GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station

PROJECT INITIATION

Date: September 27, 1972

Project Title: Design Study for Surface Effect Ships Radar
Project No.: A-1466
Project Director: Mr. P. B. Dyer
Sponsor: Texas Instruments, Inc.

Effective Date: 9/5/72
Estimated to run until: 15, 657.00

Type Agreement: Purchase Order No. W-660425 (subcontract under Navy Prime)
Amount: $15,657.00

Reports Required: Interim Letter Report; Final Summary Report

Sponsor Contact Persons: Contractual Matters
Mr. Floyd Miller, Buyer
Texas Instruments, Inc.
Purchasing Department, MS 514
P.O. Box 6015
Dallas, Texas 75222

Assigned to: Sensor Systems Division

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GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station

PROJECT TERMINATION

Date: January 25, 1973

PROJECT TITLE: Design Study for Surface Effect Ships Radar

PROJECT NO: A-1466

PROJECT DIRECTOR: Mr. F. B. Dyer

SPONSOR: Texas Instruments, Inc. (Subcontract under Navy Prize)

TERMINATION EFFECTIVE: 24 January 1973 (Final Report sent)

CHARGES SHOULD CLEAR ACCOUNTING BY: 31 January 1973

Contract Closeout Items Remaining: Final Invoice & Closing Documents
Government Property Inventory/Certificate
Final Report of Inventions

Sensor Systems Division

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m EES 402 (R10-62)
2 November 1972

Mr. Harlan Smith N/S-266
Texas Instruments, Inc.
Equipment Group
P. O. Box 6015
Dallas, Texas 75222

Reference: (1) Visit by F. B. Dyer to TI, 12 October 1972.
            (2) Memorandum by Carl Benning, 23 October 1972.
            (3) "Aids-to-Navigation Radar Requirements," W. Rivers,
                TR 1 on A-1277, January 1971.

Subject: Interim Report on TI P. O. W-660425

Dear Mr. Smith:

The purpose of this letter is to summarize work on Tasks 1, 2, and 4 to date. It provides recommendations for optimum completion of the requirements of Tasks 1 and 2.

The radar cross section predictions of debris type targets as called for by Task 1 have been carried to the point where a decision is required as to the optimum approach to meeting your requirements. Basically, the computer predictions and laboratory measurements show that (1) the reflectivity of various simply shaped pieces of dry wood (i.e., cylinders and rectangular shapes) is down by only 10 to 15 dB from the equivalent metal shape, while wet wood approaches metal in its reflectivity as it absorbs more and more moisture, and (2) height of the target above the surface of the sea is an extremely important parameter in determining median effective cross section. Preliminary measurements on a horizontally floating rail tie at the Boca Raton field site have substantially verified the results obtained by DECCA previously; however, all efforts, both analytical and experimental, to repeat the DECCA results for the piling and other vertically extending targets have failed. It is concluded that the cross section of targets, even of dry wood, which extend several feet above the surface is significantly greater than reported by DECCA. It is recommended that an intensive, but limited duration, field operation at Boca Raton be undertaken with the money remaining under this Task. It is believed that this approach will be the most effective in providing you with supporting data on cross section of debris targets.
Work on Task 2 has proceeded as planned. The prediction plots of shadowing probabilities which I delivered to you on the 12th are believed to be indicative of the actual probability of clear line-of-sight; however, numerous errors have been noted in the computer program developed by Wayne Rivers. Its most important failings lie in its lack of sensitivity to some of the variables which I believe intuitively should be of significance. We have not completed our review of the basic concepts of the shadowing model at this time. I recommend that we continue on our parallel paths on the development of the shadowing predictions and that we continue to compare notes at frequent intervals. It also may be practical to obtain experiment confirmation during the cross section measurement program recommended above.

I believe that work will be initiated shortly on the preparation of the test plan. I will need to discuss your requirements with you again, soon, particularly in the light of your recent briefing of PM-17. I will continue to be available for technical consultation, as required.

Yours truly,

F. B. Dyer
Senior Research Physicist
ENGINEERING EXPERIMENT STATION
Georgia Institute of Technology
Atlanta, Georgia 30332

Memorandum Report 1
Project A-1466

FIELD OPERATIONS AT BOCA RATON
4 - 8 DECEMBER 1972

by

S. P. Zehner and J. C. Butterworth

15 December 1973

Prepared for

Texas Instruments, Inc.
Dallas, Texas 75222
Purchase Order W-660425

Under
Contract N00024-73-C-0901
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I. SUMMARY

Data were taken at Boca Raton using the Georgia Tech radar (9.4 GHz), 0.25 μs pulse width, 250 kW peak power, -93 dBm receiver sensitivity, 81-foot antenna height) on 5, 6, 7, and 8 December. The data on the 5th were at one mile and the targets were not visible. On the 8th the sea was too rough to deploy the targets and only a clutter profile was taken. The data on the 6th and 7th had reasonable target-to-clutter ratios for the lens, the spar, and the drum. The floating log was only slightly above noise at one mile (there was very little clutter) and a peak effective cross section (99%) was measured as -48 dBsm. At all other times this target was far below the clutter signal levels.

On both the 6th and 7th atmospheric conditions were suitable for the formation of a surface evaporation layer and resultant microwave trapping. The peak effective cross section (99%) of the lens was 21 dBsm at 6-1/2 feet and 17 dBsm at 2-1/2 feet and did not change significantly with range. The values are slightly enhanced over its free-space value of 13 dBsm as measured at Georgia Tech before and after the field operation. Typical peak effective cross section for the spar was about 0 dBsm and for the drum was about -7 dBsm.

One successful observation of optical shadowing was made. This was at a range of about one mile and is in reasonable agreement with the probabilistic model.
II. ACTIVITIES AT BOCA RATON DECEMBER 4 - 8 1972

The X-band radar system was activated and data-collecting instrumentation assembled in the Georgia Tech operating van. After a moderate drying-out period, the radar was operated and data-collecting equipment was calibrated.

The Florida Ocean Sciences Institute (FOSI) at Deerfield Beach, Fla. was to furnish boat services and supply various targets to be used as typical objects which might be encountered as navigation hazards. FOSI was contacted and arrangements were made for deploying the following targets: (1) 55-gallon oil drum, (2) simulated spar buoy or small piling, (3) floating log, (4) two swimmers, and (5) calibration sphere +13 dBsm (lens). Photographs of targets were taken and are included. The simulated spar buoy was made up from a 3" x 8" x 16' weathered board with about 1-1/2 cubic feet of styrofoam for floatation and a scrap engine head and manifold for counterweight. This allowed six feet of the board to be out of the water and approximately vertical. The floating log was an old railroad tie 8" x 8" x 8' which floated 1" to 2" out of the water. The two swimmers were in the water with a boat cushion for floatation. The calibration sphere is an Emerson and Cummings Model 3L-112 Type 140 with measured cross section of +13 dBsm at 9.4 GHz.

A 42' sports fishing boat was used to haul targets from dock to target area, while a 22' open-hull stern-drive boat was used to tow and move targets to specific ranges. After trial movements were made by the small boat successfully the 42' sport fishing boat was released.

Radar cross section measurements were planned as follows. At several ranges (1/2, 1, 2, 3, 4, 5 miles) Targets (1) - (4) were to be deployed and return signal level from the radar's logarithmic receiver was to be recorded on magnetic tape and a time history recorded on strip chart. Both recordings were made by using a 50-nanosecond
sample and hold circuit which is gated in range and bearing. During all radar measurements, the antenna was scanning at a rate of ten scans per second. Calibration of absolute signal levels was verified by injecting an X-band signal generator pulse into the front of the receiver. Target (5) was used as a standard reflector to enable radar parameters and propagation conditions to be evaluated.

Observations were made from a height of 40' above sea level using a 30-power telescope mounted on the roof of a building. On 6 December a lobster pot marker (tentatively identified as a 1-gallon plastic jug) at approximately 1 mile was observed to be riding wave crests having a period of 5 seconds and was shadowed at this angle (1/3°) only 1 to 2 seconds per period. The sea conditions at this time were estimated from the boat to be 2' to 3' peak height with random chop. There seemed to be no long-period swells during observation. The observations were made looking up-wind to the marker. On 7 December another marker was observed in the morning when the sea was flat with no period and 100% visibility.

Weather and Sea State Conditions

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<tr>
<td>6</td>
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<td>SE</td>
<td>2-3</td>
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<tr>
<td>7 07:00 to 10:00</td>
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<td>SE</td>
<td>0</td>
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<td>7 10:00 to 16:00</td>
<td>5-7</td>
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<td>8</td>
<td>15-25</td>
<td>ESE</td>
<td>3-4</td>
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</table>
III. OPTICAL SHADOWING

Observations of a small float were made on 6 December 1972. The following estimates of the important parameters were made: observer height, 40 feet; target height, about 10 inches; seas, two-feet peak; wave period, five seconds; target range, about one mile (there was no corresponding radar contact). The fraction of time the target was obscured was observed to be about 20% to 40%.

Taking a simple geometric ray optics model with a spherical earth, we find that the angle of incidence at the target is 0.0066 radians for a 40-foot observer height, 6000-foot range, and an effective earth radius of one and an half times the geometric radius.

For a peak wave height of two feet, the dominant wave height is one foot. Using a simple wave form for the sea waves (the negative half of a sinusoid) and a 70% probability of a clear line of sight, the effective target height was computed to be nine inches for a forty-foot sea wavelength and eight and a half inches for a sixty-foot sea wavelength.

Using the probabilistic shadowing model as reported by Rivers in "Aids-to-Navigation Radar Requirements," the shadowing probability has been computed and is presented in Figures 1 and 2. The parameters used are: observer height, forty feet; standard deviation of sea height, four tenths of a foot; average sea wavelength, forty and sixty feet; bandwidth parameter ε = 0.7, effective earth radius, one and a half times the geometric earth radius; and target heights, 0.5, 0.6, 0.7, 0.8, 0.9, and 1.0 feet.

The effective height as determined from these curves is 1 foot for the forty-foot sea wavelength and 0.94 feet for the sixty-foot sea wavelength. If, on the other hand, we suppose that the target height was 0.8 feet, then the shadowing model predicts 0.5 to 0.6 for the probability of a clear line of sight.
The approximations in the deterministic model are such that the effective height as computed from it ought to be less than the effective height as computed from the probabilistic model. The assumed wave shape is probably too peaked and it neglects the effects of the higher than average waves. The results here would thus appear to be reasonably consistent.
figure 1. probability of clear line-of-sight for a sea wavelength of forty feet.
HC = 40.0 FEET. SZ = 0.40 FEET. RL = 60.00 FEET. EP = 0.70. RE = 1.5 x 2.09E7 FEET

HC = 0.50 , 0.60 , 0.70 , 0.80 , 0.90 , 1.00 FEET

Figure 2. Probability of clear line-of-sight for a sea wavelength of sixty feet.
IV. DATA ANALYSIS

The radar-return data as recorded on the strip chart were compared
with the signal generator calibration steps (10 dB steps, -20 dBm to
-90 dBm), and the median and peak values of each target run are tabu-
lated in Tables I and II using target type and range as a means of sort-
ing. These values were then substituted in the radar equation:

$$\sigma_e = -K + P_r + 40 \log R$$

where $\sigma_e$ = effective radar cross section in dBsm,

- $K$ = radar constant in dBm for 1 m$^2$ target at 1 nmi,
  -37.6 for high power
  -54.6 for low power
- $P_r$ = return power in dBm,
- $R$ = range in nmi.

The calibration and radar-return power levels as recorded on mag-
netic tape were transferred into a Fabritek Model 1072 Signal Averaging
System where signal generator calibration steps (10 dB steps, -20 dBm
to -90 dBm) as well as radar-return power levels are stored in a 256
(18-bit) word per memory quadrant. A signal processing amplifier which
controls gain and D.C. offset was used between the output of the tape
recorder and the input to the Fabritek. This transfers calibration
and radar target return power level to a digital probability density
form. The memory was then scanned and data punched in paper tape.
The digitized data and calibration were then read into a Digital Equip-
ment Corporation PDP-8 computer programmed to yield density functions
and cumulative distributions; these were then plotted by hand and are
appended to the report. The plotted distributions are listed in Tables
I and II and are presented in chronological order.
During the field operation the lens and the boat were observed to have little polarization dependence. The lens was held by hand in the boat at the various heights. It should be noted that the lens return at 1/2-foot height was less than or equal to the signal from the boat alone, and so was clearly dominated by the boat.

An attempt was also made to determine true cross section from effective cross section. This was done by computing and plotting propagation factors which account for the interference effect. These plots are appended to this report. The $F_1^4$ plots are for an incoherent uniformly distributed target and were used for all extended targets. The other plots include both a point-target interference model and the $R^4$ dependence and were used for the lens. These results and the calculated true cross section are included in the table. The radar equation for this case is

$$\sigma = -K + P_r + 40 \log R - 40 \log F,$$

where $F$ is the appropriate propagation factor.

The lack of a similar range dependence in the propagation factor and the effective cross section indicates that this approach is not appropriate. This effort met with limited and doubtful success and thus it appears reasonable to conclude that some trapping existed.
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<th>$\sigma_e$ dBsm 99%</th>
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Figure 3. Propagation factor for a point target at 0.5 feet and a smooth sea.
Figure 4. Propagation factor for a point target at 2.5 feet and a smooth sea.
Figure 5. Propagation factor for a point target at 6.5 feet and a smooth sea.
Figure 6. Propagation factor for a point target at 0.5 feet and a standard deviation of sea surface height of 1 foot.
Figure 7. Propagation factor for a point target at 2.5 feet and a standard deviation of sea surface height of 1 foot.
Figure 8. Propagation factor for a point target at 6.5 feet and a standard deviation of sea surface height of 1 foot.
Figure 9. Propagation factor for an extended target and a standard deviation of sea surface height of 0.16 feet.
$Z_1 = 91$ ft.  $AE = 10000$ nmi.  $DH = 0.56$ ft.  $\lambda = 0.106$ ft.
$Z_2 = 2.00, 6.00$ ft.  (HT-LAW NOT USED)

Figure 10. Propagation factor for an extended target and a standard deviation of sea surface height of 0.56 feet.
Figure 11. Propagation factor for an extended target and a standard deviation of sea surface height of 1.00 feet.
V. APPENDIX

Cumulative Distribution of Received Power
F-BAND DATA
7 DEC 1972
HIGH POWER

LENS %

PHASE: LON W1
X-BAND DATA
9 DEC 1972
HIGH POWER
14/12/72

L奈G 3''
 RANGE 2.72 Mi

1350 1352
V  X  M  -  o
Technical Report 1
Project A-1466

SURFACE EFFECT SHIP
NAVIGATION AND COLLISION AVOIDANCE
SYSTEM RADAR TEST
AND EVALUATION PLAN

by

Frederick B. Dyer

22 December 1972

Prepared for

Texas Instruments, Inc.
Dallas, Texas 75222
Purchase Order W-660425
Under
Contract N00024-73-C-0901
FOREWORD

The test program set forth herein was prepared for Texas Instruments, Inc. under Purchase Order W-660425 as a subcontract to contract N00024-73-C-0901. The work under this contract was a design study prepared for the Surface Effect Ship Program Office (PM-17) which details the parameters of a candidate radar system for use as a part of a Navigation and Collision Avoidance System (NACAS) which is required for use with surface effect ships. The test plan is written with the Texas Instruments system in mind; however, the general approach and most of the test program outlined is applicable for the testing of any similar radar and/or application.

The contributions of Messrs. J. C. Butterworth and S. P. Zehner and Mrs. M. J. Gary on this program and the efforts of Mrs. C. J. Murrell in preparing the final typing of this report are greatly appreciated.
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I. ORGANIZATION OF TEST PROGRAM

The purpose of the test program described herein is to provide the Navy with engineering and trials data which are sufficient to result in the definition of a radar/navigation system (NACAS) suitable for fulfilling the collision avoidance and navigation requirements of the high-speed, all-weather environment envisioned for the Surface Effect Ship (SES). A number of generally pertinent references are given in Section VI.

A. Concept of the Test Program

In order to achieve the goals implicit in the overall objective set forth above, the test program must provide data and/or guidance in the following areas:

(1) Specific tests are needed for the purpose of providing answers to conceptual questions and engineering problems which were not satisfactorily settled by laboratory or analytical investigations.

(2) Tests should be performed which validate the design concepts and assumptions forming the basis of the candidate system. It is particularly important that adequate time be allowed for the tests so that a variety of sea and weather conditions may be observed.

(3) Tests and operating experience, particularly in the early shore based tests, must be directed to shakedown of the equipment in order that interface, reliability, and maintenance problem areas be identified.

(4) Sufficient data must be obtained during the tests to provide for detailed evaluation of system performance against all priority targets or obstacles and in all anticipated operating modes. In order to achieve this goal in a finite time, it will be necessary to establish a matrix of priority measurement objectives and work to close schedules.

(5) Data should be obtained in an orderly fashion, with the primary numerical data resulting from use of well-established instrumentation and procedures. Extensive use of manual data log-keeping is a must for
providing the necessary controls implied under (4) above. It is important that timely analysis of the intermediate results be completed to ensure that all test objectives are achieved.

(6) At-sea and overall operational evaluation must be deferred until the shore tests have been assessed and preliminary integration tests on the test vehicle have been successfully completed. This suggests that at least three series of tests and/or trials should be planned: (a) shore tests; (b) preliminary sea tests; and, (c) sea trials.

While not strictly a part of the tests and trials program, it is recommended that a reasonable amount of time and funds be allotted to modifications and fixes of the candidate system between major test periods. The tests and trials are not to be considered completed until reasonable documentation has been completed and delivered, and a formal review of the results of the trials has been completed. These measures are indicated by previous experience as important steps toward the timely and satisfactory completion of a development effort.

Extensive tests are required to achieve the goals and objective outlined above. Specifically, measurements or observations of the following factors are necessary (only major categories are listed):

(1) Engineering Parameters
(2) Reliability
(3) Clutter/Weather Parameters
(4) Backscatter Behavior (both targets and clutter)
(5) Subsystem Performance
(6) Interface Effectiveness
(7) Human Engineering Effectiveness
(8) Ship and Operational Parameters
(9) Basic Performance (i.e., detection ranges, PD, P_{FA}, etc.)
(10) Subjective Performance (e.g., with operators)
(11) Mission Effectiveness
(12) Detailed Target and Clutter Data
(13) Electromagnetic Compatibility
B. Test Philosophy

Testing will be conducted to assess the candidate radar performance in meeting the goals set forth above. The general approach to the organization of the tests will be in terms of four basic categories: (1) engineering verification measurements, (2) engineering performance measurements, (3) dynamic performance measurements, and (4) evaluation of system effectiveness.

It is anticipated that (1) and (2) will be primarily accomplished at the shore test site using the extensive and elaborate test instrumentation which is required. A matrix of targets which are representative of the various classes of targets expected to be encountered by the Surface Effect Ship will be used. The organization of this phase of the test program will be carefully controlled and coordinated in order to provide extensive and detailed measurement data.

Data from the shore test phase will be used to provide statistically relevant measures of the pertinent system parameters and basic engineering performance. These tests will also be used to provide training and preliminary assessments of operational effectiveness. Shore testing will also allow for maximum interaction between engineering personnel and the radar, and will provide the opportunity for modification and debugging which would not be conveniently available on a ship.

The second phase of the test program makes use of a relatively spacious, lower performance ship other than the Surface Effect Ship. This phase will provide for extensive testing of the dynamic performance of the NACAS radar in the less rigorous and more spacious environment of a conventional ship. An additional benefit of including this phase in the trials program is the relaxing of the additional schedule demands that would be made on the Aerojet 100A test vehicle by reducing the need for extensive test time on the SES for the candidate NACAS radar.
Phase II of the test program would also be conducted in a controlled test area with continuous surveillance provided by shore-based radars. It is anticipated that the bulk of the detailed data required on a ship during at-sea testing would be obtained during this phase of the program.

The installation and actual trials of the NACAS on the 100A SES would be primarily directed toward operational evaluation of the candidate radar as a part of the integrated navigation system. Benchmark data will be obtained to correlate with the extensive engineering data which will have been obtained under Phases I and II. It is anticipated that data would be primarily in the form of manual logs and photography of the various displays. It is anticipated that the 100A SES would be operated in a number of different locations in order to obtain a better overall assessment of its utility for the mission requirements under a variety of environmental conditions.

C. Shore Tests

The shore site should have appropriate antenna heights available overlooking the ocean or large bay. The environmental conditions should be representative of the nominal operating conditions anticipated for the SES. This requirement suggests the need for an ocean site. While open sea conditions cannot be fully simulated at any shore site, certain sites experience a wide range of conditions.

The shore site should have buildings or shelters with sufficient space (estimated requirement is 200 sq. ft.) for housing the candidate radar system and necessary test equipment and auxiliary equipment. A suitable source of prime power (estimated requirement is 10 kW, 60-cycle, 3-phase) should be available, including converters for 400-cycle and 28 volts, as required. Logistic support and personnel accommodations should be readily available at minimum cost to the Navy. In addition to the specific test instrumentation, other equipment should be available for measuring and recording environmental conditions including
all pertinent atmospheric factors (i.e., wind speed and direction, refraction, and precipitation) and oceanographic factors (i.e., wave height, wave length, and sea direction). Ready access to a variety of support craft and mobile targets should also be available. Adequate communications equipment should be available.

A possible choice of site is the radar field site at Boca Raton, Florida. This site is leased by the Navy and is currently operated by Georgia Tech for use on several Navy programs. Extensive instrumentation, including several radars, is available at the site. A detailed description of this site is included in Appendix B.

D. Preliminary Sea-Trials

It is recommended that the second phase in the test and evaluation program be the installation of the candidate radar system on a boat of suitable size offering more readily accessible space and availability than the Aerojet 100A test vehicle. It is recommended that the test craft used for Phase II be a Coast Guard patrol boat of the WPB class (82 feet) or larger. A variety of candidate craft are available in Coast Guard or Navy inventory; it is recommended that the choice be based on availability at the appropriate time in the program. The requirement is for a ship that can be made available to the program for a minimum of two months in order to allow for adequate testing of the radar on board ship. It is anticipated that the candidate radar will be of modular construction such as to be readily installed and de-installed and will require little or no modification to the ship.

E. At-Sea Tests and Trials

The final series of testing (Phase III) contemplated here would be on the Aerojet 100A Surface Effect Ship. It is anticipated that careful scheduling will be required to ensure it would be available for installation and trials of the NACAS. Since the basic test schedule has been structured to arrive at Phase III with a radar which has
been extensively tested and evaluated it is anticipated that a minimum
of equipment difficulties will be experienced in Phase III. It would
be the focus of the test program at this point to obtain specific per-
formance data under the real environment of the SES. It is particularly
important to obtain data on those modes which are speed dependent and to
evaluate the utility of the NACAS under actual operating conditions.

F. Cost Estimates

The detailed cost estimates summarized in Table I are based on
evaluation experience with high-performance airborne radars and assume
that: (1) the development of all basic cabling and built-in test equip-
ment (BITE) will be borne by the equipment development program, (2) any
extensive rework or addition of new features found to be required during
testing will be separately budgeted, and (3) operating costs and direct
support costs for the test vehicles will have to be based on detailed
operating experience which is not yet available. The limitation implied
in (3) is based in part on the assumption that costs of operation of
the 100A during radar tests will be borne by the test program.

Supporting data for the cost estimates here are to be found in
principally in Sections II, IV, and V below. It is assumed that cost
factors of $40,000 per man-year of senior engineering support (both
Navy and Contractor) and $30,000 per man-year of technician support
are applicable. The manning requirements summarized in Table I result
in total cost estimates of approximately $50,000 for Program Office
personnel, and $50,000 for direct support personnel (not including boat
crews and support). The resulting total of $410,000 covers all three
phases of testing and all reporting. It is estimated that the test pro-
gram could be completed in nine months, including reporting, if required,
however it is recommended that a twelve-month period be considered for
the total test program in order to allow for contingencies, particularly
in scheduling. It is estimated that a total of $500,000 might be more
reasonable, particularly if portions of the operating costs of the 100A
are included. Such a budget would also allow for contingencies.
Table I. Cost Breakout

<table>
<thead>
<tr>
<th>Function</th>
<th>Cost By Manning Requirements (man-months)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Navy</td>
</tr>
<tr>
<td>I. Direct</td>
<td></td>
</tr>
<tr>
<td>A. Shore Tests</td>
<td>1</td>
</tr>
<tr>
<td>B. Preliminary</td>
<td>2</td>
</tr>
<tr>
<td>Sea</td>
<td></td>
</tr>
<tr>
<td>C. Trials</td>
<td>2</td>
</tr>
<tr>
<td>II. Indirect</td>
<td></td>
</tr>
<tr>
<td>A. Planning</td>
<td>3</td>
</tr>
<tr>
<td>B. Site Prepa-</td>
<td>1</td>
</tr>
<tr>
<td>ration</td>
<td></td>
</tr>
<tr>
<td>C. Installation</td>
<td>1</td>
</tr>
<tr>
<td>D. Reporting</td>
<td>2</td>
</tr>
<tr>
<td>Totals</td>
<td>14</td>
</tr>
</tbody>
</table>

* Transportation and logistics support; base support personnel, not including boat crews.

** Estimated totals for all three Phases.
G. Growth Potential

This test program outlined herein is structured to provide a thorough evaluation of the candidate radar for use in the NACAS as called for by the SESPO (PM-17). It is recognized that a high-performance vehicle such as the SES is very likely to be used as a weapon systems platform or for patrol or ASW missions. Since topside space and weight limitations are significant factors in the efficient use of the SES, it is recommended that the potential for multimode capability of the candidate radar system be evaluated in this test program.

The evaluation of the candidate radar system for potential use for detection and tracking of low-flying, high-speed aircraft and missiles and for use in an ASW mission could be accomplished directly in the framework of this test program by (1) providing appropriate targets, (2) providing the required additional time, and (3) by adding to the radar the required antenna modifications and airborne target signal processing. The basic concept of the candidate radar inherently is compatible with the concept of a multimode mission, therefore, only modest additions would be required to the hardware for including these expanded capabilities.
II. FACILITIES AND EQUIPMENT

This Section is a summary of the more pertinent characteristics of the candidate NACAS radar system and of the test equipment and facilities required for use in the tests described in Section III.

A. Candidate Radar

The radar system described in this section is the baseline system proposed by Texas Instrument for use in the navigation and collision avoidance system of the SES. This radar is based on the technology that was developed by Texas Instruments on the AN/APS-116 radar program for the Navy. The baseline radar is developed primarily around the concept of high resolution, using pulse compression and large-aperture antenna, and with other high-performance parameters commensurate with the limitations of the platform. A simplified block diagram of the candidate system is shown in Figure 1. Table II is a summary of those parameters of most interest to the test program.

Basically the candidate radar system consist of two complete radar systems having a common antenna assembly. Each radar operates continuously through its own feed and reflector system with capability for either circular or linear polarization, so that both radars are operated simultaneously but radiating in directions 180° apart. A concept of up-chirp and down-chirp on alternate pulses, alternating between transmitters, is used to minimize problems with range ambiguity and reduce interference problems between the two subsystems. This approach of complete redundancy is used in order to realize the specified system MTBF of 1000 hours. Certain items are common between the parallel systems, however, the high-risk components are all redundant. The system also has built-into fault-isolation features, and has a system integrity, GO/No GO, test capability for verification of total system operation capabilities.
Figure 1. Block Diagram of NACAS Radar
### Table II. Parameters of the Candidate Radar

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency - (GHz)</td>
<td>9.7</td>
</tr>
<tr>
<td>Peak Power - (kW)</td>
<td>50</td>
</tr>
<tr>
<td>Average Power - (W)</td>
<td>461</td>
</tr>
<tr>
<td>PC Gain - (dB)</td>
<td>24</td>
</tr>
<tr>
<td>PW - Transmit (μs)</td>
<td>3</td>
</tr>
<tr>
<td>PW - Compressed (μs)</td>
<td>0.01</td>
</tr>
<tr>
<td>System NF (NF₀) (dB)</td>
<td>3.5</td>
</tr>
<tr>
<td>PRF (Hz)</td>
<td>3,075</td>
</tr>
<tr>
<td>IF Beamwidth (MHz)</td>
<td>110</td>
</tr>
<tr>
<td>Transmit System Losses (dB)</td>
<td>5</td>
</tr>
<tr>
<td>One-Way Antenna Azimuth Beamwidth (Deg)</td>
<td>1</td>
</tr>
<tr>
<td>One-Way Antenna Elevation Beamwidth (Deg)</td>
<td>2.26</td>
</tr>
<tr>
<td>Antenna Gain (dB)</td>
<td>41</td>
</tr>
<tr>
<td>Effective Scan Rate (RPM)</td>
<td>360</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Debris Target</th>
<th>Mobile Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration Gain S/N (dB)</td>
<td>+11.1</td>
<td>+6.5</td>
</tr>
<tr>
<td>Integration Gain S/SR (dB)</td>
<td>+ 9.2</td>
<td>+5</td>
</tr>
<tr>
<td>Integration Gain S/RC (dB)</td>
<td>+ 9.2</td>
<td>+5</td>
</tr>
<tr>
<td>Rain Clutter Enhancement S/RC (dB)</td>
<td>- 7.8</td>
<td>-7.8</td>
</tr>
<tr>
<td>CP Loss S/N (dB)</td>
<td>- 4</td>
<td>-2</td>
</tr>
<tr>
<td>CP Gain S/RC (dB)</td>
<td>+10</td>
<td>+10</td>
</tr>
</tbody>
</table>
In addition to the 10-nanosecond pulse used for all longer ranges, a noncompressed 20-nanosecond pulse is also transmitted for very near range use. The two transmitter modes are operated concurrently so as to provide full coverage in range. The receiver is based on a very low-noise parametric amplifier front end with a successive chain of three AGC loops which act to keep the signal of interest within the dynamic range of the receiver as a function of range and bearing and changing sea conditions. The AGC loops are dynamically adjusted so as to control the false-alarm rates presented to the digital processors in the output phase.

Among the special features built into the radar which are significant to the test program are: (1) a searchlight mode for the antenna includes a special servo drive for positioning along any azimuth bearing, as required; (2) rf directional coupler and Test Panel which enable injected signal calibration of the receiver and testing of the performance of the pulse compression mode; and (3) a system for range and azimuth gating of any selected cell so as to allow data acquisition from a specific resolution cell.

While the radar is operated essentially in one mode, the video signal processing is organized in multiple but parallel paths so that simultaneous processing can take place for either mobile or debris type targets and tracking data for the CAANS can be provided at the same time as shown in Figure 2. If the advanced option of an aircraft detection mode is included, an additional parallel processing channel would be provided.

The scan-to-scan processing required to detect small targets in a sea-clutter environment is accomplished in the system shown in Figure 3(A). This system is similar in nature to the radar automatic target detector developed for the AN/APS-116, and consists basically of four parts plus the required timing and control associated with each part. These parts are the pulse-to-pulse processor, scan-to-scan processor, automatic gain control, and ground stabilization. A pulse-to-pulse processor reduces data so that scan-to-scan processing can be accomplished with a reasonable amount of storage. The pulse-to-pulse processor also yields an in-
Figure 2. Block Diagram of Receiver and Signal Processor Interface.
Figure 3(A). Stationary Target Detection Block Diagram.

Figure 3(B). Scan-to-Scan Track Partitioning.

Figure 3(C). Mobile Target Detection Block Diagram.

Figure 3(D). Mobile Target Processing Concept.

Figure 3. Block Diagrams and Concepts of Mobile and Debris Processors.
tegration improvement against noise. A scan-to-scan processor accepts the output of the pulse-to-pulse processor and performs the scan-to-scan integration required for detection.

Automatic gain control circuitry is required to ensure that the desired probability of detection and false-alarm rate are maintained. This is accomplished by monitoring both the input and the output of the pulse-to-pulse processor. In this manner, the number of false alarms from the radar is determined, and also the type of false alarm (noise or clutter) can be determined. This allows the input false-alarm rate to be adjusted as a function of range and also environment.

Because of the motion of the ship, ground stabilization is required for scan-to-scan integration. This is accomplished in three stages. First the scan-to-scan memory is North-stabilized to take care of any ship turns. Second, the change in range of a stationary target, due to the ship velocity, is corrected for by allowing the target to be tracked in azimuth, on a scan-to-scan basis. The range and bearing of the target, as well as the ship's velocity, affect the movement of the target in azimuth. Figure 3(B) shows how the area is partitioned for a maximum ship velocity of 100 knots. Numbers in the partitioned area represent the maximum number of azimuth bins the target is allowed to move between scans. As the target is tracked in azimuth, its past history is shifted to the new location at each scan.

The problems of detecting mobile targets are somewhat different from those of detecting floating debris. The detection threshold can be set more than 13 dB higher, because of the targets larger cross-section and height. This eliminates the requirement for extensive scan-to-scan integration and therefore the need for large dedicated storage. This is fortunate since the target, because of its mobility, does not remain in a small dedicated storage location long enough to allow any appreciable amount of scan-to-scan processing. However, associative tracking techniques can be applied to provide limited scan-to-scan integration and automatic detection of the larger mobile or stationary targets as illustrated in Figures 3(C) and 3(D).
Although the threshold used to obtain video for the mobile target detection processor will be set considerably higher than the threshold for stationary target detection, it is necessary to be able to automatically adjust the threshold to ensure that the target storage capacity of the mobile target processor is not exceeded. To accomplish this, the outputs of the pulse-to-pulse processor which are not declared to be land are counted on a scan-to-scan basis. The adaptive threshold is then automatically adjusted to provide the desired number of threshold crossings for optimum detection. In order to detect land masses and to exclude them from the processed area, the waveform generated for the stationary target threshold is constantly monitored.

The radar system has incorporated a Debris Display based on a 12-inch CRT that may be used either in a PPI Mode or as the readout for the digital scan converter. Associated with this display are the usual display controls plus the normal operating functions of the radar. This display unit has the flexibility needed to display either fully processed video or any one of several of the intermediate forms of videos. While this display unit is supplemental to main collision avoidance and navigational display (CANNS), it will be the primary display available for the shore tests. It may also be the only display available for use on the dedicated ship during the preliminary sea tests.

The display can be relatively simple because of the extensive pre-processing afforded by the various digital processing units, particularly the digital scan converter. This display has nominal range scales of 4, 8, 12, and 24 nautical miles, and may be used in a stabilized mode so that the true bearings can be provided in addition to relative bearing information. It also has the capability of providing a track symbol display that may be used for obtaining accurate range and bearing data on the selected cell. In addition to the integral BITE tests, built into the display system is a test mode in which a test pattern can be displayed as needed.
B. Test Instrumentation

The following is a brief description of the test equipment to be used during the evaluations. The equipment is divided into two categories, radar verification and performance data collection. The former will be used to verify that the radars are operating properly, and the latter will acquire the statistical data taken at the receiver's video output as well as the blip/scan data taken from the radar displays. The emphasis on detailed data collection during the shore tests requires the most extensive instrumentation to be available at the shore site. Tables III and IV are summaries of the instrument requirements for the shore and shipborne tests.

Verification that the radars are operating properly will be made prior to every series of tests. Measurements to be made are average transmitter power and receiver sensitivity. Average power will be measured using commercially available instruments and receiver sensitivity will be measured using a calibrated test signal provided by the radar manufacturer and an oscilloscope to indicate MDS. Visual checks will be made of the spectrum and time waveform transmitted, as well as the waveform of the video output pulse as displayed on an oscilloscope.

Performance measurements of the candidate radars are accomplished with three sets of equipment. Statistical data from the receiver's video output is gathered using pulse height analyzers and associated instruments. Qualitative measurements from the radar displays are recorded on counters and strip charts using a specially built interface. Performance in potentially high false alarm conditions will be recorded using a special test system called the Area Alarm Counter. All data are to be recorded either on magnetic tape or manual logs as appropriate.

Each of these sets of equipment is discussed in the following sections along with environmental instrumentation and other special requirements.

1. Shore Instrumentation

The statistical data collection equipment consists of a PHA (Pulse Height Analyzer, Fabritek Model 1072) which can generate probability density functions, sample and hold circuits to interface the radar video to the PHA inputs, and readout and storage equipment. This equipment can also be used to provide auto- and cross-correlations and time history summaries of selected data runs.
Table III. Test Equipment List

1. Oscilloscope - Tektronix 453A or equivalent
   Camera       - Tektronix C30 or equivalent
   Camera       - Polaroid CR.9 or equivalent

2. Voltmeter - Heathkit IM-102 or equivalent

3. Power Meter - HP 432A with HP 478A and HP 486A or equivalent

4. VSWR Indicator - HP 432A with HP 424A or equivalent

5. X-band signal generator - HP 620B or equivalent

6. Pulse Generators - HP 8004A or equivalent

7. Strip Chart Recorder - HP 680 or equivalent

8. DC Power Supply - HP 6204B or equivalent

9. PHA - Fabritek 1072 or equivalent

10. Waveguide Attenuator - HP X382A or equivalent

11. Magnetic Tape Recorder - CEC3300 or equivalent

12. Coax Attenuators (UHF) - HP 355C +355D or equivalent

13. Radiation Intensity Meter - Narda 8300 or equivalent

14. Transit - Keuffel and Esser Model 740000 or equivalent

15. Chain - Keuffel and Esser Model 880000 or equivalent

16. Sextant - Mark II or equivalent

17. Calculator - HP 9100 or equivalent

18. Sweep Generator - HP 8601A or equivalent

19. TV Camera - Panasonic WV-360P + WV-U90 + UVC-4508 NZ
   Recorder    - Panasonic NV-8020

20. PDP-8E, 8K words - Digital Equipment Corp., with Model LA30 DECwriter or equivalent

21. Sample-hold Circuits - Datel Systems Inc. Model SHM-2 or equivalent

22. Corner Reflector - 300 m² cross-section
Table III. Test Equipment List (continued)

23. Optical Micrometer - American Optical Corp. Models 71 + 424C + C109 or equivalent

24. Pulse Counter - HP 5324B or equivalent

25. Digital Magnetic Tape Recorder - Ampex TM-X or equivalent

26. Luneburg Lens - 1 m², 10 m², and 60 m² Emerson and Cummings or equivalent

27. Special Test Equipment
   (a) Area Alarm Counter
   (b) Radar Test Panel
   (c) Test Instrumentation Control Panel

28. Digital Clock - HP

29. 16mm Movie Camera - Bolex 16M, with radar synchronizer

30. Voice and Event Recorder - standard cassette recorder, battery operated
Table IV. Shipboard Test Equipment

1. Digital Tape Recorder - Ampex TM-X
2. Recorder Interface, A/D, Sample and Hold - Special Fabrication
3. 16mm Movie Camera - Bolex 16M
4. Digital Clock - Hewlett-Packard
5. Voice and Event Recorder - Standard Cassette Recorder
6. Polaroid Camera - Polaroid CR-9
7. Test Instrumentation Control Panel - Special Fabrication
8. Radar Test Panel
9. Oscilloscope - Tektronix 453A or equivalent

Notes: 1. Instrumentation to be rack mounted.
2. Test and Control Panels to be located near display console.
3. The 16-mm camera to be mounted on Debris Display; quick release fasteners to be used.
4. Storage space for film, magnetic tape, and supplies is required.
The sample-and-hold circuits are similar to those used in wide-bandwidth sampling oscilloscopes; however, the response is tailored to the radar pulse width and repetition rates. The waveform to be sampled (in this case, the video output of the radar) is passed into one input of a gate. The other input to the gate is a very narrow pulse of a fixed amplitude. The pulse gates a very short portion of the radar video onto a capacitor which stores the amplitude of the sample. The sampling pulse is synchronized to the PRF of the radar so that the sample always occurs at a fixed time (corresponding to a specific range) after the transmitter fires. The timing relative to the transmitted pulse is adjustable so that various ranges can be selected.

The pulse height analyzers sample the output of the sample and hold circuits at a time synchronized to the radar but after the video is sampled. The pulse height analyzer then counts and stores the number of times that the sampled radar output lies in one of 256 or 1024 (if required) amplitude "bins." After a predetermined number of samples have been taken, the process is stopped. The storage in the pulse height analyzer now contains a histogram of amplitude versus number of hits. This can be directly converted into a probability density function. A digital magnetic tape provides permanent storage for the contents of the pulse height analyzer. Multiplexing the input signals is used to remove the requirement for multiple measurement setups, but still allows for measurements on clutter and target-plus-clutter resolution cells simultaneously and for more than one video test point.

For surface-target data collection, a Hewlett-Packard Model 5245L electronic counter with Model 5264A preset plug-in will be used in conjunction with the radar display. The counter accumulates the number of times the operator indicates the presence of a blip on the display out of a preset number of scans. A key is provided each operator to indicate blip occurrences.

For airborne and other high-speed target data collection, a two-channel strip-chart recorder is implemented to record blip occurrences. One channel is used for blip indications. The other channel is used to record target range information acquired from a specially configured IFF interrogator. The resultant record provides indication of maximum detection range for
each target run as well as target track information to indicate performance limitations imposed by the clutter background. Time is also recorded along with data during each run.

Sophisticated equipment for acquiring meteorological and oceanographic data in the test area will be used. In general, visual estimates of the ocean's roughness are not considered to be adequate for all tests. Whenever surface targets are used in conjunction with the test operation, they will be requested to supply observations of wave height and wind speed and direction, thus providing supplemental data on subjective observations of the sea. The primary instrumentation will include a wave-height gauge, and air and water thermometers, recording anemometers, and a barometer.

An instrument of special significance for the test program is called the Area Alarm Counter. A conceptual block diagram of this instrument is shown in Figure 4; however the actual implementation will vary between the shore and the shipborne tests. The concept is intended to provide (1) a direct measure of the alarm rate from a selected area, and (2) greatly increase data rate for statistical data from area-extensive returns (i.e., clutter or precipitation). Since intermediate stages of processing can be analyzed with this equipment, it will be practical to explore in detail the actual improvements obtained by the various processing modes of the candidate radar. The key feature to this approach of evaluation is that it allows a direct interchange of temporal and spatial data, thus not only reducing the required observation time (by providing more independent samples in a given period of time than other techniques) but also improving the quality of the sampling of spatially dependent clutter.

The Test Panel to be furnished by the contractor will provide the processed and calibrated rf injected signal required for properly testing the pulse-compression receiver of the candidate radar. This unit will also provide interface for system test signals and system clock for use by external equipment. Also included as a part of the Test Panel and associated interface is a manual STC which may be used in place of the first AGC loop for certain tests. The injected signal of the Test Panel simulates an actual return signal of controllable amplitude; thus it will be one of the primary test aids provided for standardization of measurements.
Figure 4. Simplified block diagram of area alarm rate counter.
A seven-channel analog magnetic-tape recorder will be used to record receiver video and several of the related variables. A digital magnetic-tape recorder will be used to store the data obtained by the pulse height analyser and other digital output data from the candidate radar. A master time code generator, with slaved readouts at each recording or monitoring station, will be used to synchronize all events. Both sound-powered headsets and an intercom system will be available at all key locations.

A Digital Equipment Corporation PDP-8 will be available, on site, for analysis of the data in near-real-time and for use in preparing special analytical predictions, as needed. This computer will be interfaced to the PHA and recorders so that on-line analysis of selected runs can be accomplished if desired. The flexibility of this equipment, which is programmed in FOCAL* (a user-oriented language), is believed to be a very powerful tool for use in a complex test program such as envisioned here.

2. Ship Instrumentation

The instrumentation which will be used on board the test ships must be simpler and carefully chosen so as to minimize the load on the test personnel and operators. The equipment listed in Table IV is believed to be a good compromise between the desire to obtain as much data as possible from each run and the need for simplicity. Manual logs, voice tapes, and photography will be the primary modes of data acquisition. The sampling system and magnetic-tape recorder will be used for selected data runs to obtain priority measurements. The recorder will also be used to log the various input signals from the ship’s sensors.

The range support craft and larger target boats will be equipped with communications, time, and voice log equipments. They will also be provided with manual logs and cameras for use in recording pertinent supplemental data. The target aircraft will be required to log altitude, air speed, and any unusual events; however, only compatible communications equipment and radar altimeter will be required.

*Trademark of Digital Equipment Corporation.
C. Shore Facilities

The facilities described here are in addition to the general requirements for the shore facilities outlined in Section I. It is anticipated that the shore site selected will have adequate space for a modest level of maintenance support, including electrical and mechanical shops, and for data reduction and other paper work. This requirement may be met either by space in permanent buildings or by the use of vans. The shore facility should be set up to provide a reasonable transition from the environment of the laboratory to that of the ship, thereby minimizing the confusion which can result when initial testing is attempted in a hostile environment.

The site should be provided with a reliable, high performance, instrumentation radar that may be used to coordinate the tests, track mobile targets, and provide general surveillance of the test area. Use of this radar, together with good communications and chase boats, will ensure maximum utilization of available testing time. The Test Director may also use the instrumentation radar to set up specific test geometries without alerting the operators of the system under test. Use of this radar can also increase the reliability of the data obtained as well as help ensure safe operation of the target craft.

Redundant communications should be provided to ensure a minimum of problems with communications equipment and in the control of target and range craft. It is important that multiple channels and bands be provided in addition to spare equipment. Extensive experience has shown that poor communications has cost more test time than any other single item. In addition to VHF and UHF equipment, both Citizens Band and Marine Band (HF) facilities should be available. It will be necessary to coordinate licenses and frequency assignments early in the planning stages if necessary approvals are to be obtained in time.

It will be necessary to establish either IFF facilities or other transponder equipment for use with aircraft targets should they be included in the target matrix. Either approach is practical and would be optimum use of high-performance aircraft. Skin tracking is unreliable
under some conditions, and multiple aircraft in the area can lead to confusion. Strobe lights and other optical aids also can be of value in maximizing data from limited flight times.

D. Test Vehicles

Several craft will be required to provide adequate support of the shore test phase. The requirements include (1) target craft, (2) range safety craft, and (3) a work boat. The target boats include a dinghy (Boston Whaler), a 16- to 22-foot outboard or stern drive boat, a 30- to 40-foot fishing boat, and larger targets of opportunity. The range safety boat must be at least a 22-foot craft or larger which is free to monitor potential hazards. The work boat should be in the 50-foot class and be equipped with work platform and crane. The work boat will be required to position the larger debris targets and calibration buoys.

During the at-sea tests, the dedicated test ship will be required in addition to the various small craft described above. During the preliminary sea tests, the WPB, ocean-going tug, or similar craft can operate independently during portions of the test, if required. It is anticipated that range safety boats will be required when the 100A SES is operated in the test area because of its high performance. The number of supporting craft required will be dependent upon the weather and specific tests for the day; however, all movements of test or target craft will be closely coordinated.

E. Installation Requirements

Detailed plans for installation of the equipment will be required prior to the actual installation of the candidate system at the shore test site or on either test craft. Among the considerations are:

1. Good electrical and mechanical practices
2. Adequate ventilation and cooling
3. Good access to the equipment
4. Controllable lighting in the area of the displays
5. Adequate power
6. Good grounding and interconnection practices
7. Attention to EMC and potential radiation hazards
8. Human engineering to minimize operator fatigue
9. Coordination of locations and interconnections to facilitate data acquisition
10. Minimum of modifications to existing structures

It is anticipated that the Contractor will provide the detailed engineering necessary for satisfactory installation of the candidate radar at each test location, and that the Test Team will coordinate and plan the installation of all special instrumentation. The actual installations will be cooperatively accomplished by the Contractor, Test Team, and Host Facility.
III. SPECIFIC TEST REQUIREMENTS

The concept of the test program as described above results in the requirements for (1) engineering measurements of parameters of each subsystem; (2) performance measurements on each pertinent operating mode of the system, including measurements of probability of detection and probability of false alarm, and detection ranges for various classes of targets; (3) qualitative and quantitative measures of effectiveness of the system in fulfilling its intended mission; and (4) statistical data on the characteristics of target and clutter returns as observed by the candidate system.

The primary emphasis for Phase I (shore tests) will be on obtaining engineering data, statistical performance data, and target and clutter data. Data obtained with sample and hold circuits and recorded on magnetic tape for computer analysis will be supplemented by manual data logs and photographic records. Matrices of operating modes, targets, ranges, sea conditions, and data acquisition methods will be required to make sure that all pertinent data are actually obtained.

The emphasis for Phase II (preliminary sea tests) will be on obtaining: (1) performance data to compare with the detailed data obtained at the shore site, (2) dynamic operating data, and (3) data to use for guiding the development of interface hardware and procedures for maximization of the potential of the NACAS in the SES.

The emphasis for Phase III (at-sea trials) will be on actual operating experience in the dynamic environment of the SES.

Table V lists the principal target classes to be used during the test. Clutter measurements will include not only sea and precipitation returns, but land and other area returns where appropriate.

The principal video test points and outputs of the proposed NACAS radar are compiled in Table VI along with the nature of the output signals. The principal output of the CAANS system will be in the form of displayed data and auto/alert and auto/alarm outputs.
### Table V. Target Classes

#### Class I. Fixed, Calibration (Luneberg Lens)
A. Elevated Lens (kite or balloon) \( \sigma = 1 \text{ m}^2 \)
B. Calibration Buoy \( \sigma = 1 \text{ m}^2, 10 \text{ m}^2 \)
   Height Above MWL -- 2 and 10 feet
C. Positionable Lens \( \sigma = 65 \text{ m}^2 \)
   Height Above MWL -- 0 to 12 feet
D. Navigation Buoy -- USCG Classes 1 through 5; as available

#### Class II. Debris (Drifting)
A. Simple -- Telephone Pole, Oil Drum
B. Complex -- Tree with limbs, Cluster of timbers
C. Other -- Occupied Dinghy, Log Raft

#### Class III. Mobile
A. 16-ft Motor Boat
B. 30-ft Fishing Boat
C. Larger Craft (Targets of Opportunity)

#### Class IV. Special
A. Light Civilian Aircraft (Skyhawk)
B. Small Military Aircraft (T-33, A-4)
C. Simulated ASW Targets
D. High-Speed Surface Craft
Table VI. Video Test Points

<table>
<thead>
<tr>
<th></th>
<th>Nominal Pulsewidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. CAANS Tracker Video</td>
<td>150 ns</td>
</tr>
<tr>
<td>2. SC Video (Background Video Map)</td>
<td>150 ns</td>
</tr>
<tr>
<td>3. 10 ns Test Point Video</td>
<td>10 ns</td>
</tr>
<tr>
<td>4. Mobile Target Video (Area Gate Single Level Threshold Detected, specified $P_D$ &amp; $P_{FA}$)</td>
<td>75 ns</td>
</tr>
<tr>
<td>5. Mobile Target Video (above Video W/O Gating)</td>
<td>30 ns</td>
</tr>
<tr>
<td>6. Debris Target Threshold Video</td>
<td>30 ns</td>
</tr>
<tr>
<td>7. Automatically Detected Debris Target</td>
<td>R, $\theta$ Coordinates</td>
</tr>
<tr>
<td>8. Scan Converter Output Concentric Ring or Spiral</td>
<td>SC Output Raster</td>
</tr>
<tr>
<td>9. Scan Converter Output 60 RPM, 200-$\mu$sec Dead Time, 2-kHz PRF</td>
<td>Optimized for Display Range</td>
</tr>
<tr>
<td>10. Land Mass Output</td>
<td>R, $\theta$ Coordinates and/or Video Level Indicating Presence of Land</td>
</tr>
</tbody>
</table>
Analytical investigations have shown that the following items will be significant factors for investigation during the testing:

1. False-alarm rates in the higher seas
2. Detection and tracking of debris targets
3. Performance in precipitation
4. Dynamic performance on the SES
5. Effectiveness of chirp modes in suppressing ambiguities
6. Trade offs between antenna scan rates, stability, and performance

Special attention will be directed to assessing these factors.

A. Test Matrix

A review of the potential combinations of independent variables already mentioned above shows that there are five Sea States, three precipitation conditions (clear, light, and moderate), two pulse lengths, two polarizations, ten video test points, three output signals, and four classes of targets. The total number of combinations exceeds 25,000 if all fourteen types of targets are included. It is important that care be taken to select the most pertinent combinations so as to obtain a reasonable number of repetitions in a finite test program.

Table VII is a summary of the general categories of tests and measurements which will be considered. While this list is not exhaustive, it is intended to be a guideline to the more important tests which will be required. The tests listed cover the full range from calibration and verification all the way to qualitative assessments and dynamic operational evaluations. Detailed test procedures must be structured from such general tests in order to obtain specific, detailed data.

Several forms of recording will be used to collect the various related data; however, included on each magnetic tape, strip chart, or manual log will be time from a master time code generator. Regardless of other cross referencing data, time will be the primary correlation factor. Frequent time checks will be conducted, requiring that all reporting and recording stations have time indicating equipment. All primary variables will be logged both manually and by voice log.
Table VII. General List of Tests and Measurements

1. Statistical target and clutter data (Sample and Hold)
2. Area Statistics of clutter (Area Alarm Counter, Photos)
3. Engineering Verification Measurements (Injected Signal)
4. \( P_D \) and \( P_{FA} \) Measurements
5. Operator/Display Measurements
6. Shadowing Measurements (radar and optical)
7. Scan Time Visibility
8. Tracking and Maximum Range Measurements
9. Calibration/Propagation Measurements
10. Parameter Changes (i.e., Antenna Height, Polarization)
11. Software Tests
12. Human Engineering Evaluation
13. Reliability Measurements
The various required tests can be divided into four general categories as indicated in Table VIII. Each category covers a number of individual tests; however, the amount of time allocated to each category will depend more on the priority of the output data than on the number of possible tests in a category - specifically, each category must be considered in numerical order until a reasonable level of confidence has been achieved. That is to say, extensive Category I measurements are required prior to emphasis on Category II or higher tests. This approach requires care, in that a determined effort must be made to move to the next category as quickly as possible in order to arrive at the primary result of the test program, namely, the evaluation of the usefulness of the candidate radar system.

The most direct method of assessing the performance of the NACAS radar is by actual use against a variety of targets for extended periods. The most practical method of quickly obtaining data to guide an assessment is to establish a matrix of targets at several range intervals and directly measure $P_\text{D}$ and $P_\text{FA}$ for all targets and ranges. Repetition of this matrix for sea and weather changes provides a measure of the performance over most of the key input variables. If the radar meets all design objectives, either of these procedures is sufficient for the assessment.

The approach described here is based on the above techniques but is extended to provide the background data necessary to understand the limitations which will be uncovered. The extensive use of Category I tests initially will provide both a verification of parameters and a basis of understanding of the system for guiding the more sophisticated tests of Category III. The data from Category II measurements are needed for comparison with the analytical prediction models which are used to guide the interpretation of the Category III tests. The assessment from Category IV tests should follow readily from the basis provided by the more detailed assessments of Category III.
Table VIII. Test Categories

Category I

- measurement of engineering parameters
- calibration
- system verification

Category II

- statistical target and clutter data
- shadowing measurements
- area statistics

Category III

- performance measurements
- $P_D$ and $P_{FA}$
- tracking and maximum ranges
- software tests

Category IV

- evaluations of effectiveness
- dynamic performance
- qualitative assessments
Initial measurements will be directed to calibration and engineering parameter verification in all three test Phases. It will be particularly important to review losses, scan speeds, peak power, noise figure, and system integrity each time the system undergoes a major change or is moved to a new installation. Calibration against known quality Luneberg lens targets must be accomplished at least twice weekly, preferably daily. Injected signal calibrations will be included in every measurement sequence. Detailed calibration with the injected signal will be included on every magnetic tape and strip chart recording. The injected signal will also be used to assess MDS on a daily basis.

While Category III measurements will have priority during the measurement program, at least limited measurements of clutter background and area alarm rates will be included in every series of measurements of detection performance on targets. In the event that controlled targets are not available on a given day, every effort will be made to accomplish one of the following: (1) basic measurements of returns from the sea, (2) MDS and $P_{FA}$ measurements, or (3) observations of targets of opportunity. Equipment modifications or maintenance will be accomplished on a second shift whenever possible so as to minimize delays to the test schedule.

Every effort must be made to obtain some data early in the shore test program on the value of measurements from each of the several video test points. The most valuable points will be determined and attention will then be concentrated on those for future measurements.

The measurements schedule must be flexible enough to allow for special weather or sea conditions. It is important that any opportunity to obtain data in precipitation or in especially difficult (i.e., very spikey) seas is used to best advantage, even if scheduled targets or visitors must be delayed or cancelled.

The Test Director will use the full resources of the test range, including the instrumentation radar and safety boats, to exercise tight control over all measurements and establish knowledge of the placement and nature of each target. This is required for all test Phases but is extremely important for every run where detailed numerical data are to be
recorded and for trials runs with the SES where control of the environment will be especially difficult. If necessary, runs must be repeated until the quality of the data is verified.

B. Target Support Requirements

The target requirements will be approximately the same for similar tests whether a part of the shore tests or the at-sea tests. Specifically, for each run involving the detectability of mobile targets, at least two high-speed craft in the 16- to 22-foot class and at least one larger craft, such as a 30- to 40-foot fishing boat will be required. Each target will be positioned for maximum effectiveness according to the sea and weather conditions. For example, in high seas one, craft will be maneuvered in the region of maximum sea return and the other will be placed in the transition region between clutter and noise. The craft will then be run back and forth between areas of high and low detectability while measurements are made at the radar. Range safety craft will be placed so that data may be obtained from them during many of the tests.

The work boat which is used to place debris targets will also serve as a target as well as a platform for supplemental observations. The debris targets will be placed at ranges from the radar which are predicted to be marginal for existing sea conditions. Although several debris targets will be deployed on any given series, each debris target will be repositioned to several ranges during the course of a measurement series. The work boat or range boat will be used to provide positive identification of each debris target by moving to its vicinity, as required. All debris targets and buoys will be recovered when not needed so as to minimize hazards to navigation. Any buoy or floating target which is deployed for an extended period must be reported and included in Notices to Mariners.

Target aircraft will be carefully maneuvered to minimize hazards. All low-altitude flights will be undertaken along radials to the test site which are clear of shipping and other obstructions and which maximize the opportunity for observation and recovery of the pilot in the event of a forced landing. Initial runs will be made under optimum conditions of wind and
sea so as to minimize data acquisition difficulties. Additional runs with high seas will be scheduled after priority measurements are completed.

C. Data Requirements

The primary forms of output data will be (1) graphs and tables of $P_D$ and $P_{FA}$ for various targets, ranges, and sea states; (2) graphs and tables of effective cross-section of various targets versus the key independent variables; (3) summaries of reliability data, effectiveness, qualitative observations; (4) chronological summaries of sea and weather observations; (5) calibrated time histories of selected runs; (6) graphical summaries of shadowing, visibility, correlation times, and alarms versus threshold levels for various sea states; and (7) selected photographic examples. The tabulated and graphical data will be used, together with analytical predictions, to support qualitative assessments of the overall performance of the system.

Preliminary summaries of daily results must be prepared if at all possible. Weekly summaries, including graphical presentation of the data, are mandatory. These measures will help ensure adequate control of the tests, and will provide the Test Director with a running assessment of the performance of the radar and of the tests themselves. Proper formatting of the data, especially of calibration procedures, together with the use of automated reduction methods will greatly facilitate achieving these goals. The use of a minicomputer (PDP-8E) on-site will provide the required reduction of numerical data. Special arrangements must be made to get all data films developed quickly so that their review and analysis can be accomplished on-site.
IV. PERSONNEL REQUIREMENTS

The personnel requirements needed to accomplish this test program can be divided into three categories: (1) Navy personnel (program), (2) contractor, and (3) support (Navy and contract). The objective of this section is to define the duties and requirements for the key personnel involved in testing and evaluation.

The personnel whose primary responsibility it will be to ensure that the objectives of the test and evaluation program are met are the Project Engineer (SESPO), the Senior Engineer (contractor), and the Test Director. Their duties as well as those of the personnel who will provide them with direct support are outlined below.

A. Program Office

The SESPO Program Manager will provide a Project Engineer whose duties will be to coordinate the efforts of the contractor during every phase of development and evaluation. The Project Engineer will be assisted by a Technical Advisor, whose primary duties will be to assist in development of specific technical objectives of the program and will be available to review detailed design changes and technical problem areas, and by other Program Office personnel as needed.

A part of the duties of the Project Engineer will be to provide for coordination with other Navy activities, such as OPTEVFOR, in order that Fleet support, facilities, and other needed support personnel and logistics are available when needed.

The Navy will name an Activity or contractor to serve as the focal point for ensuring that the detailed test program is accomplished. The key individual involved will be the Test Director whose primary responsibility will be to prepare and coordinate the detailed test program and to provide direction of the Test Team. The Test Team will consist of
an Assistant Test Director and several senior engineering personnel who are experienced in field testing and who have worked for the Test Director or Assistant Test Director on other programs. The Test Director will coordinate closely with the Project Engineer and key contractor individuals to ensure the success of the program. As a matter of principle, the Test Director will be responsible to the Program Office and will provide all test results directly to the Program Office.

The Program Manager will closely monitor the progress of the effort on the test and evaluation program through the Project Engineer so as to provide key decisions in a timely manner. It is important that this review be accomplished at several check points as indicated in Section V below in order to ensure that significant objectives of the evaluation are met.

B. System Contractor

The System Contractor will provide a Program Manager and a Senior Engineer whose primary duties for the Test Program will be coordination of the efforts of the contractor-supplied engineers and technicians during the several phases of testing and evaluation. The Project Engineer will be responsible for ensuring that necessary documentation and maintenance support is provided during testing and that appropriate engineering talent is available as required.

The Contractor will provide two, or more, technicians and/or field engineers who are thoroughly familiar with the equipment continuously throughout the testing. These support personnel are to be supplemented by specialists, as required. During all testing phases, the contractor personnel are to be under the direction of the Test Director who will coordinate with the contractor Senior Engineer as needed.

C. Other

Other personnel requirements will be provided either by Navy Activities or under contract to fulfill the support roles required during each of the three Phases of the test program. During the tests, commercial charter craft and/or Navy vessels will be required both as mobile targets
and for the placement of other targets and test buoys. Logistics and maintenance support will be required of the host facilities involved during each phase of testing.
V. SCHEDULES

This section contains a tentative schedule of events for each phase of the test program. It is the purpose of this schedule outline to provide a perspective to the interrelationship of the various tests and measurements rather than to provide a specific time sequence of events as will be required for actual testing. A detailed schedule must be based on the specific nature of the candidate system to be tested as well as on choices of sites and test vehicles.

It is anticipated that detailed laboratory engineering measurements of all pertinent system and subsystem parameters will be made prior to delivery of the candidate radar. If the Project Engineer and Test Director are not satisfied that an adequate documentation of these parameters has been achieved, it will be necessary that additional measurements be obtained either at the contractor's facility or other suitable laboratory. This requirement is to ensure that (1) the system is ready for field testing, and (2) minimum field-test time is expended on basic measurements. It is also assumed that test and project personnel will have had sufficient orientation and training in the operation of the radar system prior to initiation of field testing to allow immediate, productive utilization of the test time.

The shore tests will be undertaken in four overlapping phases: (1) installation and shakedown, (2) engineering verification, (3) performance evaluation and (4) de-installation. It is anticipated that a minimum of eight (8) weeks will be required to accomplish the goals of the shore testing. If correction of major deficiencies or extensive engineering changes are undertaken as a result of the shore testing, it may be necessary to repeat some or all of the shore tests for verification.

The preliminary sea tests will be undertaken in three phases: (1) installation and shakedown, (2) performance evaluation, and (3) de-installation. Since it is anticipated that extensive engineering data will al-
ready be obtained, the additional verification data required will be ob-
tained during the shakedown period. It is anticipated that a minimum of
six (6) weeks will be required to accomplish the goals of the preliminary
sea tests. The primary pacing items here should be the weather and schedul-
ing of target services.

The final phase of at-sea trials on the 100A SES will be undertaken
in three phases: (1) installation and shakedown, (2) performance evalu-
ation, and (3) de-installation. It is anticipated that a minimum of six
(6) weeks will be required to accomplish the goals of this phase. The
pacing items here are target schedules and weather versus priority sched-
ules for the test vehicle. At the conclusion of the evaluation and
trials, as determined jointly by the Project Engineer and Test Director,
the results will be presented to the Program Manager. At the discretion
of the Program Office it may be desirable to leave the NACAS installed
on the test vehicle for an extended period for long-term evaluation.

A. Shore Site Schedule

The weekly summaries below are intended to highlight the key events.
Many measurements and test procedures will continue throughout the test
period at the shore test site.

First Week: Installation of radar system in test facility. Run wave-
guide and install antenna at initial height (40 feet).
Install data acquisition instrumentation. Begin extensive
system checking, including voltage, waveform, thermal
measurements. Begin verification check list. Install
calibration buoys.

Second Week: Complete installation of equipment. Complete preliminary
verification measurements. Establish daily parameter check
list for basic system verification checks. Verify operation
of range instrumentation, monitors, surveillance radar,
communications, and IFF. Walk through complete dress re-
hearsal of data acquisition procedure, including logs and
time sequence events. Test Director will determine if
Phase (1) is completed; if necessary, additional time will
be allowed for successful completion of Phase (1) goals.

Third Week: Begin Phase (2), detailed engineering verification. Con-
tinue daily parameter check list and basic system checks.
Continue smoothing data acquisition procedures and begin
preliminary performance measurements on Class I and Class II
targets. Test Director will determine if Phase (3), evalu-
ations, can begin. Phase (2) will continue as needed.

Fourth Week: Begin Phase (3), performance evaluation. Continue daily
parameter checks. Perform daily calibration measurements
on Class I targets. Establish daily performance measure-
ments on Classes I, II, or III targets as weather and sea
permit. Obtain statistical data on various targets and sea
return. Begin assessment of various operating modes and
signal processing formats. Begin weekly review by Project
Engineer and Test Director of results of measurements and
evaluations - plan succeeding week's schedule to maximize
target utilization.

Fifth Week: Continue Phase (3) as per Week Four. Interim report to
Program Manager on results to date. Review schedules
and priorities.

Sixth Week: Continue Phase (3). Concentrate on priority matrix of
measurements. Establish detailed operating procedures
for use of various modes. Make any necessary field changes.
Begin measurements with Class IV targets (aircraft). Weekly
review and assessment of results.

Seventh Week: Continue Phase (3). Increase emphasis on expanded target
matrix and multiple target operations. Detailed review
of results and preliminary report to Project Engineer.
Eighth Week: Continue Phase (3). Complete priority tests which have not already been completed. Preliminary report to Program Manager and critique of evaluations. Decision on status of Phase (3). If the conclusion is that Phase (3) is completed, begin Phase (4), de-installation; if not, continue field operations as required.

B. Preliminary Sea Tests

The preliminary sea tests will be scheduled to follow any factory rework period which may be required as a result of the shore tests. Installation will be coordinated with availability of test ship.

First Week: Installation of equipment at dockside. Facing item will probably be installation of antenna and radome assembly. Hot Tests at dock side. Check of EMC and interface with CAANS (if available for this Phase). Decision by Test Director and Commanding Officer as to suitability of and completion of installation.

Second Week: Transit to controlled test area (if necessary) and begin shakedown tests. Operations with calibration targets (Class I) under surveillance radar control in the test area. Evaluation of operation procedures and data acquisition methods. Begin performance evaluations on Class I and II targets. Status evaluation by Test Director-decision to proceed to Phase (2) or not.

Third Week: Continue operations in controlled test area as a part of Phase (2) tests. Continue performance evaluations with Class I and II targets. Begin performance evaluations with Class III (mobile) targets. Detailed review of results to date by Project Engineer and Test Director. Interim report to Program Manager.

Fourth Week: Continue operations in controlled test area as a part of
Phase (2) tests. Continue performance evaluations with Class I, II, and III targets. Begin operations in open-sea and high-traffic areas. Review of results by Test Director decision on priority measurements for Week Five.

Fifth Week: Continue Phase (2), performance tests, and efforts to complete matrix of priority measurements. Continue operations in less controlled areas (operational assessments). Review by Project Engineer and Test Director—decision as to priorities for Week Six.

Sixth Week: Completion of measurements. Demonstrations for visitors. Review by Program Manager—decision as to termination of preliminary Sea Tests. De-installation of equipment and release of test craft for other duties.

C. At-Sea Trials

The at-sea trials on the Aerojet 100A SES will be scheduled by the SESPO upon recommendations by Test Director and Project Engineer at the completion by Test Director and Project Engineer at the completion of Phase II testing. It is anticipated that essentially all equipment modifications required will have been accomplished at this time. Key testing will be directed to operational evaluation of the composite NACAS including automatic target acquisition and tracking modes under high-speed operations.

First Week: Installation of equipment at dockside. Pacing items will be cabling and antenna installation. Hot Tests at dockside. Check of EMC and interface with other ship's systems. Walk through on operations and data acquisition procedures. Refinement of check lists and procedures.

Second Week: Completion of installation and check outs. Dress rehearsal of data acquisition and evaluation procedures. Shakedown run if approved by both Test Director and Commanding Officer of test vehicle. Review of status by Project Engineer and
Test Director—decision to proceed to Phase (2), performance evaluations.

**Third Week:** Begin operations in controlled test area as a part of Phase (2) tests. Performance evaluations with Class I, II, and III targets. Begin assessments of total NACAS including GAANS and various automatic modes.

**Fourth Week:** Continue operations in controlled test area as a part of Phase (2) tests. Continue assessments of automatic modes. Detailed review of results to date by Project Engineer and Test Director. Interim report to Program Manager.

**Fifth Week:** Continue assessments, especially automatic modes against Class III targets (mobile). Operations in high density traffic areas. Complete detailed performance tests. Review of status of test program by senior personnel. Decision on completion of Phase (2) tests—continue into week six if necessary.

**Sixth Week:** Simulated operational use. Demonstration runs for key personnel. Decision by SESPO on status of test program. Remove equipment from test vehicle, if required. Final report on Phase III testing.

**D. Reporting**

It is considered very important that periodic and timely reporting be included as a part of the test and evaluation program so as to ensure that the evaluation objectives are met. The schedules above call out interim and final reports for each test phase. A final summary report of the results from the total test program will be provided within 60 days of the completion of the test program. This report will include detailed data summaries as well as the results of the evaluation.
VI. REFERENCES


VII. APPENDICES
A. Generalized Experiment Design

The following steps form an approach which explicitly states some of the factors affecting experiment design decisions. The purpose of the outline is to make the process of design as automatic and as complete as practical, to reduce the work of preparing input data for decision by systematic organization, and to reduce the likelihood of overlooking important factors. These steps should serve to remind the experimenter of things he should consider, but some features will be more relevant to a particular experiment than others, and have been included for generality.

Step I. Identification and classification of variables: The list of variables of a given experiment can be lengthy, and if they were all of equivalent importance, a complex experiment would be more than difficult to carry out. Experimental variables can be classified into three types:

A. Can be chosen at will by the experimenter; perhaps subject to constraints such as domain limits or quantization or resolution. The experimenter is responsible for designating values to be used.

B. Variables set by factors or conditions not under control of the experimenter; e.g., environmental conditions, system parameters which are a result of design, combined with natural drifts.

C. The dependent variable(s) of the experiment, those which represent the outcome. Because they are to some extent unknown, attention must be given to prediction of likely range of values, so that successful measurements can be made.

This classification scheme identifies the duties of the experimenter with respect to the variables of the experiment.
Step II. Characterization of the variables: For those variables in the groups shown the following are estimated.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Type</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain or Values</td>
<td>Indep., Dep.</td>
<td>The range over which the variable is expected to vary, or the values which are to be set or achieved. The units in which the variables are to be measured are chosen.</td>
</tr>
<tr>
<td>Increment or factor</td>
<td>Indep.</td>
<td>Step size of the primary independents.</td>
</tr>
<tr>
<td>Precision</td>
<td>All</td>
<td>The resolution with which the variables are to be measured.</td>
</tr>
<tr>
<td>Base bandwidth</td>
<td>All</td>
<td>The rate at which the measurable is expected to change.</td>
</tr>
<tr>
<td>Smoothing time constant</td>
<td>All</td>
<td>How much integration is used prior to sampling or recording.</td>
</tr>
<tr>
<td>Sampling rate</td>
<td>All</td>
<td>How often the variable is to be recorded.</td>
</tr>
<tr>
<td>Recording medium</td>
<td>All</td>
<td></td>
</tr>
</tbody>
</table>

These properties serve as input information for the selection and specification of sensor, signal conditioning, telemetry and recording equipment as well as the definition of the matrix of independent variables. A form is attached to aid in identifying measurement requirements.

Step III. Equipment: Block diagrams are required which show the relationship of equipment elements of the experiment. These elements include not only the sensors and recording devices but also the means of transmitting signals between them. The diagrams show the relationships and the guide choice of communication channels.

Specifications are prepared for the equipment, and these are separated into internal performance and parametric parts and interface specifications. The interface specifications are of particular importance as a check on the compatibility of the equipment elements.
Step IV. Manning requirements: The functions which must be performed by humans are delineated, roles are defined, and the duties of units and individuals are listed.

Step V. Experiment matrix and time schedule: The independent variables have been examined to establish the domain over which they are to be set. In general, the joint domain is a large volume in a multidimensional space, and for any given assignment of variables quantization (step size) the total number of combinations of experiment points is too great for the time or funding budgets of most programs. Therefore, it is usually necessary to make two compromises. One is to reduce the number of points along most of the independent variable dimensional axes to a very few; the other is to examine only principal-axis values of the variables where the cross coupling of variables can be estimated to be acceptably weak. Information to guide these decisions comes from theoretical models and parameter sensitivity analyses.

The experiment matrix is used to outline a time schedule for the orderly and efficient acquisition of data for each of the matrix points. Operational factors affect such features as the continuity of measurement along certain variable axes and the accuracy with which the experiment procedure simulates intended tactical use of sensors.

It should be recognized that efforts to outline schedules reflecting the experiment matrix indicate primarily desire at this point and that realism may be lacking until rehearsal opportunities are afforded. However, an early outline of the Epoch, Duration, Event Descriptor and Functions of the various units of the experiment is an important hypothesis for testing by later rehearsal or detailed scenario preparation.

Step VI. Data handling: Flow diagrams are prepared which show how each measured or recorded datum is to be handled or processed from the point of acquisition through the recording, format changing, cali-
bration, combination with other data, and organization and output for
interpretation by the experimenters. These flow diagrams are used to
design procedures and assure their completeness and adequacy for data
reduction in bulk by forcing attention to each step of the handling in
turn.

Step VII. Supporting information: One of the outputs of theoretical
model studies should be a substantial amount of software in the form of
programs, tables, and graphs which are a basis a priori against which re-
duced experimental data can be compared. These aids to the reduction
and interpretation of the data come largely from analytic models based
on assumptions set prior to the experiment; they form a package which
must be carried forward to the time after the data acquisition.

The above steps are elements of a plan for experiment design, but
they do not constitute a field document. To the above must be added
material on:

1. Operational description of instrumentation
2. Set up procedures
3. Data collection and verification procedures
4. Calibration procedures
5. Logistics requirements
6. Operational information such as communications data and a
calendar-related schedule.
B. Boca Raton Field Site

1. Introduction

This appendix describes some aspects of a radar/radio field test site that has been operated by Georgia Tech's Engineering Experiment Station for the Navy since 1953. The field site is situated directly on the shore at Boca Raton on the eastern coast of Florida. Its location has the great advantage of overlooking an area where there is deep water very close to shore, making possible controlled observations of targets, including large vessels, under clutter conditions closely resembling those of the open ocean. Moreover, the depth of the water and the passage of the Gulf Stream very close to shore in this area bring about the presence of an unusually high density of interesting targets of opportunity.

2. Location of Site

The field site is located on the Atlantic Ocean within the city limits of Boca Raton, Florida, a small city with a population of about twenty-five thousand. Boca Raton is forty miles north of Miami and twenty-five miles south of West Palm Beach. Airline service is available via connections to Miami, West Palm Beach, and Fort Lauderdale. Boca Raton has a general aviation airport with a 5000-foot runway and instrument approach. The precise geographical location is latitude 26° 22' 12" north, longitude 80° 40' 07" west.

3. Topography and Weather

The Gulf Stream passes unusually close to shore along this section of coast, its near edge being typically between a few hundred yards and a few miles off-shore. This fortuitous occurrence of the deep water of the Gulf Stream so close to shore is the prime reason for choosing this particular area for the field site. Most ocean vessels can maneuver in relative safety as close as 3,000 yards to shore. Because the water is
quite deep so close to shore, the surface of the ocean retains many of the characteristics of the open sea. Figure 5 shows the water depths in the area, and Figure 6 details the bottom near the field site.

The climate is quite mild and allows work to proceed year around with a minimum of delay due to weather. Extremes of weather are rare and generally arise from hurricanes or squall lines. Hurricanes can occur in this area throughout the year, but the months of greatest frequency are September and October. Extremely heavy precipitation has been observed at times. The overall climate may best be described as maritime tropical and similar to that of the Caribbean region. Influenced by the close approach of the Gulf Stream, the winters are dry and mild, while the summers are warm with considerable rainfall. See Figures 7 and 8 for yearly rainfall and waveheight details.

The topography of the area is dominated by the elevated coastal ridge which begins at West Palm Beach and continues to the Miami area, where it becomes partially submerged and forms the backbone of the Florida Keys. On the beach side of the coastal ridge, a dune has formed which varies in height and width with location. It is on this dune that the tower for the Georgia Tech Field Site is located. At the base of the tower, approximately 100 feet from the mean surf line, the dune is 28 feet above the mean water level. The 53-foot height of the tower gives a total antenna height of 81 feet above the water. The resulting depression angles at most ranges of interest are comparable to those encountered in shipboard installation. The tower is shown in Figure 9.

4. Grounds and Support Facilities

The test site comprises a large parking area and a fenced compound approximately 85 feet by 60 feet. The compound has two concrete-block buildings, each 27 by 20 feet in size, connected by a breezeway. The van containing the X-band radar is located at the north end of the enclosure. See Figures 10 and 11. The north building, which is completely
Figure 5. Boca Raton Area Chart.
Figure 6. Ocean Bottom Detail for Boca Raton Radar Site.
(Surveyed by Florida Atlantic University)
Figure 7. Average Weather Conditions for Boca Raton Coastal Area. (U.S. Weather Bureau)
FOR COASTAL AREA FROM PALM BEACH TO MIAMI FLORIDA
SEA AND SWELL UNIT, DIVISION OF OCEANOGRAPHY
US NAVY HYDROGRAPHIC OFFICE.

Figure 8. Observed Ocean Wave Height for Boca Raton Coastal Area. (U.S. Navy Hydrographic Office)
Figure 9. A View of the Radar Tower at Boca Raton.
Figure 10. Elevation View of Boca Raton Radar Site.
Figure 11. Plan View of Boca Raton Radar Site.
air conditioned, contains two equipment rooms, work shop, and bathroom. The south buildings, used primarily for storage, has a double door six feet wide opening onto a concrete slab. This is convenient when moving heavy or bulky equipment.

The buildings have all utilities, including city water, telephone with outside bell, and 120/208 volt three-phase power service. The electrical capacity has been revised recently to 200 amperes. Power at 400 cycles is also available for equipment requiring this frequency.

A steel piling has been installed 700 yards due east of the site in approximately 30 feet of water; this piling services as a platform for oceanographic and meteorological sensors. At present it supports a Hytech Model 9010 wave and tide monitor system, and a red obstruction light. An undersea cable supplies power for the light and connects the wave monitor to recording equipment in the compound. See Figures 12 and 13.

Wind speed and direction at the field site are measured by instrumentation located inside the compound. Remote readouts are provided in the X-band radar van.

The Florida Ocean Science Institute (a non-profit corporation) is available to provide diving service and rental of various sizes of support craft upon reasonable notice. Other commercial marine, fabrication, and support-oriented businesses are convenient to the site.
Figure 12. Profile of Ocean Bottom Looking East.
Figure 13. Oceanographic Piling at Boca Raton.
Mr. Harlan Smith, M/S-266  
Texas Instruments, Inc.  
Equipment Group  
P. O. Box 6015  
Dallas, Texas 75222  

Subject: Final Report on Georgia Tech Efforts Under  
Purchase Order W-660425  

Dear Mr. Smith:

The purpose of this letter is to summarize efforts on the four  
tasks called out under the subject Purchase Order. This letter will  
also serve as the final report, as no formal final technical report  
was required.

The work under Item I included a series of analytical efforts  
to provide a realistic model of the shadowing of debris targets by  
sea waves. A limited summary of the analytical work and a set of working  
curves were provided as part of a letter to Mr. Carl Benning (dated 22  
December 1972). Limited experimental confirmation was obtained in the  
Boca Raton field operation of 4 through 8 December. These data were  
reported in Memorandum Report Number 1, dated 15 December 1972. Extensive  
discussions of the influence of shadowing took place in a series of  
meetings held at Texas Instruments.

The work under Item 2 included limited analytical predictions and  
laboratory measurements of the effective radar cross-section of debris  
targets of simple geometry and an extensive series of measurements of  
returns from actual debris targets at the Boca Raton field site. A  
simplified technique for prediction of effective cross-section was  
described to Mr. Carl Benning during the October meeting. The experimental  
measurements tend to confirm the predictions made from that model. The  
experimental measurements are summarized in Memorandum Report Number 1.

The work under Item 3 was completed in December and a preliminary  
draft of a composite test plan was delivered on 24 December. This test  
plan includes all aspects of the testing of the NACAS radar and includes,  
as a subset, those requirements for a minimal test of the system. The

The work on Item 4 has included extensive discussions of the trade-offs between the candidate approaches to the NACAS radar with Texas Instruments personnel. It was concluded that a high-resolution system, as originally selected by TI, would be the best approach for the design study since it would draw extensively on the experience which TI has already obtained under other Navy programs. These discussions were part of the meetings held at Texas Instruments on 10 October 1972 and 17 November 1972.

We at Georgia Tech feel that the work represented by our joint efforts on this program are important to the advancement of Navy radar. We appreciate the opportunity which it has presented us and look forward to continued association on future programs. I personally have enjoyed our association on this program and have found our many discussions very profitable.

Yours truly,

Frederick B. Dyer
Senior Research Physicist

FBD/cm