated, and the near-photographic-quality thermal pictures obtainable with such a device should be of considerable value for target classification and oceanographic studies.

RECOMMENDATIONS

It is recommended that:

1. Studies of infrared mapping systems, ship and submarine wakes, and natural sea background patterns continue.
2. The possibility of correlating sonar propagation characteristics with the surface expression of bulk temperature variations in the sea, as recorded by an airborne infrared mapping device, should be investigated.
3. A fleet investigation of a high-resolution, line-scanning, infrared mapping system should be made for classification of ships at night, and for submarine wake detection, with particular attention to wakes generated by submarines on or near the surface before and after submergence.

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FLIGHT TRIALS

INTRODUCTION

Reference (a) directed the NAVAIRDEVGEN to develop techniques for detecting wakes of submerged submarines by use of small, lightweight, infrared equipments designed for installation in heavier-than-air craft. Reference (b) directed the NAVAIRDEVGEN to conduct studies, establish equipment characteristics, procure equipment, and conduct technical and flight evaluation of modified line-scan passive infrared surveillance systems for submerged submarine wake detection. Reference (c) enumerates and classifies wake phenomena from a theoretical point of view. Reference (d) outlines the NAVAIRDEVGEN experimental infrared wake detection program and gives preliminary results. As part of this experimental program, a number of already existing thermal mapping devices have been investigated. The purpose of this investigation was two-fold:

1. Actual experience with a variety of thermal mappers would aid in determining optimum system parameters for a submarine wake detection system.
2. If equipments already in existence proved successful after only minor modification, infrared wake detectors would become available to the fleet in a much shorter time than if a completely new development program were to be initiated.

Investigations of six thermal mapping devices have been made under the NAVAIRDEVGEN submarine wake detection program. Final results of investigations of the AN/AAS-4(XA-2), the AN/AAR-9(XA-2), the Reconofax Camera, the Infrared Antisubmarine Warfare Bomb Director Sight Unit, and the AN/AAR-13(XH-1) are given in references (d), (e), (f), (g), and (h). Partial results of the flight trials of the AN/AAD-2 are given in references (i), (j), and (k). This report describes the final results of the flight trials of the AN/AAD-2 infrared mapping set installed in the Cessna 310-B aircraft of HRB-Singer, Inc. under NAVAIRDEVGEN Contract N62269-1200. See figure 1.

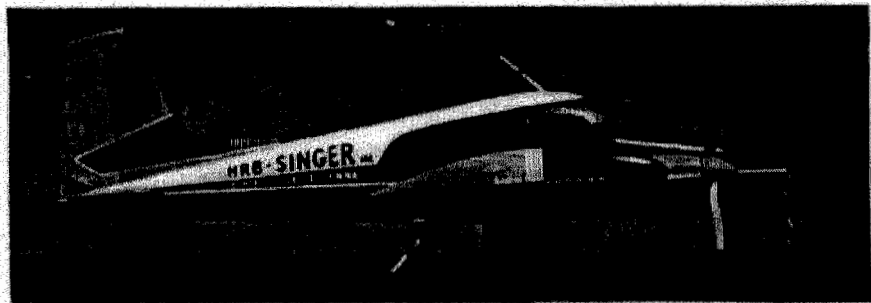


FIGURE 1 - Cessna 310-B Aircraft Used for Flight Trials of the AN/AAD-2

THE AN/AAD-2

The AN/AAD-2 is a small lightweight infrared mapping set developed by HRB-Singer, Inc. for the U. S. Army Electronic Proving Ground, Fort Huachuca, for use in drone aircraft. The scanner, optics, infrared detector, electronics, 70-mm film recorder, and 5-watt telemetering transmitter are all contained in a single 45-lb package. See figure 2. (The transmitter was not utilized for these flight trials.) The AN/AAD-2 is a relatively simple, single-detector, line-scan device that yields a continuous strip map on photographic film.

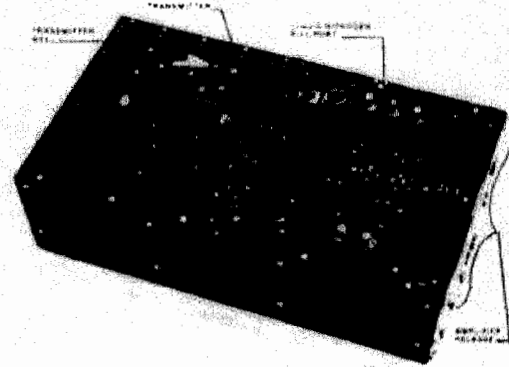


FIGURE 2 - AN/AAD-2 Scanner Unit

The operation of the basic system is illustrated in figure 3. All objects radiate infrared energy at a rate dependent on their absolute temperatures. A small portion of the infrared radiation emitted by the objects under surveillance is intercepted by the scanner mirror. The mirror is mounted on a rotating shaft whose axis is parallel to the flight path of the aircraft. As the scanner rotates, radiant energy from each object point along a line perpendicular to the flight path is sampled sequentially and focused by means of a parabolic mirror onto an infrared detector. In the detector an electrical signal proportional to the impinging infrared radiation is generated. This signal is amplified and passed on to a glow tube which emits light whose intensity is proportional to the electrical signal impressed upon it. Light from the glow tube is focused to a small spot by means of a microscopic objective, which is also mounted on the rotating shaft. The intensity modulated spot of light scans, in synchronism

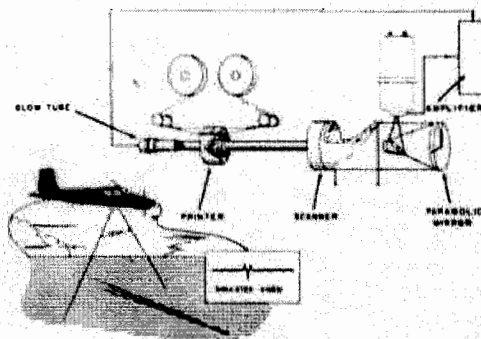


FIGURE 3 - Schematic of AN/AAD-2 Operation

with the scanner, across a piece of slowly advancing photographic film. As the aircraft advances, a wide-angle, 120-degree field of view is swept out by the scanner and recorded on photographic film in the form of a continuous strip map.

The scan rate of the AN/AAD-2 is 100 scans per second; the total transverse field of view is 120 degrees. All receiving optics in the AN/AAD-2 are reflective. The diameter of the parabolic collecting mirror is 3-1/4 inches; its focal length is 6 inches; the useful aperture is 47.6 cm². The design angular resolution of the system of 3 milliradians is achievable when a 0.5 by 0.5 mm detector cell is used. This equipment was designed for an aircraft velocity/altitude range of 0.01 to 0.5 radians/second. Roll stabilization of the display to ±30 degrees is provided. The AN/AAD-2 mounts rigidly in the carrying aircraft.

Temperature sensitivity, spectral response, and angular resolution of this equipment are functions of the detector cell and filter(s) used. The detectors used in the AN/AAD-2 during these flight trials are listed in table I. All of these detectors were operated at the normal boiling point of nitrogen.

TABLE I

<u>Detector Type</u>	<u>Symbol</u>	<u>Size (mm)</u>	<u>Est. Temp. Sensitivity (airborne)(C°)</u>	<u>Approx. Spectral Response (microns)</u>
Lead selenide	PbSe	0.5 by 0.5	0.28	0.5 to 6.5
Gold-doped germanium (p-type)	Ge:Au	2.0 dia	0.03	0.5 to 9
Lead selenide	PbSe	2.5 by 2.5	0.06	0.5 to 6.5
Indium antimonide	InSb	0.5 by 0.5	0.03	0.5 to 5.5

To provide the AN/AAD-2 with high sensitivity in the 8- to 13-micron portion of the infrared spectrum, the NAVAIRDEVCON awarded Contract N62269-1393 to HRB-Singer, Inc. on 14 June 1961 to provide services of a Texas Instruments Inc. copper-doped germanium (Ge:Cu) detector for these flight trials. This liquid-helium-cooled detector was expected to provide an order of magnitude greater sensitivity than the best liquid-nitrogen-cooled detectors available. This project was to proceed in four phases.

Phase I - Study techniques for handling liquid helium and associated apparatus. Modify the AN/AAD-2 to accept the Ge:Cu detector.

Phase II - Conduct laboratory tests of the Ge:Cu detector and of the modified AN/AAD-2 using this detector.

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Phase III - Conduct flight tests of the AN/AAD-2 using this detector.

Phase IV - Prepare a final engineering report.

The NAVAIRDEVGEN had the option of purchasing or renting the Ge:Cu detector upon completion of phase III.

Phases III and IV of Contract N62269-1393 were cancelled on 27 February 1962 for the following reasons:

1. This Ge:Cu detector was not as sensitive as some available liquid-nitrogen-cooled detectors.
2. Independently, the NAVAIRDEVGEN had procured several, more sensitive, liquid-helium-cooled detectors. The excellent results obtained with an AN/AAD-2 using liquid-helium-cooled detectors and operating in naval aircraft will be discussed in subsequent reports.

FLIGHT EXERCISES

Twenty-one flight trials were scheduled from 21 September 1960 to 25 July 1961; HRE-Singer, Inc. provided the flight and engineering services under NAVAIRDEVGEN Contract N62269-1200 of 20 September 1960. The contractor's Cessna 310-B aircraft was escorted to and from the submarine operating areas by a naval aircraft from NAS, Johnsville, Pennsylvania. The procedure for the exercises with controlled submarines was as follows:

1. The aircraft rendezvoused with the surfaced submarine and requested the submarine to travel at some specified depth, speed, and direction. The direction was generally chosen to permit ease of sighting flashing-light marker buoys.
2. The submarine executed straight line runs and released NAVAIRDEVGEN-type flashing-light marker buoys at 1- or 2-mile intervals according to a prescribed schedule.
3. The aircraft executed a racetrack pattern, which included the line of marker buoys as one of its legs. Additionally, the aircraft crossed the submarine's path at oblique angles at various distances astern the submarine.
4. The submarine was requested to provide after each exercise wet- and dry-bulb thermometer readings, surface-wind speed and direction, sea state, water-temperature readings at 10-foot intervals of depth from surface to the depth of the submarine's submerged run, time of each reading, time of release of each marker buoy, and a DRT plot of its course with at least one geographical reference.

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RESULTS OF FLIGHT TRIALS

Eleven of the 21 flights scheduled were cancelled for reasons given in table II. The results of the remaining 10 flights scheduled are described in turn. The indicated aircraft speed averaged 130 knots during the exercises. All times indicated are Eastern Standard Time.

TABLE II

<u>Date</u>	<u>Target Submarine</u>	<u>Reason for Cancellation</u>
16 Nov 1960	USS TORO (SS-422)	Bad weather predicted
1 Dec 1960	USS BECUNA (SS-319)	Bad weather
14 Dec 1960	USS IREX (SS-482)	Change in submarine schedule
23 Jan 1961	USS SAILFISH (SSR-572)	Bad weather (snow)
30 Jan 1961	USS PIPER (SS-409)	Contractor's aircraft not available
13 Mar 1961	USS IREX (SS-482)	Bad weather
18 Apr 1961	USS SAILFISH (SSR-572)	Cancellation of submarine's schedule
26 Apr 1961	USS DIAELO (SS-479)	Bad weather (high winds and air turbulence produced unsafe flying conditions for the Cessna 310-B aircraft)
14 Jun 1961	USS CROAKER (SSK-246)	Bad weather (event cancelled en route to the operating area)
6 Jul 1961	USS CORSAIR (SS-435)	Bad weather predicted for the operating area
25 Jul 1961	USS BANG (SS-385)	A suitable naval aircraft was not available to escort the Cessna to the operating area

21 September 1960

Target submarine: USS CAVALLA (SSK-244)
 Operating area: 40°39'N, 71°45'W
 Scheduled time: 1900 to 2100 hours
 Detector used: PbSe 0.5 by 0.5 mm

1. This event was preceded by a two-week rainy period characterized by small diurnal air temperature variations.
2. The only available detector was a 0.5 by 0.5 mm lead selenide which yielded a noise-equivalent-temperature-difference of approximately one-fourth of a centigrade degree in the airborne AN/AAD-2. Detection of submarine wakes with this detector could have been expected only under the most favorable conditions.
3. No wakes, even from surface vessels, were recorded.

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4. Two equipment difficulties were noticed after this exercise:
 - a. the transport which drives the recording film past the glow tube operated with a jerky motion and produced a pattern of light and dark lines on the film;
 - b. the glow tube did not develop adequate drive for proper recording over water.

27 September 1960

Target submarine:	USS BLENNY (SS-324)
Operating area:	40°43'N, 71°36'W
Scheduled time:	1900 to 2100 hours
Detector used:	PbSe 0.5 by 0.5 mm

1. During most of this event a low-hanging fog made sighting of the submarine-launched flashing-light marker buoys so difficult that the event was terminated before the scheduled finex time.
2. No wakes were recorded.

21 November 1960

Target submarine:	USS SEAWOLF (SSN-575)
Operating area:	39°30'N, 71°32'W
Scheduled time:	1800 to 2000 hours
Detector used:	PbSe 0.5 by 0.5 mm

1. No infrared data were recorded on this exercise because of an equipment malfunction which was not detected until after the film record had been developed. The failure occurred in a jury-rigged condensing lens system which was added to the AN/AAD-2 photographic film recorder to increase its printing spot brightness in an effort to increase the average film density. This lens system consisted of two lenses (one stationary and one rotating) separated by about 0.03 inch. Shortly after takeoff, the stationary lens became loose. It came into contact with the rotating lens, and both lenses ground down and produced a diffusing effect on the transmitted light rather than the desired condensing effect. The jury-rigged condensing lens system was later replaced by a permanent condenser which was being fabricated at the time of this exercise.

30 November 1960

Target submarine:	USS BECUNA (SS-319)
Operating area:	39°21'N, 71°44'W
Scheduled time:	1800 to 2100 hours
Detector used:	PbSe 0.5 by 0.5 mm

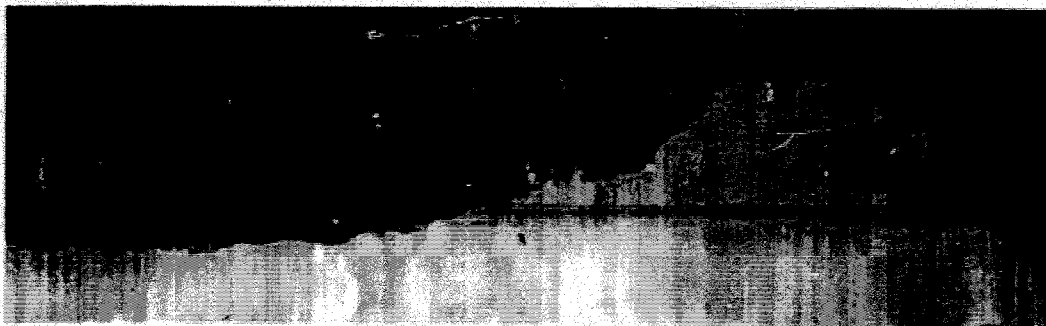
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1. Effectively cold wakes of two surface vessels were recorded by the AN/AAD-2 en route to the operating area. These wakes, which were recorded at 1805 and 1807 hours under clear skies and bright moonlight, were about 150 feet wide and were recorded on the film for a distance of about 1/3 mile astern the ships.
2. This exercise was conducted under conditions of gusty winds (30 to 40 knots), high sea state (10 to 12 feet), complete cloud cover, and occasional snow showers. The air temperature recorded by the submarine was 40° F; the water temperature from surface to 50-foot depth was uniform at 51° F; from 60 to 100 feet the temperature was 56° F. Apparently, surface mixing prevented establishment of a vertical temperature gradient in the first 50 feet of depth despite a fairly large air-sea temperature difference.
3. In the exercise area at 1830 hours, the AN/AAD-2 recorded on several passes an effectively cold region of disturbance in the immediate vicinity of the surfaced submarine.
4. While submerging, the submarine generated a short length of effectively cold V-shaped wake of 90-degree apex angle. This V-shaped wake was recorded by the AN/AAD-2 and observed visually.
5. No wake was detected by the AN/AAD-2 in 23 passes of the aircraft over the submerged or periscope-depth submarine.

14 February 1961

Target submarine:	USS SEA OWL (SSK-405)
Operating area:	39°52'N, 71°29'W
Scheduled time:	1800 to 2000 hours
Detectors used:	(1) PbSe 0.5 by 0.5 mm
	(2) p-type Ge:Au 2.0 mm diameter

1. En route to its assigned operating area, the submarine was delayed by dense fog. As a result, the submarine was still approximately 40 miles north of its operating area when a rendezvous was effected at 1900 hours. The submarine was not able to submerge during the remaining one hour the Cessna could remain on station.
2. The PbSe detector was used on four aircraft passes over the submarine and the Ge:Au detector was used on eleven passes. The AN/AAD-2 detected the submarine itself on all passes except one. (During this one run the operator was making an adjustment on the AN/AAD-2.) On only one of the runs was the submarine's wake detected and in this case it was quite faint. Figure 4 shows the submarine and this faint wake extending approximately four ship lengths astern. This wake is about 150 feet wide. For the first ship length astern the submarine, the wake appears cold. It appears as though the submarine has dragged some cold water along with it into a region of warmer water.



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Date:	14 Feb 1961	Aircraft Type:	Cessna 310-B	Submarine:	USS SEA OWL (SS405)
Time:	1900 hours	Altitude:	1300 feet	Heading:	175° mag.
Sunset:	1736 hours	Heading:	310° mag. (indicated)	Speed:	6 knots
Moonset:	1700 hours	Airspeed:	135 knots (indicated)		
Sea State:	3-4	Operating Area:	39-52 N, 71-29 W		

Detector used: Syracuse University p-type gold doped germanium cell having a circular sensitive area of 3 square millimeters

FIGURE 4 - Surfaced Submarine, Its Wake, and Thermal Anomaly in Water Recorded by the AN/AAD-2

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3. On most of the infrared pictures of the submarine recorded during this event, a warm area appears approximately three-fourths of a ship length aft of the submarine's bow. This is believed to be due to engine exhaust and heat from the engine rooms warming the hull.
4. The striated, mottled, cloud-like structure is believed to be an oceanic "cold front."
5. The two broad, dark lines and the several sharp parallel, horizontal lines in figures 4, 5, and 6 are produced by the recording instrument itself and are to be ignored.

The exercises of 27 February and 3 April 1961 were conducted jointly with the AN/AAD-2 in the Cessna aircraft and the AN/AAR-13 thermal reconnaissance device in NAVAIRDEVGEN F2V-5F aircraft BuNo 131403. See reference (h).

27 February 1961

Target submarine:	USS GROUFER (AGSS-214)
Operating area:	40°31'N, 71°46'W
Scheduled time:	1800 to 2000 hours
Detector used:	p-type Ge:Au 2.0 mm diameter

1. The Cessna made 34 passes over the submarine and/or its wake on a wide variety of headings at altitudes ranging from 1000 to 3000 feet. The wake was detected on all 14 passes made while the submarine was on the surface and on all 10 passes made while the submarine was at snorkel depth, but the wake was not detected on any of the 10 passes made while the submarine was completely submerged. In addition, on 13 of 16 passes over surface vessels, wakes were recorded by the AN/AAD-2.
2. The AN/AAR-13 thermal reconnaissance device installed in the NAVAIRDEVGEN F2V-5F aircraft recorded the wake of the surfaced and snorkelling submarine on 6 of a total of 16 passes. (A number of the passes presented no possibility of detection because occasional operation of the aircraft's radio transmitters produced interference on the AN/AAR-13.)
3. All wakes observed were effectively warm, approximately 150 feet wide, and up to 1 mile long. Occasionally, when the aircraft was in the proper positions, the wakes could be observed visually as smoothed regions which appeared either brighter or darker than the surrounding waters depending on whether the moon was before or behind the observer. Since all of the wakes recorded by both infrared equipments appeared "warm" regardless of orientation of the aircraft with respect to the moon and regardless of the viewing angles of their detectors, it was inferred that the moon was not a significant factor in their detection.

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3 April 1961

Target submarine: USS TENCH (SS-417)
Operating area: 40°10'N, 71°30'W
Scheduled time: 2000 to 2200 hours
Detectors used: (1) p-type Ge:Cu 2.0 mm diameter
(2) PbSe 2.5 by 2.5 mm

1. No submarine wakes were recorded by the AN/AAD-2 during this exercise. This is attributable perhaps to the fact that no directly measurable horizontal or vertical water temperature gradients existed in the immediate area of interest, as indicated by the constancy of the water injection temperature (42° F) recorded by the submarine at 10-minute intervals during the exercise.

2. The AN/AAD-2 did record, however, what are believed to be natural surface temperature variations similar to those detected on 14 February 1961 but considerably less intense. An irregular line of demarcation having a general northeast-southwest orientation and separating the warmer water to the northwest from the cooler water to the southeast was recorded on 6 passes.

3. The AN/AAR-13 recorded 11 images which were believed to correspond to the wakes of the submarine and of a surface vessel which had apparently passed through the operating area. It is interesting to note that the surface vessel was not observed during the exercise by personnel in the two aircraft; its passage through the operating area was inferred after the exercise from an examination of the AN/AAR-13 records which implied a prior passage of the ship on a northeasterly heading. This suspicion was strengthened when the DRT plot submitted by the submarine was received and examined. It indicated that a merchant ship had been detected by sonar 6 miles northeast of where the AN/AAR-13 had made its detections; however, two curious facts remained: first, the more sensitive AN/AAD-2 had failed to detect any wakes and, second, with two exceptions, the "wakes" detected by the AN/AAR-13 appeared "warm" when the P2V was heading generally north and "cold" when the P2V was heading south. These discrepancies were resolved by a simultaneous examination of both AN/AAD-2 and AN/AAR-13 film records. It was concluded that neither equipment had detected any wakes but that each had recorded the same natural thermal anomaly in its own way; that is, the AN/AAD-2 presented a recognizable thermal picture of the anomaly but the AN/AAR-13, because it records the first derivative of water surface temperature as a function of position along the flight path of the aircraft, presented only the line of demarcation outlining the anomaly. This experience indicates the extreme importance in the interpretation of infrared images to being mindful of how the infrared system itself modifies the information it receives. It further illustrates the false alarm suppressing value of a device that yields a true thermal picture over one that yields a picture of thermal gradients.

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23 May 1961

Target submarine: USS TENCH (SS-417)
Operating area: 44°15'N, 68°01'W
Scheduled time: 1900 to 2230 hours
Detector used: InSb 0.5 by 0.5 mm

1. The AN/AAD-2 recorded surface effects generated by the submarine operating on the surface, at communications depth, and at keel depths of 55 feet (snorkelling), 80 feet (2 tons positive buoyancy requested), and 100 feet (4 tons positive buoyancy requested). Figure 5 shows portions of infrared pictures of the sea surface recorded on 4 aircraft passes over an area traversed by the submarine. Common to all 4 views is the natural background pattern. Detailed results of this exercise are given in reference (k).

Daytime Exercise of 24 May 1961

Target submarine: USS TENCH (SS-417)
Operating area: 44°16'N, 68°01'W
Scheduled time: 1500 to 1630 hours
Detector used: InSb 0.5 by 0.5 mm

1. The AN/AAD-2 recorded the wake of the snorkelling submarine on 12 aircraft passes out of 15 opportunities. Detailed results of this exercise are given in reference (k).

Nighttime Exercise of 24 May 1961

Target submarine: USS TENCH (SS-417)
Operating area: 44°17'N, 68°03'W
Scheduled time: 1900 to 2230 hours
Detectors used: (1) InSb 0.5 by 0.5 mm
(2) p-type Ge:Au 2.0 mm diameter

1. Surface effects generated by the submarine operating at maximum periscope depth, and at keel depths of 55 feet (snorkelling), and 150 feet (2 tons positive buoyancy requested) were recorded by the AN/AAD-2. Figure 6 shows a section of the wake generated by the submarine while snorkelling. The wake from the submarine submerged at a 150-foot depth consisted of a series of "cold" patches. Detailed results of this exercise are given in reference (k).

DISCUSSION OF RESULTS

The AN/AAD-2 has recorded surface effects generated by submarines operating on the surface, at maximum periscope depth, 55-foot keel depth (snorkelling), and keel depths of 80, 100, and 150 feet for which positive buoyancy conditions were requested. These surface effects were detectable by the AN/AAD-2 for an average of 18 minutes after passage of

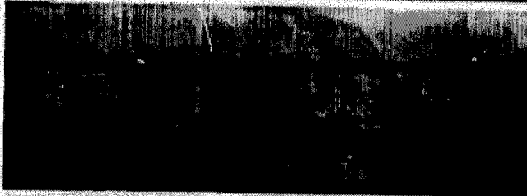
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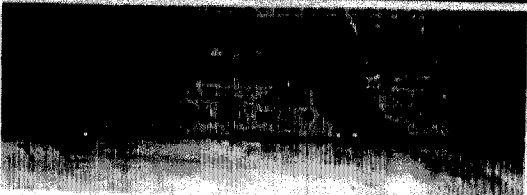
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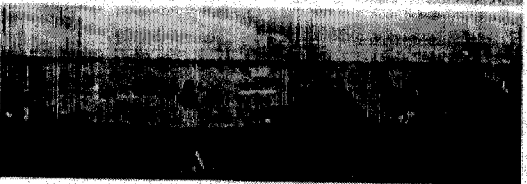
Time: 2110 hours
Submarine not yet
in area.



Time: 2123 hours
Submarine has almost
completely traversed
area. Submarine's
path marked by several
patches of effectively
cold water.



Time: 2127 hours
Five additional patches
of "cold" water mark
the submarine's path.



Time: 2134 hours
Already-existing patches
becoming diffused.

Length of each area shown:
3.9 nautical miles

Date: 23 May 1961
Aircraft altitude: 1000 feet
Detector used: InSb 0.5 by 0.5 mm

Submarine speed: 6 knots
Submarine depth: 100 feet

FIGURE 5 - Area Traversed by a Positively Buoyant
Submarine Recorded by the AN/AAD-2

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NADC-AW-6303

Position of
Submarine at 1930 hours →

Date: 24 May 1961
Time: 1930 hours
Aircraft altitude: 1000 feet
Submarine keel depth: 55 feet
Submarine speed: 8 knots
Detector: p-type Ge:Au 3 cm²
 circular
Length of wake recorded: 1.5
 nautical miles

↑
Travel
direction
of submarine

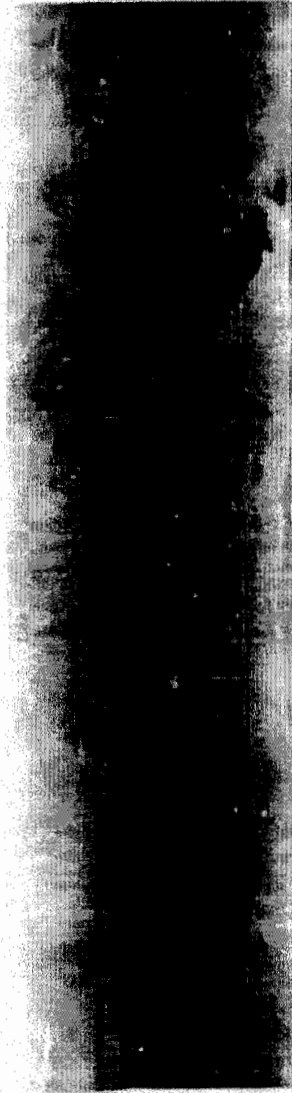


FIGURE 6 - Wake of a Snorkelling Submarine
Recorded by the AN/AAD-2

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the submarine. Average times required for the expression of these effects range from approximately 1 minute for the snorkelling submarine to approximately 10 minutes for the submarine at 150-foot keel depth. These surface effects ranged in width, as measured on the film recordings, from 30 to 280 feet. These wake widths are consistent with values given in preceding NAVAIRDEVGEN reports (references (e), (f), and (1)). Although there is some initial broadening of these surface effects, they are relatively constant in width.

The intensity of surface effects appears to depend on the geographical location as well as the mode of operation of the submarine. That is, at certain points in the exercises, surface effects from the completely submerged submarine were detected more readily than effects from the submarine on the surface at other points.

As noted in several preceding NAVAIRDEVGEN reports, (references (e) and (f)) the intensity, polarity, and persistence of surface effects produced by a submerged submarine appear to be functions of the vertical water temperature gradient, particularly in the upper 30 feet of water.

There is no evidence of enormous changes in background radiation level as a function of scan angle, despite the fact that the angle of viewing the sea surface varied through extremes of +60 to -60 degrees on each scan. A typical nonglassy sea surface appears to behave more like an ideal blackbody radiator than as a smooth dielectric surface because its radiant intensity (watts/steradian) is essentially independent of the viewing angle. In addition, there is no evidence of enormous changes in background radiation level as a function of atmospheric transmission path length, despite the fact that this path length varied by a factor of two on each scan. No such changes are to be expected particularly when there is little difference between the air and sea temperature.

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R E F E R E N C E S

- (a) BUAER Conf ltr Aer-AV-433 ser 00152 of 20 Sep 1956
- (b) BUWEPS Conf WEPTASK RUDC2B204/2021/FO01-05-002 of 15 Sep 1960
- (c) Conf Report No. NADC-AW-N5916 of 5 Jun 1959, "Submarine Wake Detection Program" (C)
- (d) Conf Report No. NADC-AW-N5917 of 8 Oct 1959, "Infrared Wake Detection" (C)
- (e) Conf Report No. NADC-AW-N5932 of 23 Feb 1960, "Phase Report, Submarine Wake Detection, Flight Trials of the AN/AAR-9(XA-2)" (C)
- (f) Secret Report No. NADC-AW-L6005 of 30 Mar 1960, "Phase Report, Submarine Wake Detection, Flight Trials of the Reconofax Camera" (C)
- (g) Conf Report No. NADC-AW-6218 of 5 Oct 1962, "Submarine Wake Detection, Flight Trials of the Infrared Antisubmarine Warfare Bomb Director Sight Unit" (C)
- (h) Conf Report No. NADC-AW-6233 of 3 Oct 1962, "Submarine Wake Detection, Flight Trials of the AN/AAR-13(XH-1)" (C)
- (i) NAVAIRDEVGEN Secret/Conf Biweekly Progress Reports Under WEPTASK RUDC-2B204/2021/FO01-05-002 covering the period 16 Sep 1960 to 30 Apr 1961
- (j) NAVAIRDEVGEN Secret/Conf Monthly Progress Reports under WEPTASK RUDC-4B204/2021/FO01-05-002 covering the period beginning May 1961
- (k) Secret Report No. NADC-AW-6230 of 2 Oct 1962, "Flight Trials of the AN/AAD-2 over the Gulf of Maine, 23-24 May 1961" (C)
- (l) Conf Report No. ADC-EL-50-50 of 8 Nov 1949, "Surface Measurements taken on Thermal Wakes Generated by Submarines" (C)
- (m) Secret Report No. NADC-AW-N6207 of 3 May 1962, "Airborne Infrared Oceanographic Mapping" (U)

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SUBMARINE WAKE DETECTION, FLIGHT TRIALS OF THE AN/AAD-2 INFRARED MAPPING SET IN A CESSNA 310-B AIRCRAFT (C); by P. M. Moser (b)(6) 31 Jul 1963; 20 p; Report No. NADC-AW-43001; PHASE REPORT, WEPTASK RUDC2B204/2021/F001-05-02 (TED Project ADC AV-43001) Report: SECRET

Ten overwater flight trials of the AN/AAD-2 infrared mapping set installed in a Cessna 310-B aircraft were performed from Sept 1960 to May 1961 to determine its capability for detecting surface effects produced by submarines. Night and day trials were over waters of the eastern seaboard of northern U.S.A. Wakes generated by submarines operating on the surface and at keel depths of 55 (snorkel and/or periscope up), 80, 100, and 150 ft were recorded by the AN/AAD-2. Abstract: SECRET

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26 Aug 2016

MEMORANDUM FOR THE RECORD

FROM: Division Director EO & Special Mission Sensors, Avionics, Sensors and E* Warfare Dept (AIR 4.5.6)

TO: Office of Counsel, Naval Air Warfare Center, Aircraft Division (NAWCAD)

Subj: SECURITY RECOMMENDATION FOR FOIA REQUEST, DON FOIA CASE FILE NUMBER 2015-008952

Ref: (a) SECNAVINST 5720.42F, DON FOIA Program, 06 Jan 99
(b) Executive Order 13526

1. Recommendation. AIR 4.5.6 reviewed each document and has the following recommendations listed by each separate document covered under the subject:
 - a. Document (2) of Subj. NAVAIRDEVCCEN Report No NADC-AW-N5916, 5 Jun 1959, "Submarine Wake Detection Program" (AD-C955796). Information found to be unclassified and releasable in its entirety.
 - b. Document (3) of Subj. NAVAIRDEVCCEN Report No NADC-AW-N5917, 8 Oct 1959, "Infrared Wake Detection" (AD-C955804). Information found to be unclassified and releasable in its entirety.
 - c. Document (4) of Subj. NAVAIRDEVCCEN Report No. NADC-AW-L5932, 23 Feb 1960, "Submarine Wake Detection" (AD-C955797). Portions of the report found to be classified under Section 3.3(4) under reference (b). Remaining portions of the document found to be unclassified and releasable.
 - d. Document (5) of Subj. NAVAIRDEVCCEN Report No. NADC-AW-L6005, 30 Mar 1962, "Submarine Wake Detection, Flight Trials of the Reconofax Camera" (AD-C955798). Information found to be unclassified and releasable in its entirety.
 - e. Document (6) of Subj. NAVAIRDEVCCEN Report No. NADC-AW-N6207, 3 May 1962, "Airborne Infrared Oceanographic Mapping" (AD-C955799). Information found to be unclassified and releasable in its entirety.
 - f. Document (7) of Subj. NAVAIRDEVCCEN Report No. NADC-AW-N6208, 8 Jun 1962, "NAVAIRDEVCCEN Airborne Infrared Developments" (AD-C955801). Information found to be unclassified and releasable in its entirety.
 - g. [REDACTED]

[REDACTED]

h. Document (11) of Subj. NAVAIRDEVCEN Report No. NADC-AW-N6304, 20 Jun 1963, "Use of an Airborne Passive Infrared Mapping Set for Submarine Wake Studies" (AD-338356L). Portions of the report are found to be exempted under reference (b) Section 3.3(6). Remaining portions of the document found to be unclassified and releasable.

i. Document (12) of Subj. NAVAIRDEVCEN Report No. NADC-AW-6303, 31 Jul 1963, Submarine Wake Detection, Flight Trials of the AN/AAD-2 Infrared Mapping Set in a Cessna 310-B Aircraft" (AD-340804). Information found to be unclassified and releasable in its entirety.

j. [REDACTED]

k. Document (14) of Subj. NAVAIRDEVCEN Report No. NADC-87161-50, 28 Oct 1987, "Applications of Airborne Passive Infrared Mapping Devices to Military Oceanography" (Reprinted from Proceedings of the First U.S. Navy Symposium on Military Oceanography, Volume II, 17-19 June 1964) (AD-C042316). Information found to be unclassified and releasable in its entirety.

l. Document (15) of Subj. NAVAIRDEVCEN Report No. NADC-AW-6421, 27 Aug-1964, "Infrared Radiation from Ships" (AD-353610L). Portions of the report found to be exempt under reference (b) Section 3.3(6). Remaining portions of the document found to be unclassified and releasable.

m. [REDACTED]

n. [REDACTED]

o. [REDACTED]

2. Basis of Recommendation. All information was reviewed with current class guides and what is considered open source information. Appropriate recommendations made above with respect to findings. Documents found with portions releasable were sanitized based on class guides and reference (b). Such disclosure of Department of the Navy classified information would give potential adversaries insight that would present a significant threat to national security.
3. Exemptions Utilized. Two separate exemptions were utilized in the determination of what information should be sanitized or exempted from release via Freedom of Information Act (FOIA) request process. All current Classified Military Information (CMI) has been sanitized out of the document under FOIA Exemption 3, Executive Order 13526 Sections 3.3(4) and 3.3(6). This Executive Order Section covers CMI that was originally classified over 25 years ago from date of this memorandum. Subject matter experts within AIR 4.5.6 were utilized in making the exemption determinations.
4. Point of Contact. The point of contact for this security review and recommendation is Mr. Paul W. Reimel, AIR 4.5.6 Division Director, paul.reimel@navy.mil, 301-342-0100.

8/30/2016

X Paul W. Reimel

Paul W. Reimel

Signed by: REIMEL.PAUL.W.1229241016

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