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A STUDY OF AERIAL SEMI-PRECISE SURVEY SYSTEMS FOR POSITION AUDI--ETC(U)
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Report No. CG-D-61-77

A STUDY OF AERIAL SEMI-PRECISE SURVEY SYSTEMS FOR POSITION AUDITING OF COAST GUARD AIDS TO NAVIGATION

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October 1977

Final Report

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DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD
Office of Research and Development
Washington, D.C. 20590

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16. Abstract

A study was undertaken to evaluate aerial imaging systems capable of establishing the position of aids to navigation to within 30 meters within 48 hours following adverse weather conditions such as ice or storm. A scenario area (400 km by 3 km) was created to simulate a region affected by such environmental conditions. The study considered aerial photograph, side-looking airborne radar, and visual observations from aircraft. It was concluded that there are no systems currently available to the Coast Guard to achieve an aerial semi-precise survey of aids to navigation.

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METRIC CONVERSION FACTORS

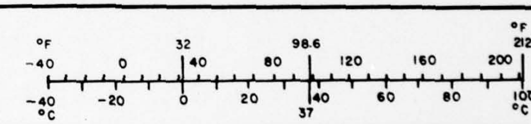
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 INTRODUCTION

A study was undertaken to evaluate aerial imaging systems capable of establishing the position of aids to navigation (AN), following adverse weather conditions such as ice or storm, that could cause the aids to be moved off station or destroyed. It was considered necessary that a suitable system be capable of: (1) providing positional accuracy of 30 meters, while (2) giving a wide coverage (400 km by 3.2 km), and (3) achieving this entire operation (from request through data analysis) within 24 hours. In addition, a suitable system should require no modification of aids to navigation or extensive Coast Guard investment of equipment and manpower.

2.0 APPROACH

There are several airborne imaging systems that can provide wide area coverage (that is, Aerial Photography, Side-Looking Airborne Radar (SLAR), various Scanners, Search Radars, and Satellite Systems). It was obvious, after a cursory study, that because of accuracy, detection, and availability, only two of these, Aerial Photography and SLAR, could be practically used by the Coast Guard for semi-precise audit. These systems were, therefore, considered to be the only ones potentially available, and were the subject of an initial investigation.

The results of this initial investigation indicated that the original requirement of a 24-hour response time was too stringent and could not be used as a practically attainable goal. Consequently, for the purposes of this investigation, the requirements were altered. These modified requirements are given in Table 1. At this time, it was also decided to add a third method to the two being evaluated, Visual Observation From Aircraft (VOFA). Although this is not strictly an imaging system, it was introduced because of its inherent simplicity and availability.

It was found that for each of the three methods considered (Aerial Photography, SLAR, and VOFA), several combinations of vendors, equipment, and procedures were possible under a given system. A large number of these combinations exist for the photographic method. To make the comparisons more meaningful, only those vendors, equipment, and procedures available in the Middle-Atlantic region were considered.

The results of the study can, however, be properly extended to any other Coast Guard region, as the costs, response times, and general availability of numerous options are anticipated to be similar from region to region.

The evaluations made were based on information exchanges with vendors and government agencies, and interpretation of selected aerial imagery. Suitable imagery of a single location was not available. Therefore, suitable imagery was obtained and utilized regardless of the location.

TABLE 1

SYSTEM REQUIREMENTS

I

The system shall be economical.

II

The system's imagery shall have sufficient resolution and contrast to allow the rapid identification of AN with a positional accuracy of no more than ±30 meters.

III

The system need not be dedicated to only semi-precision audit, but may also have other operational uses. It must be capable of being operational within a few hours after it is requested. The execution of the task, including analysis, should be completed within 48 hours from the time of initiation.

IV

The system should require only the most modest initial investment in equipment and manpower. Preferably, the system should be operational now or in the near future.

3.0 DISCUSSION

Initially, the project plan called for the evaluation of each method and its options in terms of evaluation criteria. These criteria represented those (cost, manpower, skill levels, accuracy, and response time) factors, which were tied to the Coast Guard's operational capability to utilize a given system. However, many of the options that had a potential to meet the stated requirements were of a contractural nature (i.e., a vendor would perform the actual work) and, consequently, the evaluation took the more simple form of a cost analysis. Each option was thus characterized by its cost, with its ability to perform the required work used as a qualification to the cost. Those options that required Coast Guard personnel to perform the work were also simply reduced to cost, when it was found that, in general, the impact on the Coast Guard operations was small (except as will be noted in the text and Appendix D).

A standard scenario was developed to allow comparison of the three methods. This scenario is defined by a given set of spatial and temporal conditions which allows the various systems to be compared on an equivalent scale. The geographic area selected approximates an area that might require an audit following a major storm. It measured 250 nm by 2 nm along the coast. The scenario was further divided into two classes (i.e., (1) Scenario A - in which all AN in the area are audited, and (2) Scenario B - in which only the large aids are audited) in order to provide a comparison of a full to partial audit. Aids to navigation were classified arbitrarily so that "large" was defined as greater than 1.5 meters (5 feet) in diameter, and "small" as less than 1.5 meters in diameter. This classification was instituted in order to simplify the evaluation of the various options, and is not intended to imply relative importance of the aids.

The integration of the data resulting from the implementation of these systems into the operational Coast Guard program was not considered as a part of the scenario. This was done principally not to confuse the cost picture which forms the basis of this report and also because of the complexity of such an integration. However, such an integration has to be a major component of any field demonstration.

These results, conclusions, and recommendations are intended as guidelines for future planning only. This report is written to supply information useful in making policy decisions, and is not to be misconstrued as a guide for do-it-yourself aerial audits. Many items required to successfully complete an aerial audit are not covered in this report. Misuse of this data could result in wasted manpower, dollars, and less than adequate results.

4.0 RESULTS

4.1 Aerial Photography

4.1.1 Discussion

Aerial photography is obtained using specifically designed cameras. There are (1) two main categories of aerial cameras, Cartographic and Reconnaissance, and (2) two types of film, Black and White (B&W) and Color. These are described in Appendix A. Representative photography of each of these was evaluated using either commercially available or specifically acquired photography.

4.1.2 Results

In general, it was found that the cartographic cameras are better suited for the purpose of determining the position of an aid relative to charted land and cultural features, than are the reconnaissance type cameras.

It was also found that color film, because of the increase in probability of detection due to the color contrast between the black buoys/red buoys and the blue/green water background, is essential for the detection of AN at a reasonable scale size. The dark-toned buoys and the darker water background almost always precludes the use of B&W aerial film; the exception being those areas of calm water when only large aids are of interest. A detailed discussion of these evaluations is contained in Appendix B.

Three production steps are required to use aerial photographic methods for AN audit: (1) acquisition of the photography, (2) processing the photographic film, and (3) interpretation of the imagery. Twenty options (i.e., different means of accomplishing the audit task) were identified for the photographic system. These consist of different combinations of facilities to perform the production steps (i.e., acquisition, processing and interpretation steps). The practical implementation of the production steps can thus be achieved in a number of ways as illustrated in Table 2. A single facility could, for instance, be selected to do one, two, or all three production steps, or similarly two or three facilities could be used for this purpose. In this way, several options are available to the operations officer allowing him to make a choice of the best route. The choice of the best route will be strongly dependent on the area and time of the audit.

Those options considered to be generally viable are compiled in Table 2 and are listed below:

(a) Coast Guard accomplish all three steps. The Coast Guard will have, as a part of the MRS program, operational aircraft capable of acquiring suitable photography. The proposed support facility may include roll film processing and image interpretation facilities. Three Coast Guard enlisted personnel have received formal training in image interpretation at the three-month Navy/Air Force Class A school at Lowry AFB, Colorado. This training coupled with the on-the-job training they are currently receiving is considered to be sufficient for the level of interpretation required for this task.

TABLE 2

AVAILABLE OPTIONS FOR PHOTOGRAPHIC METHOD

OPTION	STEP (a) ACQUISITION	STEP (b) PROCESSING	STEP (c) INTERPRETATION
1	Commercial	Commercial	Commercial
2	Commercial	Commercial	CG
3	Commercial	EPA	EPA
4	CG	CG	CG
5	NOS	NOS	NOS
6	DOD	DOD	DOD
7	DOD	DOD	CG

(b) Commercial firms do all three steps. There are many aerial survey firms throughout the U.S. capable and available to do this task. Several of the larger firms have an in-house processing facility, while most rely on other firms.

(c) NOS accomplish all three steps. The Coastal Mapping Division of the National Ocean Survey (NOS) is equipped and prepared to do all three steps.

(d) DOD components do all three steps. DOD components capable of doing all three steps exist throughout the country. Their availability and cost requirements will vary according to independent workloads and operating costs.

(e) Commercial firms do Steps 1 and 2, Coast Guard do Step 3. Contract commercial firms to acquire and process the aerial film and have those Coast Guard personnel trained to support MRS do the image analysis.

(f) Commercial firms do Step 1, EPA do Steps 2 and 3. A working arrangement could be made with EPA to have commercial firms acquire the photography (Step 1) and deliver to EPA for processing and analysis (Steps 2 and 3).

(g) DOD do Steps 1 and 2, and Coast Guard do Step 3. Components of DOD could acquire and process the photography, and the Coast Guard could do the image analysis.

In general, the photographic method suffers from several faults as an audit system. It requires good visibility and essentially cloud-free conditions to at least a height of 1500 meters. Adverse weather conditions may substantially affect the operations of the audit aircraft, and increase the cost of the mission. Further, the costs to acquire useful data are high even if fine weather conditions are experienced. These costs are given in Table 3 for each option considered along with an estimate of the time required to complete the mission (based on fine weather conditions). The tabulated values account for the individual costs associated with: (1) film purchase, data acquisition, (3) film processing, and (4) data reduction.

4.2 Visual Observation From Aircraft (VOFA)

4.2.1 Discussion

Visual observations from light aircraft, or helicopters, was considered as a potential method because of its basic simplicity and availability. An observer, one familiar with the area to be surveyed, would utilize a commercial light aircraft, or Coast Guard helicopter, to fly over an area. Using the best chart available and his own personal knowledge of the AN purpose and location, the observer would ascertain whether or not the AN are grossly off station by comparison with known land and sea features.

TABLE 3

COST PER MISSION FOR PHOTOGRAPHIC SYSTEMS

OPTION	AQUISITION	PROCESSING	INTERPRETATION	PHOTOGRAPHIC AQUISITION COSTS SCENARIO A	SCENARIO B	RESPONSE TIME	COMMENTS
1	CG	CG	CG	$ 7,530	$4,560	24 hours using MRS facilities. 36-48 hours using district personnel	estimates based on planned MRS support facility.
2	COM	COM	COM	$12,610	$8,320	24-36 hours	costs based on figures received from two sources
	COM	COM	COM	$ 2,760	$1,420		
3	NOS	NOS	NOS	$ 6,010	$3,670	24-36 hours	based on estimates from NOS Coastal Mapping Division
4	DOD	DOD	DOD	$ 4,200	$2,200	24-36 hours	based on costs from one unit, costs will vary
5	COM	COM	CG	$12,610	$8,320	24-36 hours	No cost change from option #2 to option #5
	COM	COM	CG	$ 2,760	$1,420		
6	COM	EPA	EPA	$10,525	$8,920	24-36 hours faster in emergency	variance due to difference in commercial aircraft costs
	COM	EPA	EPA	$ 2,625	$2,020		
7	CG	DOD	CG	$ 4,300	$2,300	24-36 hours	costs and response times will vary

All costs are based on an average airspeed of 250 knots. Airspeed will change as a function of altitude, but the cost comparative ration will remain the same. Several costs are not included here. They will, however, be one shot costs and should not be recurrent for a system-option.

4.2.2 Results

Flights were made along the Connecticut, Massachusetts, New York, and Rhode Island coasts to test this system. These flights were made using a commercial high wing light aircraft. Flights were made at an average speed of 130 knots at altitudes ranging from 150 meters to 600 meters. On these flights, R&D Center personnel were assisted by LCDR OVERATH, CO CGC HORNBEAM, and LTJG O'SHEA of CGC RED WOOD. The post-flight impressions of both of these officers were very similar. LTJG O'SHEA's remarks were integrated into this report. LCDR OVERATH's are given in Appendix D. It was determined from these flights that at altitudes below 375 meters, all AN could be detected and identified, while much above 375 meters, the detection and identification becomes difficult due to sea state and other factors. Sun angle was identified as an important factor in identifying and determining the positions of aids from the air. Sunlight penetrating into the water, as well as outlining the AN, enhances the detection and identification capabilities of the observer. Unfavorable sun angles, on the other hand, can produce glare from the aircraft and water which inhibits the capabilities of the observer.

In practice, to determine the position of an AN using this method, the observer uses known land features, underwater features, and other AN as his reference points. He establishes in his mind a system of fiduciearies and scales based on these features, from which he can estimate the range and bearing to the AN. In estimating whether or not an aid is reasonably on station, a similar procedure is used. Thus, the observer operates subjectively; he feels that the aid is where it is supposed to be. The quantization of this method's ability (i.e., man's ability) to determine position to the precision required for this task will, however, require further field testing, perhaps as a corollary to future demonstrations. Similarly, development of techniques to train the observer, which may provide enhanced position capability, will require further effort.

The VOFA method's ability to approximately determine position can be roughly divided into three classes dependent on the relative position of the aids from reference landmarks. The first class occurs when the reference landmarks are close to the AN, and the observer quickly establishes the relative position of the AN with confidence. The second class occurs when the reference landmarks are moderately distant from the AN. Here, the observer is left with some uncertainty. The third class occurs when the references are distant, leaving the observer totally uncertain as to the position of the aid. The qualification of the terms close, moderately distant, and distant have not been established. An estimate based on the observational flights conducted would define close as that condition for which references are within 150 to 300 meters, moderately distant as 300 to 900 meters, and distant as beyond 900 meters.

The costs associated with this method are simply computed, due to the way in which the data acquisition, processing, and the interpretation are all done simultaneously. Only the aircraft expenses and observer salary need be accounted for. Comparative costs for each scenario have been calculated and are presented in Table 4.

TABLE 4

COST PER MISSION FOR STANDARD SCENARIOS OF VOFA SYSTEM

	COST	RESPONSE TIME	COMMENTS
SCENARIO A	$310	12 HOURS	BASED ON $35/HOUR FLYING TIME (AVERAGE IN THE NEW ENGLAND AREA) AND $100/DAY FOR AN OBSERVER
SCENARIO B	$240	10 HOURS	

The VOFA method requires moderate (visibility about 2 km) visibility and essentially cloud-free conditions up to about 150 meters. High winds, ice, snow, or fog may prevent the deployment of the aircraft, resulting in some delays and additional costs.

4.3 Side-Looking Airborne Radar (SLAR)

4.3.1 Discussion

RADAR is an acronym from the words Radio Detection and Ranging, and is applied to a large family of devices that utilize electromagnetic energy to gather information. SLAR received its name from the fact that the antennas are mounted such that their active faces are at right angles to the longitudinal axis of the aircraft. Thus, the radar antennas "look" to the sides of the aircraft. The forward motion of the aircraft causes successive "looks" to cover new ground. By transmitting radar pulses (looks) at a rate proportional to the speed of the aircraft, the successive "looks" form a composite picture of the terrain. SLARs produce displays whose resolution is superior to that of conventional airborne search or navigation radar systems. The intensity of the reflected microwave energy is presented on the display as contrast differences. The difference in the reflected intensity of the microwave energy from AN as compared to their water background makes the detection of AN theoretically possible.

4.3.2 Results

Present Coast Guard SLAR systems lack the resolution required for the audit task, and although there are operational SLAR systems which have the resolution capabilities for this task, they are either classified by DOD or are not otherwise available. Future Coast Guard SLAR systems will be modifications of the Motorola APS94 radar, which does not have the resolution required. Thus, although the SLAR method has often been mentioned as a solution to the audit problem, it has been found that those SLAR systems that are realistically available to the Coast Guard are unsuited for the audit task. Those systems which are suitable are not realistically available. Therefore, the SLAR method is considered to be unsuitable for semi-precise audit. A representative listing of SLAR systems and capabilities is contained in Appendix D.

The SLAR method is least affected by weather. These are all-weather day or night imaging systems and only severe precipitation will significantly affect performance. However, high sea states, caused by wind, could limit the detection capabilities of SLAR systems.

Since no SLAR systems were deemed suitable for the audit, no real evaluation to determine operational costs was made. However, a simple evaluation indicates that the cost for a SLAR system would range between $4K and $6K for a single mission (Scenario A). This includes costs for aircraft, processing and data reduction.

5.0 CONCLUSIONS

Three methods were evaluated in this report. They were selected because of their potential to achieve the goals of the semi-precise audit. Although each method possesses interesting and valuable attributes, each fails to meet the system requirements for the semi-precise audit established in Table 1.

The photographic method, which is capable of achieving the most accurate AN position determination, is highly dependent on weather conditions, and it is probable that it will fail to meet the response time of 24 to 48 hours required for the semi-precise audit task. Probably the required response time would be difficult to achieve even under ideal conditions. Photographic systems are further limited in their ability to determine the position of aids greater than one nautical mile offshore (1.6 km). The cost is sufficiently high to prohibit regular use, and it is highly dependent on temporal factors which will make budget planning difficult. Further, the cost of several thousand dollars for Scenario A associated with most of the options, must be in practice augmented by the cost of pre-mission planning (and post-mission analysis) which is both time consuming and costly, but essential to insure a proper photographic audit.

The VOFA method is by far the simplest and least expensive. Its potential for rapid response and the numerous commercial and Coast Guard aircraft available give it added appeal. However, it is restricted by weather conditions, subjective in operation, and its position accuracy is not yet fully known. It is at present limited to near-shore (less than 300 meters) aids to the semi-precise audit accuracies required.

SLAR systems have near all-weather capabilities, large area coverage, and fast response time. However, these advantages are negated by the fact that for the present, and in the foreseeable future, no suitable SLAR will be available to the Coast Guard for this task.

In conclusion, the results presented here establish that there are no systems presently available to the Coast Guard with which to achieve an aerial semi-precise audit (that is within the context of the requirements established in Table 1). In all likelihood, this condition will continue to be true for the foreseeable future. An estimate of the degree with which each of the evaluated systems can perform the required survey can be obtained from this report, but care must be taken in the interpretation of the individual results (for instance, no attempt was made to demonstrate the value of one method-system over another, or to provide exact cost figures, or be definitive in locating all photographic combinations in the Middle Atlantic region, etc.). Nevertheless, based on the ability of each system to partially fulfill the audit requirements, it may be, under certain conditions, acceptable to conduct an audit using the various methods evaluated here. In this case, the system should be evaluated in terms of the individual requirements of that audit, for which the results may be substantially different than those reported here.

APPENDIX A

EVALUATION OF AERIAL PHOTOGRAPHY

To determine the relative capabilities of Cartographic cameras, Reconnaissance cameras, using B&W negative film and color reversal film, samples from each were obtained and evaluated. Photographs 1 through 6 are annotated examples of the various types used. Boston Harbor, Cape Cod Canal Approaches, New London Harbor, Baltimore Harbor, Charleston Naval Base, and several areas in the Chesapeake Bay area were used as being representative of typical conditions. The specific results of this evaluation are:

(a) Color reversal film is preferable to B&W negative film in the majority of cases, assuming scale and ground resolution to be equal. This is mainly due to the color contrast of the buoys. B&W negative film can be used in areas of calm water when only large buoys are of interest.

(b) Cartographic cameras are better than the Reconnaissance cameras in terms of area coverage per frame and overall lens quality (i.e., geometric stability). Reconnaissance cameras are capable of providing the required ground resolution and detail, but with less area coverage per frame.

(c) The maximum scale at which small aids (defined in the text as less than 5 feet diameter) can be reliably detected and identified is about 1:11,000 (equivalent to flying at 1675 meters with a 152 mm focal length lens). Large aids (greater than 5 feet diameter) can be reliably detected and identified at photographic scales of 1:22,000 (which converts to flying at a height of 3350 meters using a 152 mm focal length lens).

(d) A minimum of 25 lines/mm for a low contrast target is required to produce the results stated in Item (c).

(e) A low sun angle enhances the effect of shadows, and is useful in making proper identifications. Standard frame oblique photography and special purpose horizon-to-horizon panoramic photography are useful in aiding detection, but are poor in terms of specifying determined positions.

PHOTOGRAPH

1 National Ocean Survey
9" by 9" color positive
Wild RC-8 cartographic camera
6 inch focal length (152 mm)
Scale 1:10,000 Altitude 5000 feet
Western approach to Cape Cod Canal obtained under near ideal conditions. This is an example of the quality photography required for observation of all AN.

2 National Ocean Survey
9" by 9" color positive
Wild RC-8 cartographic camera
6 inch focal length (152 mm)
Scale 1:30,000 Altitude 15,000 feet
Western approach to Cape Cod Canal obtained under near ideal conditions. Approximately 85 percent of all AN can be located. The difference between Photo 1 and 2 is due to decreased resolution as a result of greater scale.

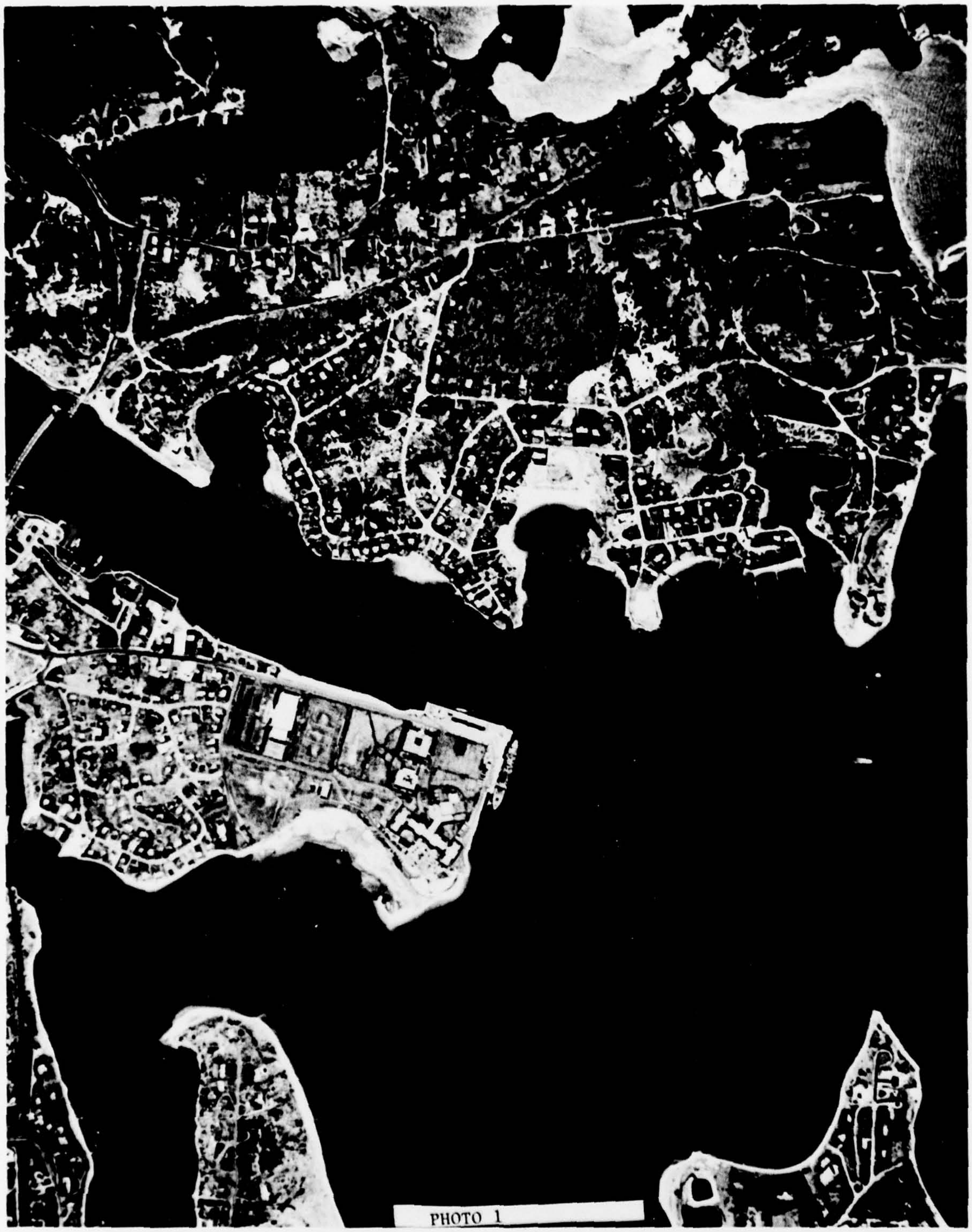
3 National Ocean Survey
9" by 9" Black & White positive
Wild RC-8 cartographic camera
6 inch focal length (152 mm)
Scale 1:30,000 Altitude 15,000 feet
Boston Harbor and Logan International Airport. This photograph is of reasonable quality, with some loss of detail due to reproduction. 75 percent of large AN can be located, and about 30 percent of small AN can be located.

4 U. S. Navy
4.5" by 4.5" Color positive
KA-51 Reconnaissance camera
6 inch focal length (152 mm)
Low Oblique Altitude 6,000 feet
Charleston, South Carolina, Naval Base, taken from an RF8G Naval Reconnaissance aircraft. Weather conditions were ideal at the time of the photograph. The obliquity of the photograph enhances the detectability of AN, but also makes photo mearsurements more difficult and less precise.

5 U. S. Navy
4.5" by 4.5" Color positive
KA-51 Reconnaissance camera
6 inch focal length (152 mm)
Scale 1:10,000 Altitude 5,000 feet
Thames River in the vicinity of the New London Submarine Base. Weather conditions, heavy overcast and poor visibility, were less than ideal. Almost all aids can be located using chart comparison and stereoscopic viewing.

6 U. S. Navy
4.5" by 4.5" Black & White positive
KA-62 Reconnaissance camera
3 inch focal length (76 mm)
Scale 1:20,000 Altitude 5,000 feet
Thames River in the vicinity of the New London Submarine Base, taken simultaneously as Photo 5. Most large aids can be located, while smaller aids are undetectable at this scale.

7 U. S. Coast Guard
8" by 10" positive print
APS-94 Motorola Side Looking Airborne Radar
Scale 1:250,000 original image
2.7 enlargement
Approach to San Francisco Bay. The Major Lane Buoys, Eight in line, are easily identified. There are many aids in this area which were not detected by the SLAR System. However, image matching techniques coupled with proper acquisition planning could probably produce imagery acceptable for gross auditing of aids in areas such as this.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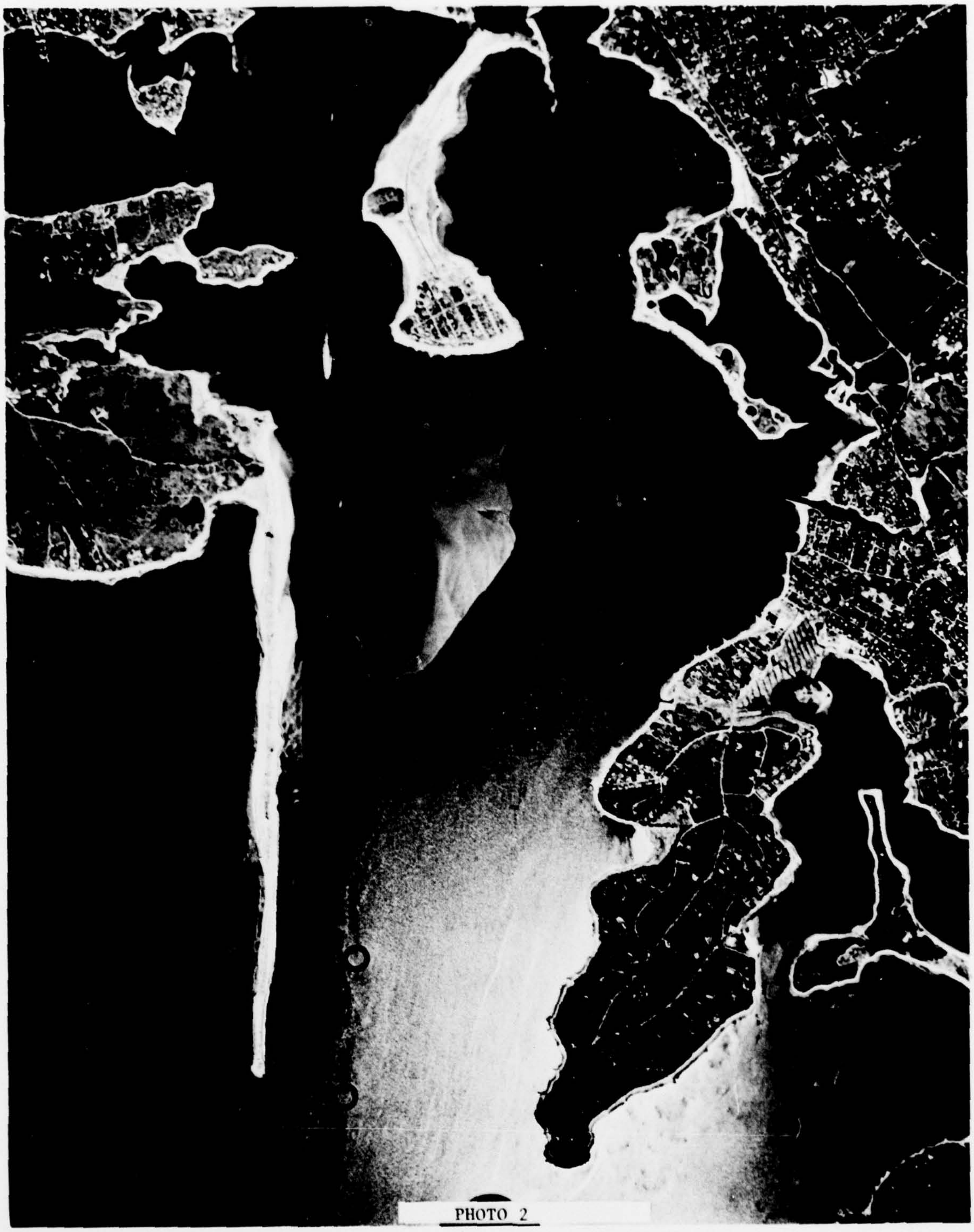

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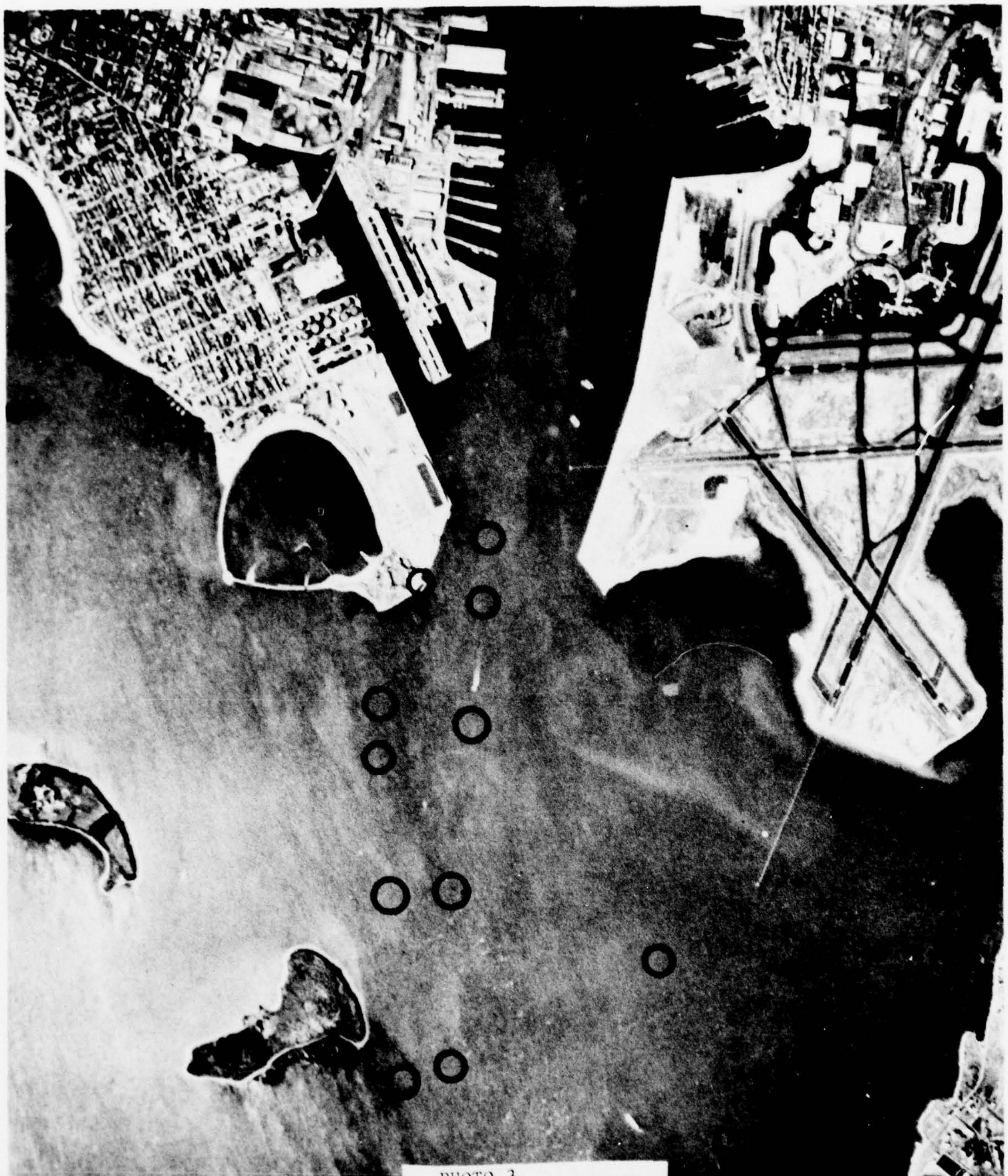
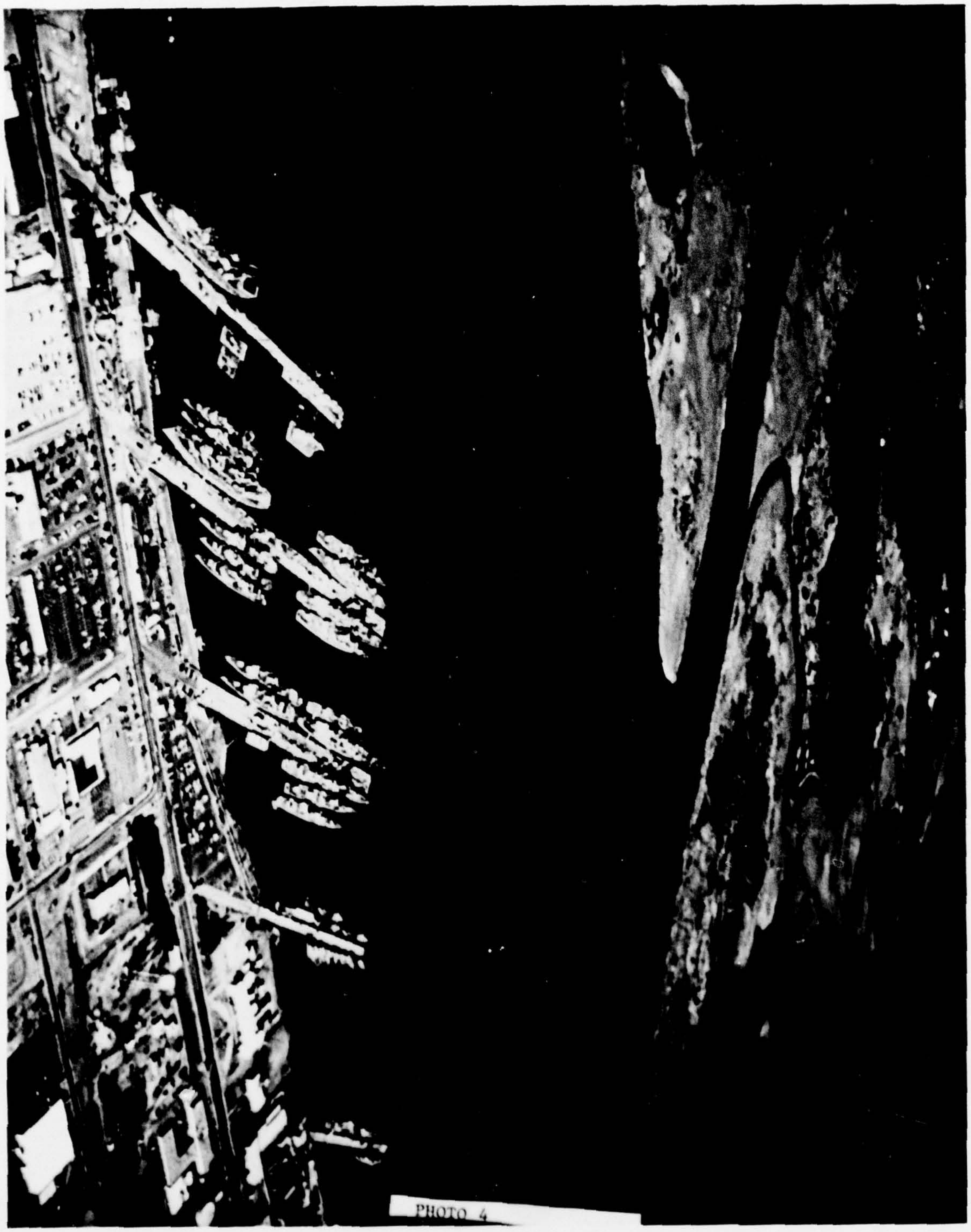


PHOTO 3



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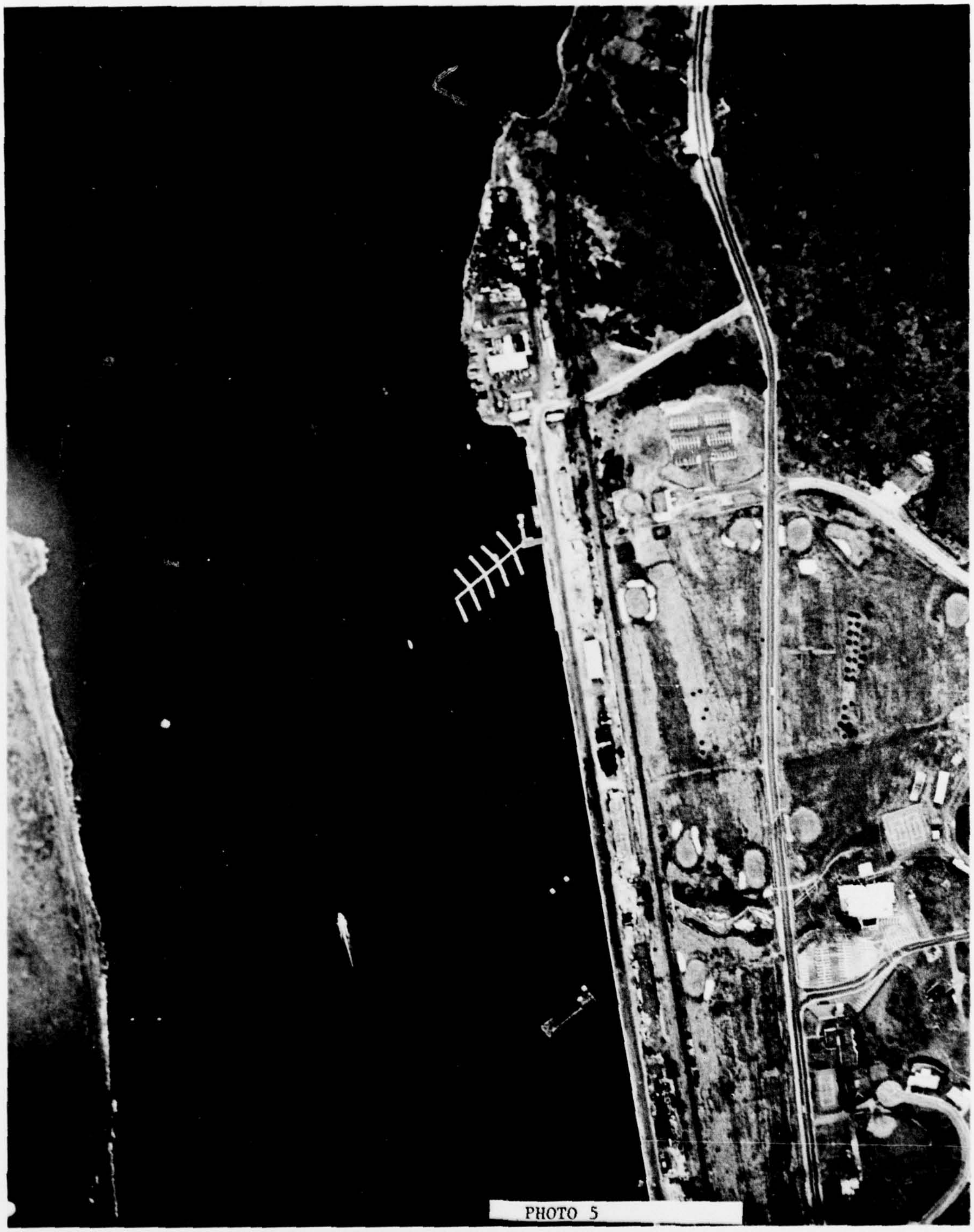

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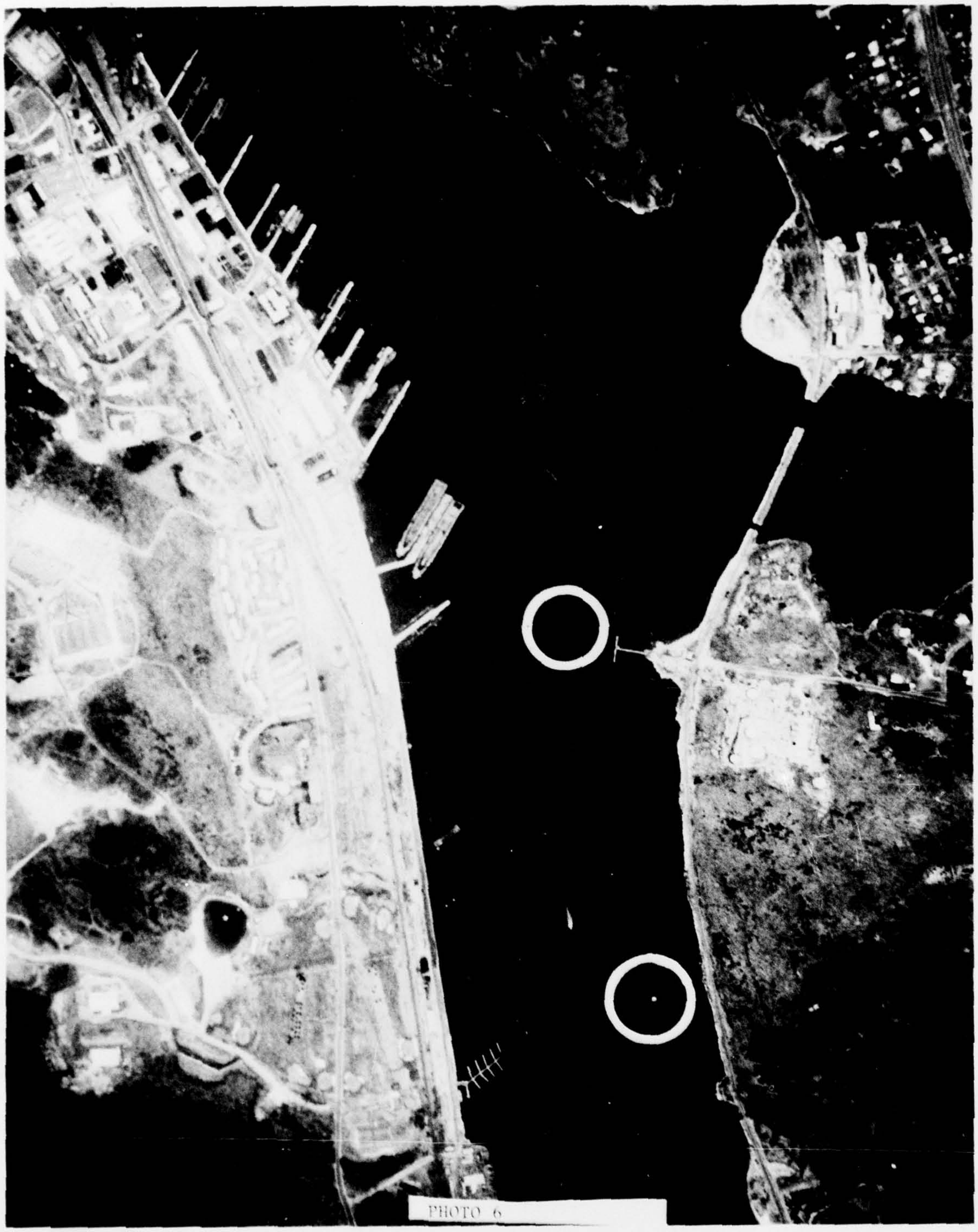


PHOTO 6

PHOTO 7

APPENDIX B

PHOTOGRAPHY

The aerial photographic method can be distinctly divided into three operational steps: (1) acquisition of the photography, (2) processing of the photographic film, and (3) interpretation of the imagery. Each of these functions is done independently, and can be treated separately.

Several special terms are used in this discussion of aerial photography and these are defined as follows:

(a) Resolution - The ability of the entire photographic system, including lens, exposure, film processing, films, and other factors, to render a sharply defined image. A mathematical expression of lens definition and/or film definition is the maximum number of contrasting line pairs per millimeter (1/mm) that can be resolved. Also referred to as resolving power.

(b) Contrast - The apparent difference in scene brightness of an object with respect to the immediate background, i.e., a buoy is generally lighter in appearance than the water on which it is floating. Contrast is often stated in ratio form, e.g., 3:1 or 2:1, etc.

(c) Density - Density = log (1/Transmittance). The density formed on a photographic film, following exposure and development, is related in a complex way to the brightness of the object photographed. On a negative film, the brighter object will give a more dense image, while on a positive film (such as color transparences) the brighter object will give the less dense image.

(d) Scale - The relation between a distance on the photograph and the actual ground distance, expressed as a representative fraction (1/20,000) or as a ratio (1:20,000).

Cameras

Aerial photography can be acquired using a variety of camera types. The two types that are applicable to the semi-precision audit task are (a) Cartographic and (b) Reconnaissance.

(a) Cartographic cameras are large format (9 inch by 9 inch) aerial mapping cameras with high precision lenses noted for their geometric uniformity. These lenses are essentially distortion-free and are calibrated to National Bureau of Standards cartographic lens specifications. (Reference: Manual of Photogrammetry Section 3.2.3.) Lens resolution normally exceeds 30 1/mm for low contrast targets (scene brightness to background ratio less than 2.5 to 1). Cartographic photography is characterized by vertical photography (optical axis perpendicular to the earth's surface), low distortion and general conformance with published limits of quality.

(b) Reconnaissance cameras are designed for use in high performance aircraft, and are characterized by speed of acquisition, high resolution (greater than 45 l/mm) and simple operations (automatic exposure control and image motion compensation). There are two general categories of reconnaissance cameras, serial frame and panoramic. Serial frame cameras are medium format (4.5 inch by 4.5 inch) roll film cameras with high resolution lenses. These cameras are designed for vertical or oblique photography, but are usually used in the vertical mode. Panoramic cameras are designed for wide area coverage with a single aircraft flight. This is accomplished through the use of rotating optical bars or scanning prisms to allow the camera to observe up to 90-0 degrees from the aircraft line of flight. This is sometimes called horizon-to-horizon photography. The film format varies with different panoramic cameras, but is always rectangular.

Vertical photography obtained using serial frame cameras is suitable for the semi-precision audit, however, a greater number of frames would be required to cover an area than would be required using a cartographic camera.

Panoramic cameras are unsuitable for this task. The involved mensuration techniques, geometric distortions, and relatively high maintenance characteristics relegate them to a supportive role.

Film

The ability of a photographic system to acquire objects of a given size is determined by both the camera lens resolution discussed previously, the film resolution, and system detectivity or sensitivity. The resolution figure is an expression of the film's ability to show distinctly line pairs of a contrast target under set conditions. A low contrast rating is used for aerial films as it more closely resembles the low contrast of subject viewed from the air.

There are many different types of aerial films. Two are applicable to the semi-precise audit task, color reversal positive film and B&W negative film.

(a) Color reversal positive film, resolution greater than 25 l/mm can be processed directly to a positive image, normal to the viewer, thus reducing resolution losses due to the two processing steps required to convert a negative film image to a positive one. Also, the end product is available for viewing in a short period of time, usually less than one hour.

(b) B&W aerial negative film, resolution of 40 l/mm low contrast rating, proved to be very good in areas of smooth water and a low density of targets, such as rivers and major harbor channels. B&W film is also useful when atmospheric haze conditions prohibit the acquisition of useful color photography.

Processing

Aerial film comes in various lengths and widths, ranging from 70 mm up to 9 inches wide and 250 to 500 feet long. This size and bulk precludes processing by other than automatic machines. Processing requires automatic machines and trained operating technicians normally not found in photographic darkrooms. This type of processing is available commercially, at many DOD facilities, and at other governmental agencies.

Interpretation

Interpretation techniques for aerial photography are varied and well developed. The interpretation techniques used for the semi-precise audit will depend on the type and quality of information being extracted.

Several methods can be used separately or in combinations. The simplest method is the visual chart reference method. A large-scale chart of the subject area and a pair of proportional dividers are all that is required. Relative positions of AN are transferred to the chart from the photography using land and cultural features as points of reference. This technique is time consuming and is limited by the accuracy of the charts used and the quality of the photography.

A quick and accurate method is direct chart comparison by transferring the photographic data to the chart. Several methods are available for this. One involves enlarged reproduction of the charts on translucent material and overlaying the photography using a light table. The positions of AN can be determined quickly and accurately within the limits of the chart (base scale) and quality of the photography. A drawback to this method is the need for the photography to be obtained at a preselected scale to match the scale of the enlarged chart. Weather, flight restrictions and camera type could hinder this operation.

The second method of direct comparison involves the use of an optical transfer or projection device. Several suitable models are commercially available. The comparison can be done quickly using this type device regardless of photographic scale. These devices are expensive (about $7K) and require training if they are to be used to advantage.

Stereographic photography and stereo viewing equipment are absolutely necessary for this task. The land features being used as references often will have relief, that is, they will be higher than the water level, and will be displaced horizontally on a single photograph. This relief can be measured and is a means of compensating for positional errors due to relief displacement. In addition, stereo photography is often the only way of separating an object from its background and making a proper identification. Stereo photography is acquired by taking the photography at selected intervals to insure proper overlap between successive frames, and has to be considered when planning the mission. The equipment needed is not expensive ($1K), needs a minimum amount of training and is often an optional feature in optical transfer or projection devices.

APPENDIX C

LETTER REPORT TO R&DC FROM LCDR OVERATH

15 June 1976

Checking Buoy Positions by use of Aircraft; Report of

1. On 21 May 1976 Mr. Farmer from CG R & D Center Groton, CT and myself departed Falmouth Airport at approximately 1310 in a Cessna 172 for a one hour flight over portions of HORNBEAM's OPAREA. Mr. Farmer occupied the right front seat while I sat in the back. We both had binoculars.

2. We flew SE over Waquoit Bay and then over Nantucket Sound. When we were North of the eastern end of Nantucket Island we headed NE toward Great Point. We turned SE after passing Great Point thence S till we were abeam of Sakaty Head thence E then N and finally WNW back toward Great Point thence W and back toward Martha's Vineyard then back to Falmouth airport.

3. During the trip I sighted Turkernuck Shoal LBB1, Great Round Shoal LBB 13, B 11, Point Rip Buoy 1, Halfmoon Shoal LBB 18, Cross Rip LHB 21, Horseshoe LB 20.

4. The weather as recorded in the ship's log for 1200 and 1600 that date was: (Ship moored Woods Hole)

1200 - Wind 245°T 10 kts., Vis 10 mi., Wx. Clear, Baro 29.67 falling, temp. dry 63 wet 59.

1600 - Wind 180°t 12 kts., Vis 6 mi, Wx. Rain, Baro 29.64 rising, Temp. dry 56 wet 56 Clouds 10/10 NS.

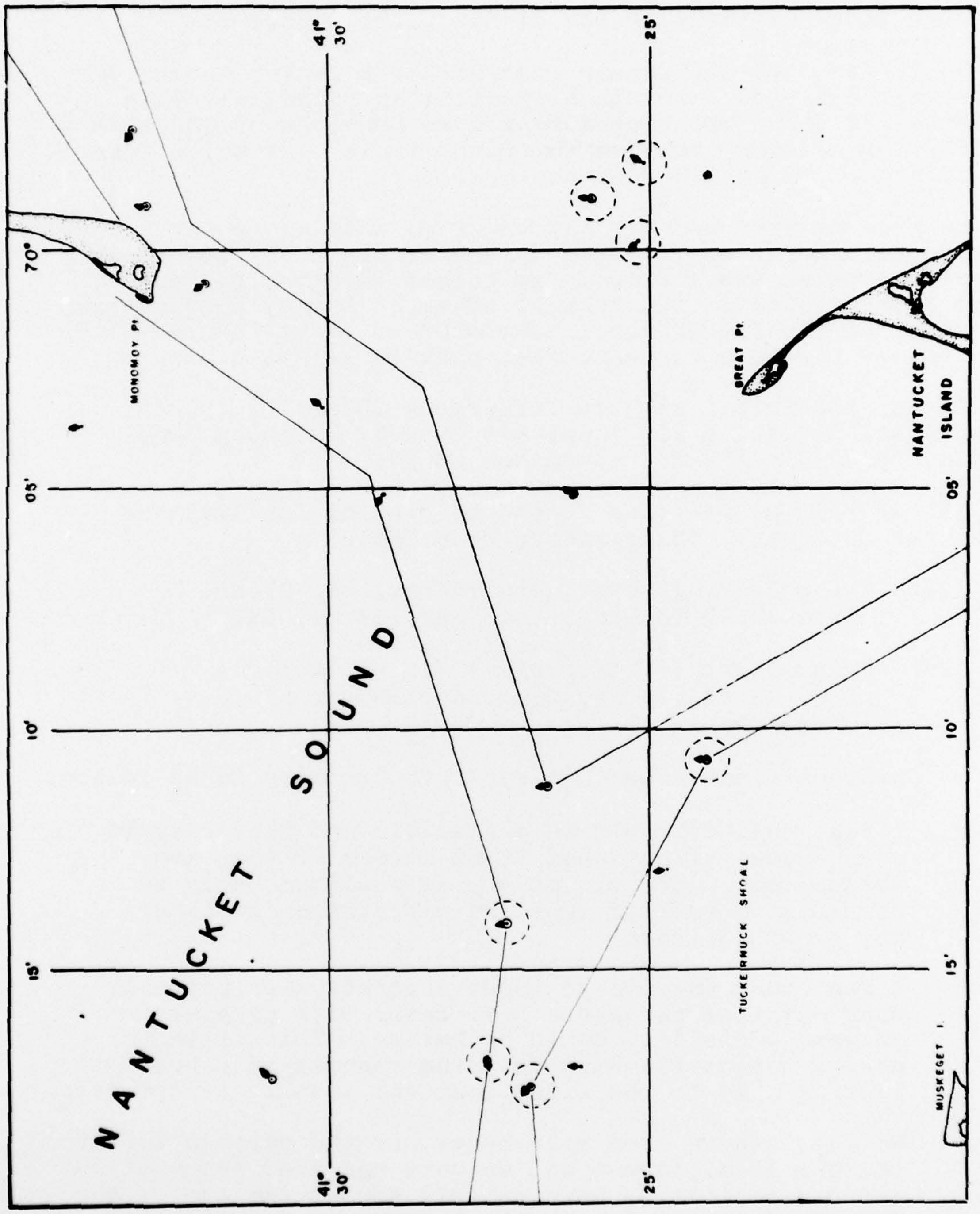
5. My opinions concerning this type of operation is as follows:

a. I feel that it would be a feasible and rapid way to check buoys after a bad storm to see if they are there. With good visibility it would probably be possible to tell if they are off station at least any great distance.

b. I feel that the use of light aircraft will probably work but that perhaps a helicopter with greater forward visibility would be better. This is the normal aspect (looking down the channel as opposed to looking only to the side) that the vessel officer sees.

c. We should have seen more buoys but the perspective from the air is different and we were hampered somewhat by reduced visibility particularly toward the end of the flight.

J. F. OVERATH
Commanding Officer
CGC HORNBEAM (WLB 394)


NANTUCKET SOUND
MONOMOY PT.
GREAT PT.
NANTUCKET ISLAND
TUCKERNUCK SHOAL
MUSKEGET I.
41° 30'
25'
70°
05'
10'
15'

APPENDIX D

SIDE-LOOKING AIRBORNE RADAR CHARACTERISTICS

THE FOLLOWING SLAR SYSTEMS ARE KNOWN TO EXIST OR CAN BE EXPECTED IN THE NEAR FUTURE

GOODYEAR APD-10:	This system has a 10-foot ground resolution and could probably provide sufficient resolution and detection for semi-precision audit.
Source:	Air Force - All units are stationed in Europe. Marine Corps- Will deploy this SLAR in one or two years, however, Corps' workload is projected to be so great as to just about rule out the use of these instruments for Coast Guard AN positioning.
GOODYEAR APD-7:	This system has a ground resolution of 100 feet.
Source:	Navy - Has operational units, however, this is a poor system, highly unreliable, and is being phased out. Probably would not be available for use on quick notice because of reliability problems.
GOODYEAR 102A:	This system has a 30-foot ground resolution and could potentially provide sufficient resolution and detection for semi-precision audit.
Source:	Litton Aero Service - This system would not be available on short notice, as required by the semi-precise audit task.
GOODYEAR 102:	This system has a 50-foot ground resolution. Insufficient information is available to establish whether the 102 has the required characteristics for AN positioning.
Source:	Air Force and National Guard Units - The Air Force, in general, has not indicated a willingness to cooperate in the AN positioning program. Individual National Guard Units might be more cooperative, or higher administrative level discussions could pave the way for Coast Guard - Air Force cooperation.

MOTOROLA
APS 94C and
APS 94D: These units have a published resolution of about 100 feet, but from the limited amounts of imagery available and from discussions with Motorola and USCG personnel familiar with this system, it does not appear that this system has demonstrated its ability to meet the requirements of the semi-precise audit task, in terms of positioning goals. Detection characteristics are also questionable, as they depend on apsect angle and sea state. Consequently, AN can go undetected.

Source: USCG AOSS program - Will deploy one unit on a C-130 early in 1977.
IIP - May obtain title to APS94C currently being used for the Great Lakes Ice Survey program.
MRS Program - Anticipates deploying six units by 1980.

Photograph #7 is an example of the higher quality Coast Guard APS 94 radar imagery.