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PRELIMINARY FORMAT AN/SQS-23 SONAR OPERATOR PERFORMANCE STANDARDS GUIDE FOR DETECTION AND TRACKING

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Prepared by:

Dunlap and Associates, Inc.
One Parkland Drive
Darien, Connecticut 06820

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(6) PRELIMINARY FORMAT AN/SQS-23 SONAR OPERATOR PERFORMANCE STANDARDS GUIDE FOR DETECTION AND TRACKING

Prepared for:

Chief of Naval Personnel
Bureau of Naval Personnel (Pers-C133)
Department of the Navy
Washington, D. C. 20370
Contract No. N00022-67-C-0172
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Prepared by:

(10) A. Van Acker
D. Pool
H. Smithline
H. Henderson

Dunlap and Associates, Inc.
One Parkland Drive
Darien, Connecticut 06820

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PREFACE

This format document is submitted as one of the steps in the development of an AN/SQS-23 Sonar Operator Performance Standards Guide under contract N00022-67-C-0172 with the Bureau of Naval Personnel. The intent underlying the submission of this format document is to describe the computation schemes we have developed and the format of the graphs, charts and tables selected to provide the data to be used in the computations. The purpose for such submission is the solicitation of comments and recommendations concerning changes of format which will make the use of the resulting standards either easier or more precise in the shipboard environment.

An indication only of the scope and tenor of the background and descriptive material will be provided in this submission, generally in outline form. Detailed text material will be provided in a later draft submission of the complete Standards Guide. The empirical charts provided are samples only. Complete sets of empirical charts will be provided with the draft submission. The values found in the charts included herein will differ from those submitted with the draft submission. They should not be used for operational evaluation of performance.

The primary purpose for operator standards is to provide the basis for an objective evaluation of operator performance. To insure that such evaluation is independent of the variations due to changes in environment or tactical situation, the effects of these changes must be "normalized" in some manner. The normalization method must be based on data available in the measurement situation (i.e., on board ship). In addition, performance must be measured along dimensions which are operationally significant (e.g., detection range). The cost of naval operations in general, and target services in particular makes it critically important that any method of operator performance evaluation not require the scheduling of additional exercises for its application; the operations and measurements involved must be compatible with exercises conducted for other purposes. Thus, the operator evaluation system must provide additional exploitation of the data already available. The system provided in the proposed standard meets all of the conditions noted above.

The exploitation of already available data clearly will require some additional data manipulation. The principle which has guided us in this effort has been that such manipulation must be of the simplest possible nature consistent with validity of the results. The method devised is believed to be compatible with the computational skills and tools normally found aboard ship.

The data developed to perform the primary function of the guide, namely, evaluation of sonar operator performance, can also provide important tactical data concerning total system performance which includes operator performance in an authoritative manner. It can provide additional guidance in such matters as ASW ship spacing, maximum effective weapon launch range, number of weapons to launch, time to fire, etc. Furthermore, collection of total system and personnel performance data on a fleet-wide basis can provide an important additional data base for use in tactical analyses.

I. INTRODUCTION

A. General

These AN/SQS-23 Sonar Operator Performance Standards have been prepared as one of the tasks under contract N00022-67-C-0172 with the Bureau of Naval Personnel. The scope of this task is to develop performance standards for two key sonar operator functions; namely, submarine detection and target tracking.

The primary purpose of such performance standards is to provide a basis against which to evaluate individual sonar operator performance under the widely varying sonar and tactical conditions encountered at sea, and to do so in terms of the performance to be expected of a "standard operator" under identical conditions. This "standard operator" is one who exhibits normal levels of visual and auditory acuity and response, psychomotor response time and accuracy, and behavioral response to tactical conditions. He also knows and follows the doctrine and procedures prescribed for optimum use of his equipment. This standard sonar operator is neither the "perfect man" nor a "superman"; rather, he should be thought of as an "average trained man." The expected performance of this standard operator is assigned, in these standards, a score of 50 percent. We would expect the performance scores of actual operators, after a statistically valid number of measurements, to average something close to this 50 percent value. No attempt is made to assign a pass or fail score; however, consistently poor performance by an individual should make evident the need for additional training or for tests of sensory capabilities. Conversely, analysis of consistently superior performance by an individual can uncover valid procedural improvements or personnel selection criteria.

B. Applications

At the shipboard command level, use of these standards can give the captain a measure of the tactical capabilities of his sonar system including the operators. It can highlight the need for and urgency of equipment maintenance or operator training. It can assist in the optimum assignment of personnel. It can provide a measure of the expected tactical performance of his sonar system under the existing environmental conditions. Study of the tracking standards can, by supplying data on probable solution accuracy and miss distance, provide a basis for reaching a decision regarding optimum time to fire and number of weapons to fire.

At higher command echelons the Standards Guide can form a basis for the evaluation of the tactical performance of units or for the determination of screen assignments, unit spacing, etc., based on the probable detection performance of units under the existing environmental conditions.

C. Guidelines

Because these performance standards are intended for shipboard use, two sets of guidelines were rigidly followed. First, there is no requirement for data not already available on board ship. Thus, the environmental data required is that regularly logged on board ship. The target data required is that regularly supplied for exercise reconstruction. No data not already available is required. Second, the guidelines used in the development of necessary computation schemes were:

1. All empirical data based on the computer simulation runs are presented in the form of charts or graphs.

2. It is presumed that personnel using this guide can easily perform the arithmetic operations of addition, subtraction, multiplication and short division. Graphical aids (graphs, nomograms, etc.) are provided for other arithmetic operations. The use of a slide rule would normally be faster and more accurate, and hence is recommended in preference to the graphical aids.

3. Tables will be provided for applicable probability functions.

One other guideline was adopted: use of the Standards Guide for the evaluation of operators shall not require additional submarine services, or additional ship operating time. However, some additional manipulation and evaluation of existing data would necessarily be involved.

D. Detection

The concept adopted for evaluation of sonar operator detection performance is that each detection made by an operator whose final classification is "possible submarine" or higher, or which subsequently is determined to have been a submarine upon exercise reconstruction, will be used in his evaluation. This will require the maintenance of a Submarine Detection Log for each operator, this log consisting of a Submarine Detection Data Sheet for each detection of a submarine and a Submarine Detection Summary for each operator. These at-sea detections can and should be supplemented by

detections using PME taped targets under at-sea conditions, so long as the operator is not familiar with the tape used, and the necessary environmental data at time of taping are available. Detections obtained on trainers (e. g., 14A2 series) should not be used.

E. Tracking

The concept chosen for the evaluation of sonar operator tracking performance is different. Each course or speed leg of a submarine during an exercise provides an evaluation of the sonar operator's tracking performance, if the actual course and speed data are made available after the exercise. Thus, a single exercise can give as many evaluations of the operator on the stack as there are course legs. To be completely valid, the target aspect angle should be varied somewhat randomly between bow, beam, quarter aspect, etc. Thus, the sonar operator can and should be evaluated in tracking performance on each submarine exercise. Similarly, PME taped targets can be used provided that actual course and speed data are available and are not preannounced on the tape, and provided that neither the sonar operator nor the attack plotter operator is familiar with the tape. A third method for evaluating sonar operator tracking performance is to use surface targets, provided that the sonar room and UB plot are insulated from data obtained using other sensors. Submarine-like speed ranges should be used by the target surface ship. A fourth method, if the ship is so equipped, is to use controllable artificial targets introduced into the sonar display. A fifth method is to use the data obtained during sessions on the 14A2 training device. No difficulty is envisioned in obtaining sufficient data for the evaluation of sonar operators in tracking performance. The basic fact underlying the entire method of sonar operator evaluation in tracking uncovered in this study, is that a reasonable trained and conscientious attack plotter operator contributes only negligibly to the errors in target course and speed solution. Rather, the levels of the errors in target course and speed solution are almost a direct measure of the accuracy with which the sonar operator positions his cursor in range and bearing.

II. DETECTION STANDARDS

(This section will present a short, relatively non-technical discussion of the basis and assumptions for the standards developed. It will again be emphasized that the selection of the standard chart to be used and the computation of corrections to be applied are based upon data which are already regularly recorded and available on board ship. This will be followed by a concise discussion of the areas of applicability of the detection standards, and a description of the standards documents provided. A lucid description of the use of the standards, "cookbook style" will also be provided. The discussion will follow the outline below.)

A. Technical Basis for the Detection Standards

1. Environmental Factors

   a. Propagation losses
   b. Reverberation computations
   c. Own ship's noise level
   d. Quenching
   e. Sonar source level

2. Operator Performance Factors

   a. Operator visual acuity (normal)

   b. Sonar room lighting level (normally darkened)

   c. Scope brightness and gain adjustment (optimum per environmental results)

   d. Clutter loss (based on reverberation-to-noise ratio)

   e. Semi-random video scan (based on experimental results)

   f. Operator auditory acuity (normal)

   g. Masking effects (noise and reverberation, effects of doppler)

   h. Use of earphones (cuts out ambient noise)

   i. Audio search pattern (normally beam-to-beam)

3. ASW Ship Alert Level

   a. Categorization
   b. Effects

4. Target General Tactical Situation

   a. Approach, screen penetration or attack phases
   b. Evasion phase or ASW freeplay
   c. Effect on data utilization

B. Applicability of the *Detection* Standards

1. AN/SQS-23 (TRAM Series)

2. Submarine Targets

3. Effect of Target Tactical Situation on Applicability (Initial Detection Versus Reacquisition)

C. Description of the Standards

1. Curves of Probability of Detection Beyond a Given Range (Sample, Figure 1)

2. Curves of Probability of Detection at a Given Range (Sample, Figure 2)

3. Correction Factors for the Following Parameters

   a. ASW alert level
   b. Surface water temperature
   c. Layer depth
   d. Target depth
   e. Wind velocity
   f. Sea state
   g. ASW ship speed
   h. Sonar source level
   i. Audio search sector width

C_D - % of total number of Targets Detected by a given Range

PROBABILITY OF DETECTION BEYOND A GIVEN RANGE

Target Speed Range	3-5 Knots
ASW Ship Speed Range	12-27 Knots
Layer Depth	300 Feet
Target Depth	600 Feet
Water Depth	2,400 Feet
Sea State	2
Wind Velocity	5.0 Knots
Water Temperature	68.0° F

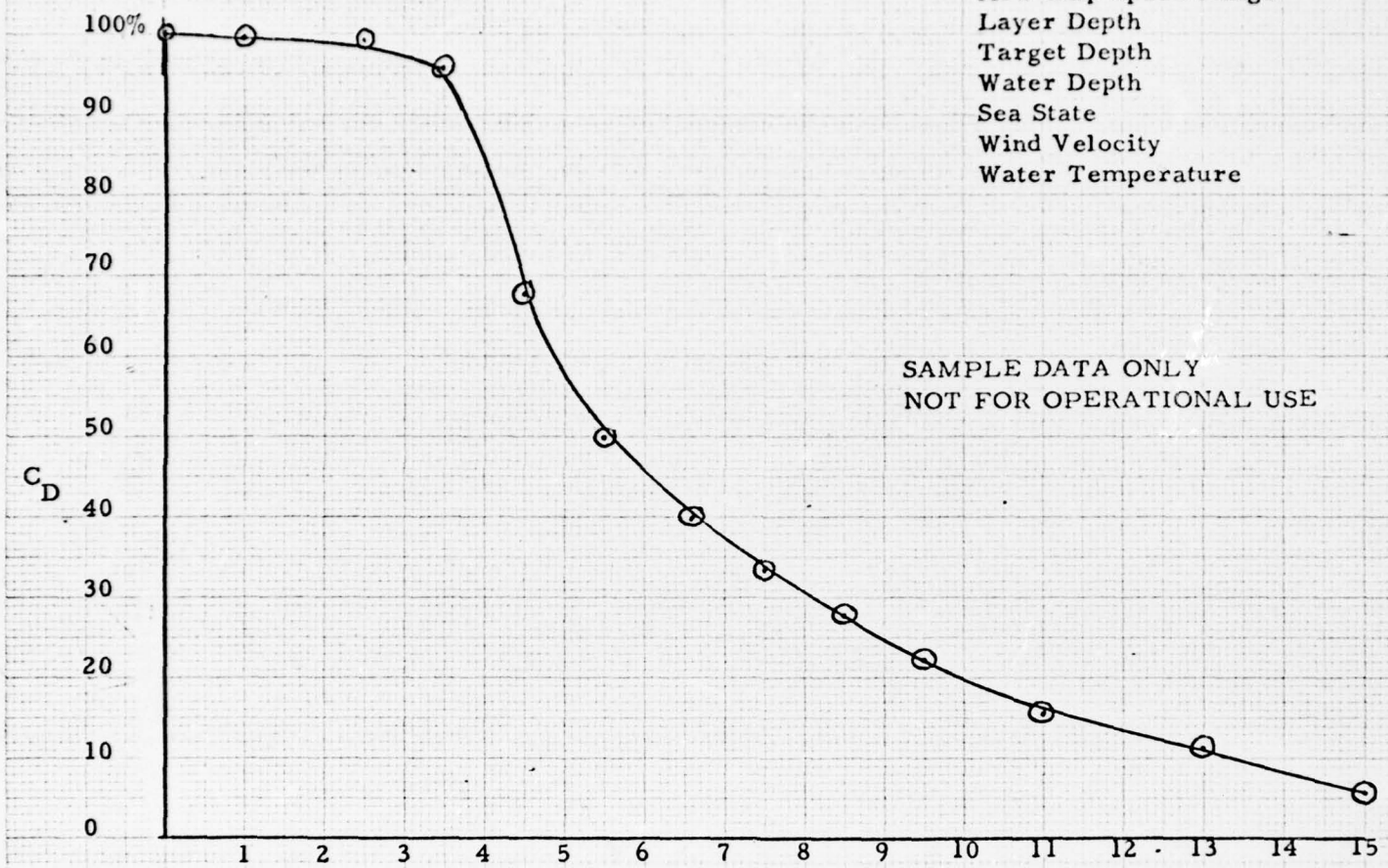

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Figure 1

P_D - % Probability of Detection at a Given Range

PROBABILITY OF DETECTION AT A GIVEN RANGE

Target Speed Range	3-15 Knots
ASW Ship Speed Range	12-27 Knots
Layer Depth	300 Feet
Target Depth	600 Feet
Sea State	2
Wind Velocity	5.0 Knots
Water Temperature	68.0° F

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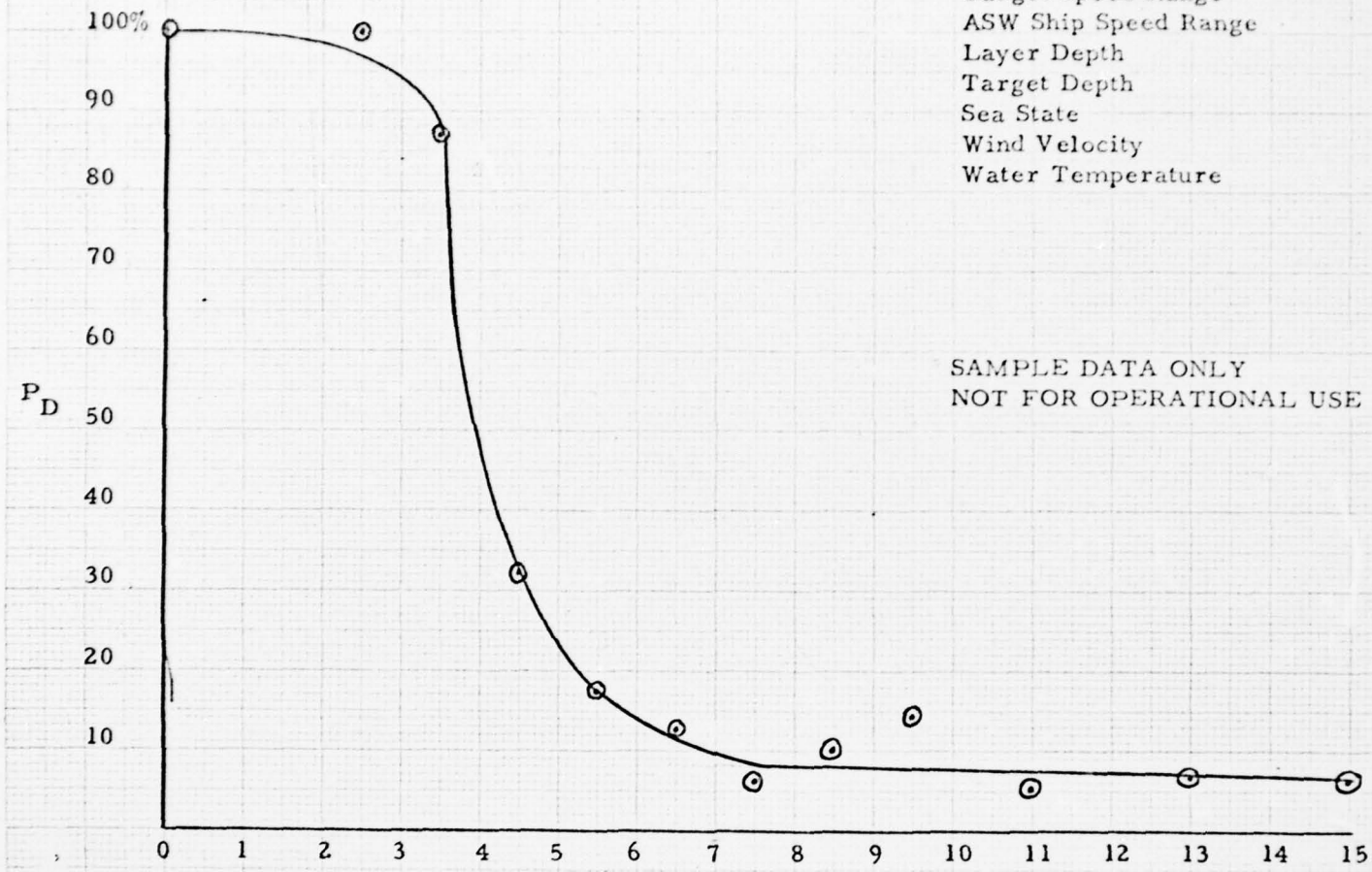


Figure 2

4. Computation and Scoring Sheets

a. Submarine Detection Data Sheet (Figure 3)

b. Sonar Operator Submarine Detection Summary (Figure 4)

c. Sonar Operator Submarine Contact Reacquisition Summary (Figure 5)

D. Use of the Standards

1. Completing the Submarine Detection Data Sheet

a. Completing the data
b. Selecting the appropriate Probability of Detection Chart
c. Computing the detection range corrections

1) Initial detection versus reacquisition or approach versus evasion

2) Environmental conditions

3) Procedure when submarine maneuvers from "below layer" to "in layer" situation

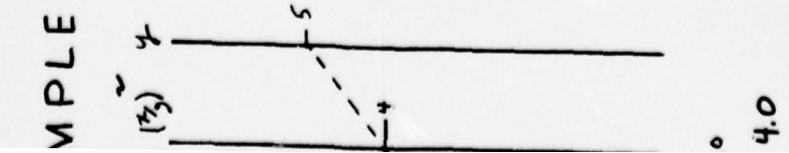
2. Completing the Sonar Operator Submarine Detection Summary

a. Selecting the detections appropriate for entry (initial detections, approach phase detections)

b. Completing the data forms

c. Computing individual detection and cumulative detection scores

d. Maintaining the operator detection performance log



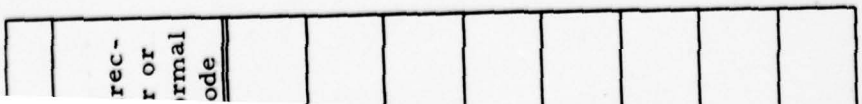
Submarine Detection Data Sheet

Sonar Operator's Name_____

	Date	Range +	Core -	
Date				
Time				
Detection Range (yards)				
Target ture bearing at detection				
Is target live or faked (PME)				
Final classification				
Reconstructed classification				
Target tactical category				
ASW alert level				
Audio search sector width				
Surface water temperature				
Water depth				
Layer depth				
Target depth (estimated)				
Reconstructed target depth				
True wind velocity				
Sea state (U.S. Hydrographic Office Code)				
Own ship speed				
Sonar source level				
Standard chart used				
		_____	_____	
Range correction, Total		+	-	(T)
Corrected detection range				
Detection probability from chart (P_d)				
Score ($1-P_d$)				

Comments: Submarine attack completed (yes, no)
Contact held for _____ minutes
Number of ASW attacks completed prior to submarine attack or lost control _____
Range at which contact was lost _____
Reason for termination of encounter _____

Figure 3. DUNLAP and ASSOCIATES, INC.



Sonar Operator Submarine Detection Summary

Sonar Operator's Name _____

Detection number (N)	Date/Time	Detection range	Corrected detection range	Standard chart used	Score (S)	Cumulative sum of scores $\Sigma(S)$	Cumulative mean score $\Sigma S/N$
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							

Notes: 1) Only detections classified possible submarine or higher, or which are identified as submarines on exercise reconstruction should be entered in this summary.
2) In general, only the initial detection of a given contact by the ship should be entered in this summary.

Figure 4. Sonar operator submarine contact reacquisition summary

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Sonar Operator Submarine Contact Reacquisition Summary

Sonar Operator's Name _____

Reacquisition number (N)	Date/Time	Range at which contact was Lost	Reacquisition range	Standard Chart used	Score (S)	Cumulative sum of scores ΣS	Cumulative mean score $\Sigma S/N$	Time between lost contact and reacquisition (min) ΔT	Cumulative reacquisition Time $\Sigma \Delta T$	Mean reacquisition Time (min) $\Sigma \Delta T/N$

Notes: Only reacquisitions of contacts classified possible submarine or higher or which are identified as submarines on exercise reconstruction should be entered in this summary.

Figure 5. Sonar operator submarine detection summary

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3. Completing the Sonar Operator Submarine Contact Reacquisition Summary (Optional)

   a. Selecting the detections appropriate for entry (contact reacquisitions, evasion phase)

   b. Completing the individual and cumulative reacquisition performance indices

   c. Validity and usefulness of the contact reacquisition performance indices. (A measure of the reliability in holding contact and speed of reacquisition.)

   d. Mantaining the operator contact reacquisition log

4. Sample Problems

   a. Initial detection

      1) In layer or below layer
      2) Below layer target which maneuvers above layer

   b. Reacquisition

   (The procedure to be followed will be expanded in the Standards Guide. In summary, it is as follows:

   Step 1

   Complete the data entries in the Submarine Detection Data Sheet.

   Step 2

   On the basis of the data, select the appropriate Probability of Detection Curve. Detailed rules will be given in the Guide.

   Step 3

   Compute the detection range corrections to be applied to account for differences of actual environmental and tactical conditions from those used in the selected Probability of Detection Curve.

Step 4

Enter the selected Probability of Detection Curve with the corrected detection range. Read the score.

Step 5

Enter the basic detection data in the Sonar Operator Submarine Detection Summary or the Sonar Operator Submarine Contact Reacquisition Summary as appropriate.

Step 6

Compute the cumulative mean score for the operator.)

III. TRACKING STANDARDS

(This section will present a short, non-technical discussion of the pertinent results and conclusions of the studies report in Dunlap and Associates, Inc., Confidential Report BSD No. 68-509 entitled "Effects of Operator Errors on Accuracy of Target Motion Analysis (U)," Dunlap and Associates, Inc., Confidential Report BSD No. 68-676 entitled "Effects of Exponential Track Smoothing Technique on Accuracy of Target Motion Analysis (U)," and further studies conducted using our tracking simulation model in conjunction with weapons systems simulations. The scope and organization of this discussion will be similar to that used for the detection standards. In addition, there will be some discussion of the tactical implications of the measures and standards presented. The discussion will follow the outline below.)

A. Technical Basis for the Tracking Standards

1. The Validity and Usefulness of Errors in Target Course and Speed Solutions as Measures of Sonar Operator Performance

2. Factors Affecting Error Levels in Target Course and Speed Solution

   a. Target range

   b. Target speed

   c. Time since last change of target course or speed

   d. Equipment errors

   e. Equipment operating modes

   f. Operator precision in positioning his cursor (display dependent)

3. Effects of Various Modes of Equipment Operation

   a. Range scale selection

b. Director mode versus Normal mode

c. Sum Brightening mode versus Difference Brightening mode and the effect of target intermittency

d. Target-centered versus ship-centered display

4. Effect of Ancillary Target Data on the Effectiveness of Tracking

a. Target aspect angle

b. Doppler

c. How accounted for in the scoring (helps his score if it is good)

5. The Technical and Theoretical Basis for the Scoring System

a. Including system bias
b. Eliminating system bias

B. Applicability of the Tracking Standards

1. AN/SQS-23 Sonar Systems

2. Mk 105, Mk 111 and Mk 114 Fire Control Systems

3. Degree of Applicability to other Sonar Systems

a. Equipments using a 7-inch CRT PPI
b. Not to equipments using sector scan indicators

C. Description of the Standards

1. Curves of Target Tracking Course Error (Samples, Figures 6 and 7)

2. Curves of Target Tracking Speed Error (Samples, Figures 8 and 9)

TARGET TRACKING COURSE ERROR

Course Error vs. Tracking Time

Target Speed Range	3-15 knots
Control Variable	Target Range
ASW Ship Speed Range	12-27 knots

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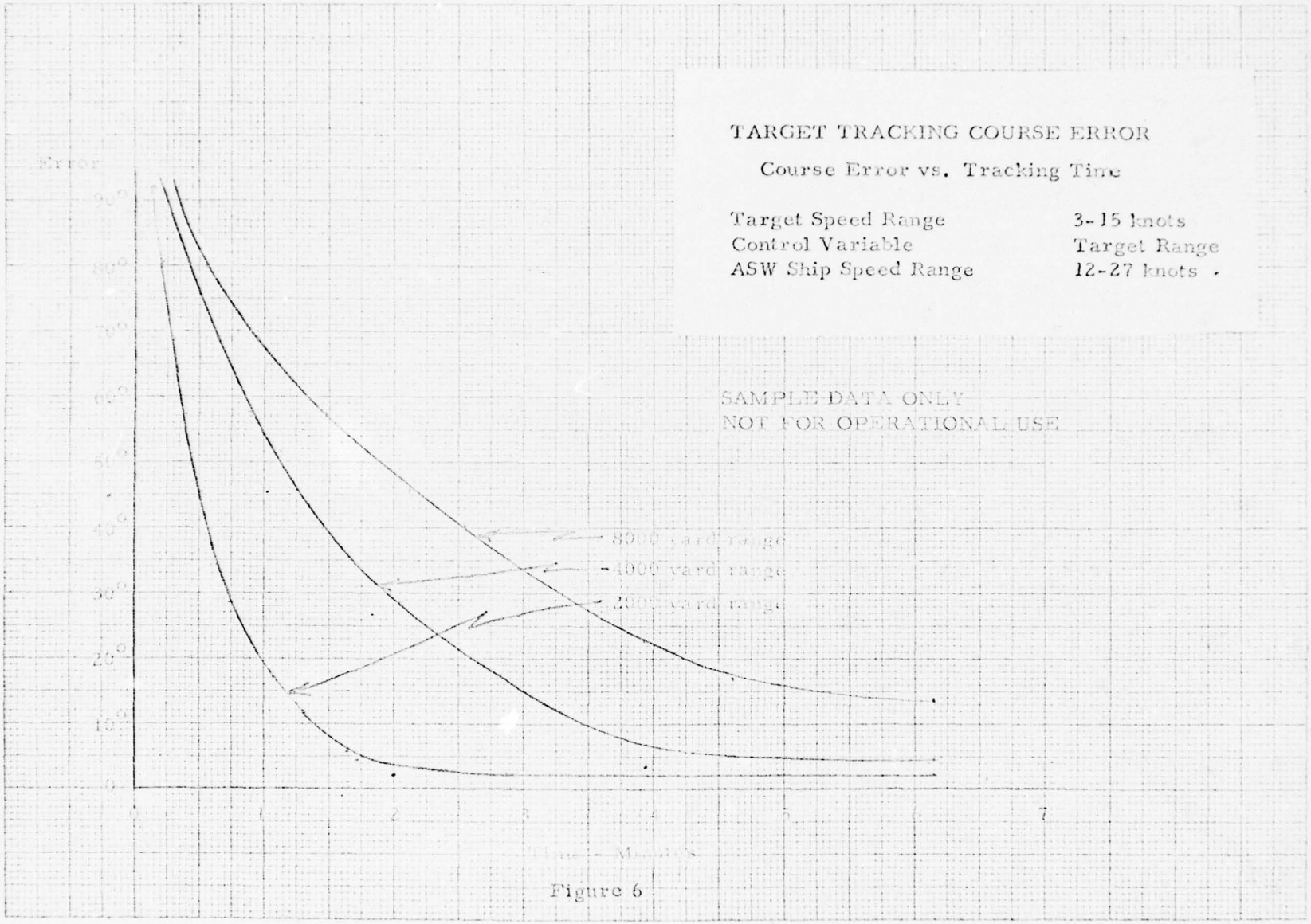

Figure 6

TARGET TRACKING COURSE ERROR

Course Error vs. Tracking Time

Target Speed Range	15-30 knots
Control Variable	Target Range
ASW Ship Speed Range	12-27 knots

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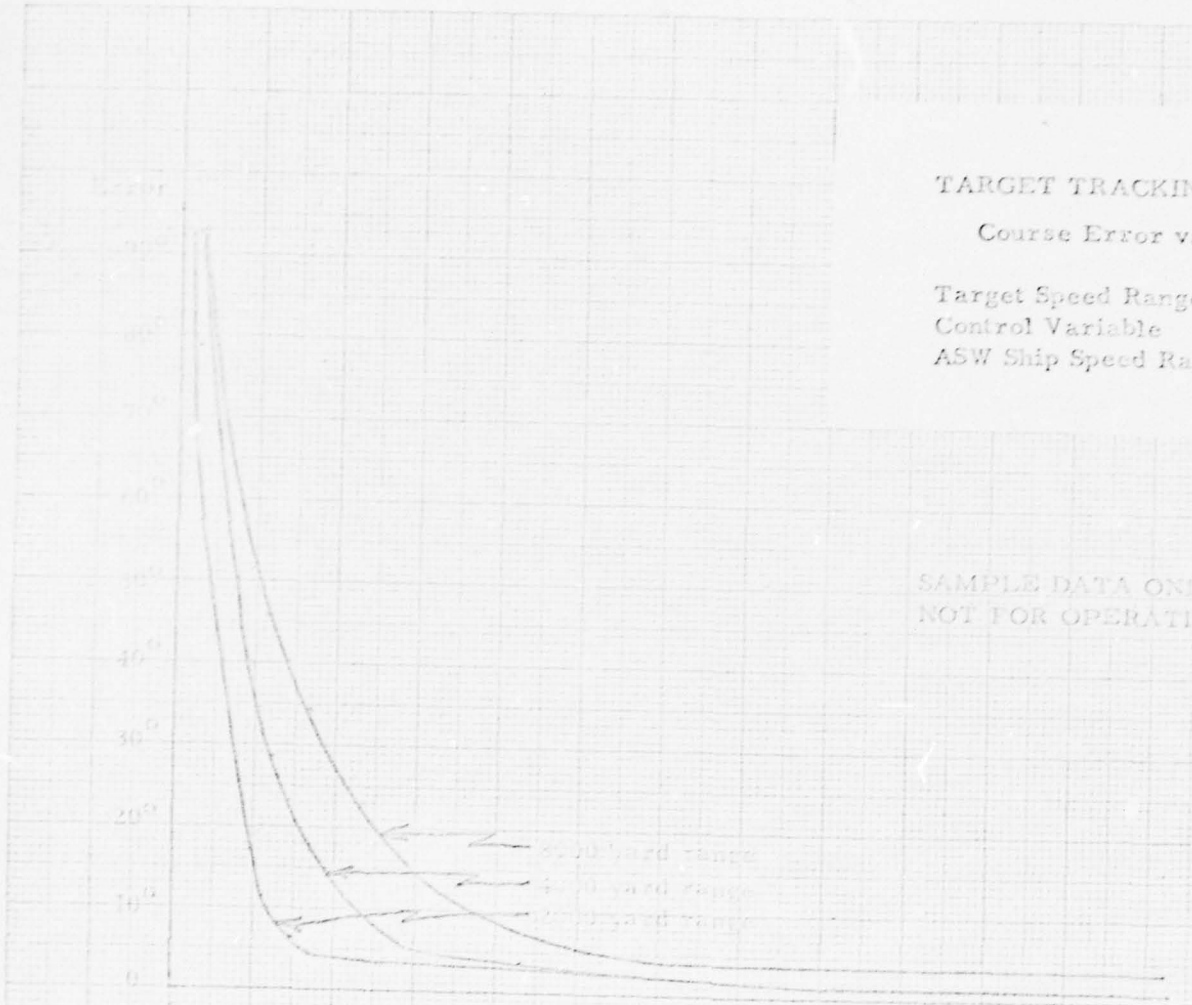

Figure 7

TARGET TRACKING SPEED ERROR

Speed Error vs. Tracking Time

Target Speed Range	3-15 knots
Control Variable	Target Range
ASW Ship Speed Range	12-27 knots

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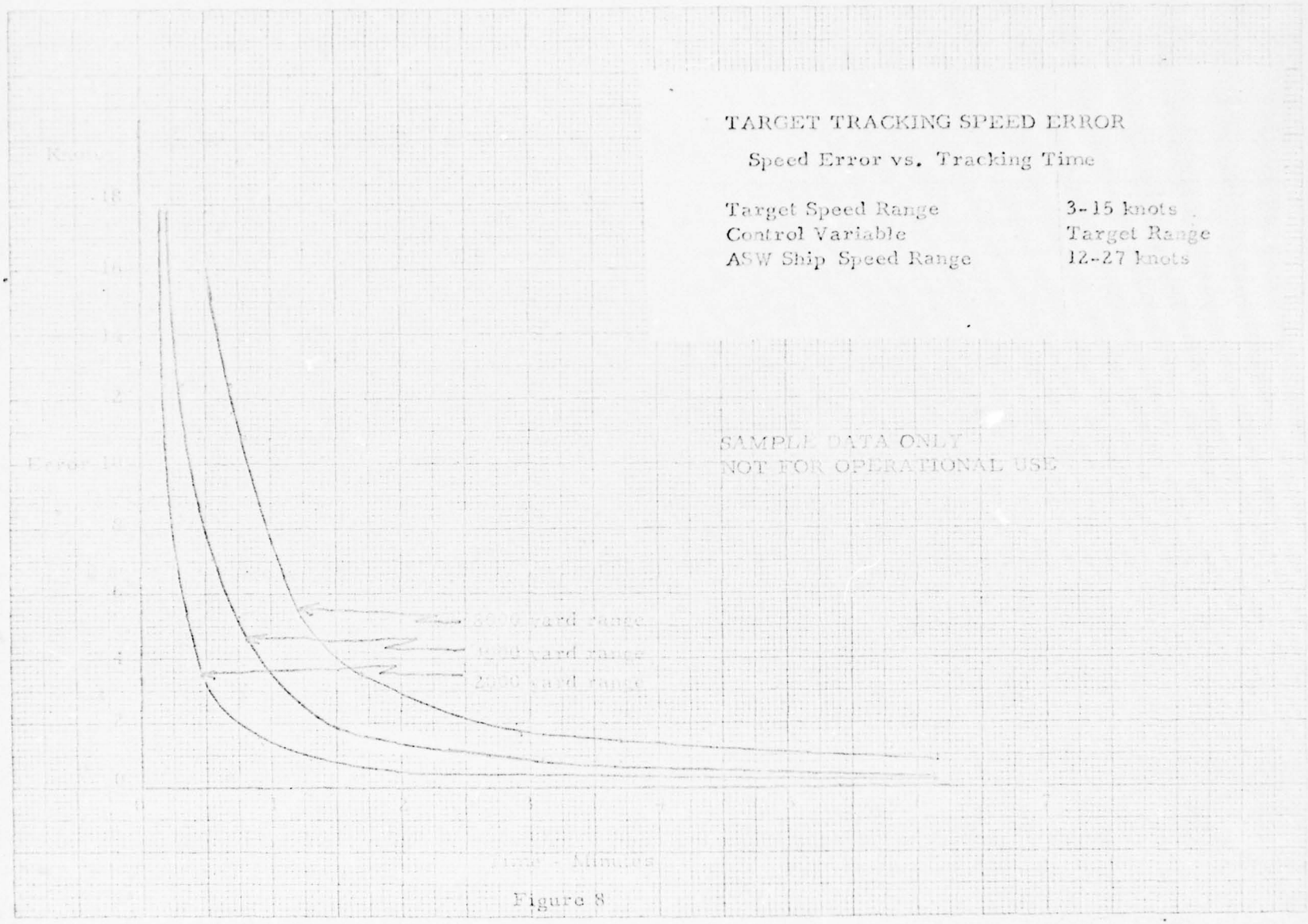

Figure 8

TARGET TRACKING SPEED ERROR

Speed Error vs. Tracking Time

Target Speed Range	15-30 knots
Control Variable	Target Range
ASW Ship Speed Range	12-27 knots

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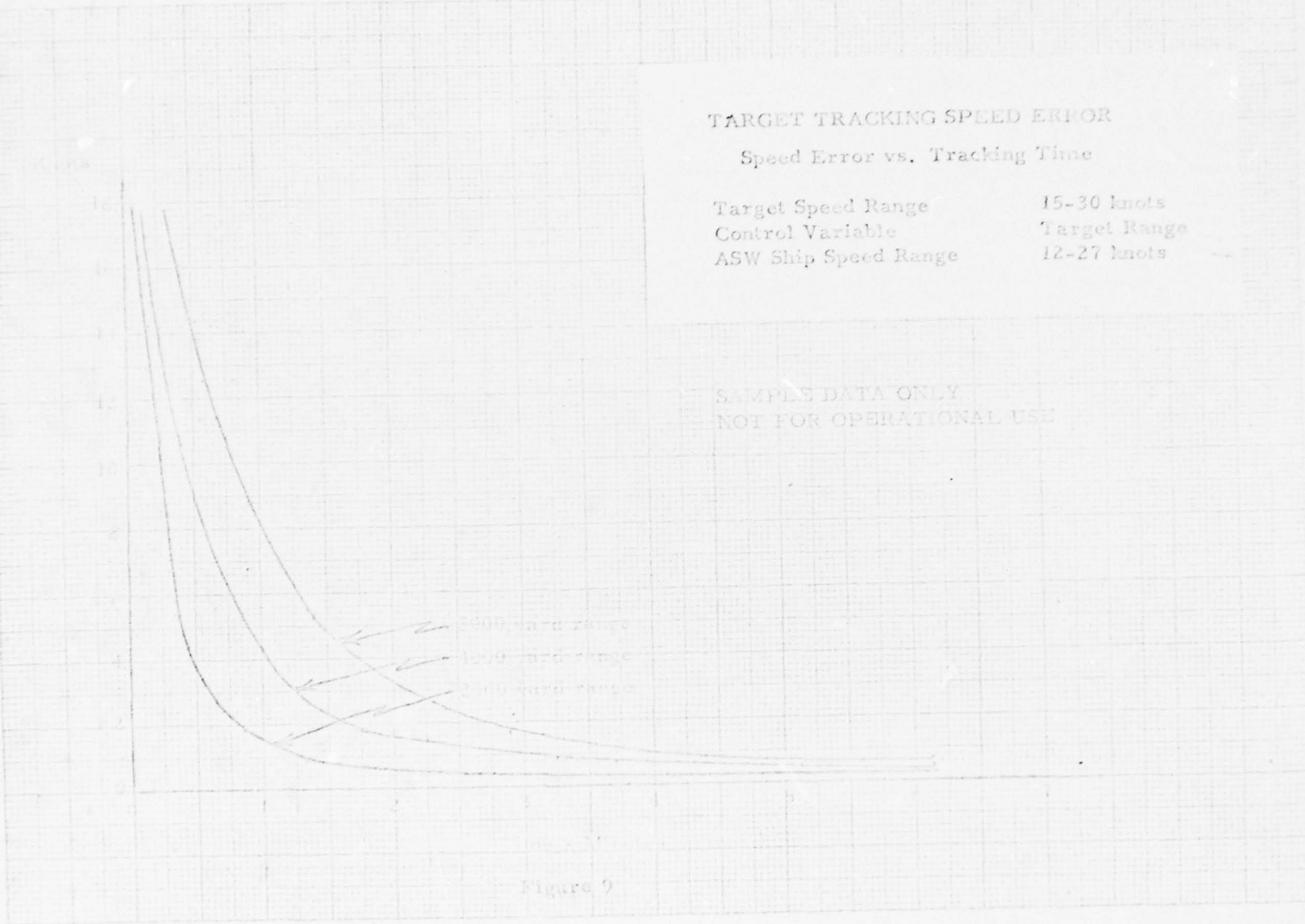


Figure 9

3. Nomogram for Computing the Ratio of Two Numbers and the Square of this Ratio (Figure 10)

4. Scoring Table (Table I)

5. Computation and Scoring Sheet

   a. Exercise Tracking Data Sheet (Figure 11)
   b. Sonar Operator Tracking Summary (Figure 12)

D. Use of the Tracking Standards

1. Completing the Exercise Tracking Data Sheet

   a. Completing the target data

      1) How to compute the number of track legs

      2) How to compute the time of a course or speed change (time at which change is initiated)

   b. Completing the track solution data

      1) How to select the measurement time for a track leg

         a) Firing time or simulated firing time
         b) Last data prior start of next leg

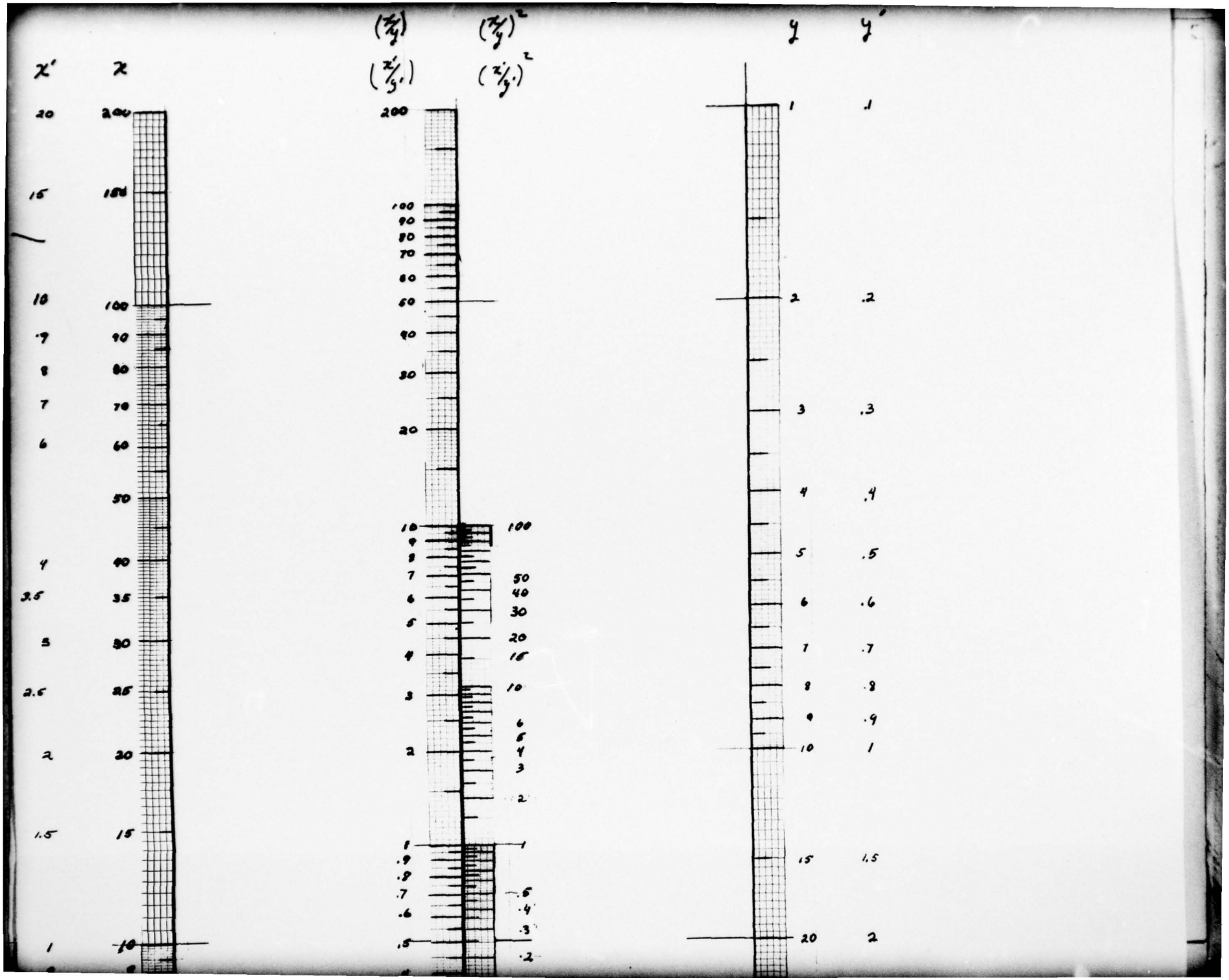
      2) Target range

   c. Determining standard course error and standard speed error

      1) Effect of time since target course change (affects both course and speed standards)

      2) Effect of time since target speed change

      3) Selecting the appropriate standard curve


x'
x
20
200
15
150
10
100
9
90
8
80
7
70
6
60
50
4
40
3.5
35
3
30
2.5
25
2
20
1.5
15
1
10
(x/y)
(x'/y')
(x/y)²
(x'/y')²
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
.9
.8
.7
.6
.5
.4
.3
.2
y
y'
1
.1
2
.2
3
.3
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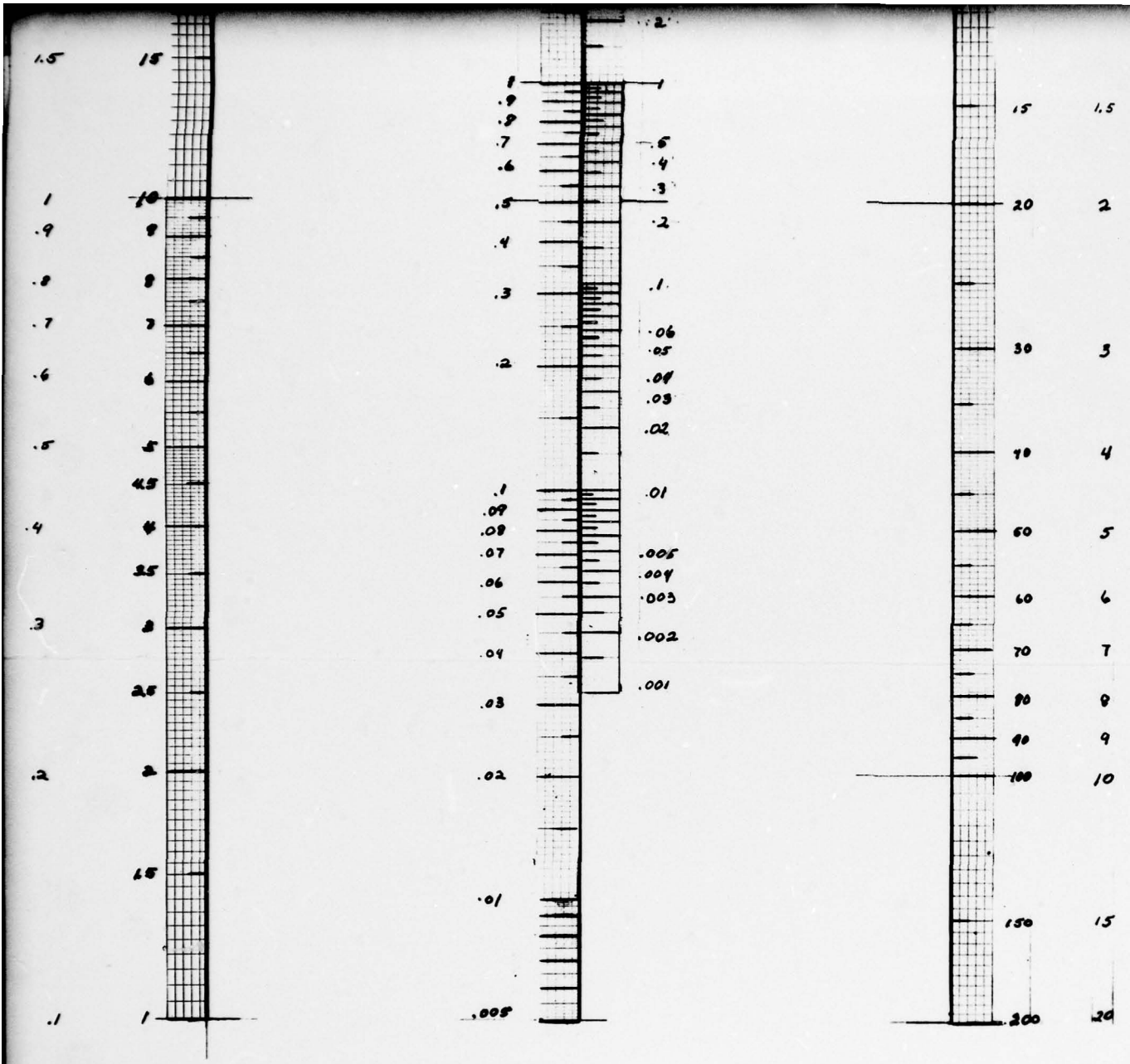
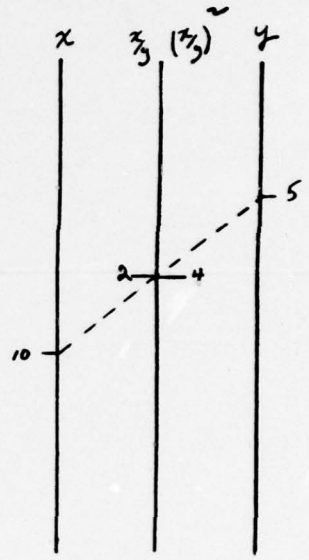


EXAMPLE



$\frac{x}{5} = \frac{10}{5} = 2.0$

$(\frac{z}{5})^2 = 2.0^2 = 4.0$

NOMOGRAPH FOR CALCULATION OF RATIO (x/y) AND SQUARE $(x/y)^2$

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EXERCISE TRACKING DATA SHEET
PART I -- DATA SHEET

Sonar Operator's Name _____
Exercise Date _____ Time _____ Type of Exercise _____

Data Source (Circle one): Waterborne Target, PME Tape, Trainer, Artificially Generated Target

Target Data						Solution Data							
Track Leg No.	Time	Course	Course Change C'	Speed	Speed Change	Solution Time	Course	Time on Course Leg	Speed	Time since speed change	Target range	Sum or difference brightening	Director or normal mode
1													
2													
3													
4													
5													
6													
7													
8													

Notes
1. A new track leg is started at the start of each change of target course. A new track leg is not started for a speed change alone. Time for each event should be recorded, however.
2. Solution time shall be actual for simulated weapon launch time, if there was a firing during the leg. If there was more than one weapon launch during leg, only the first shall be used. If there was no weapon launch during a leg, the last solution data prior to the start of the next leg shall be used.
3. If there is no speed change during a leg, time since course change will be used in computing the standard speed errc

to submarine attack or lost control ____
Range at which contact was lost ____
Reason for termination of encounter ____

Figure 3.

EXERCISE TRACKING DATA SHEET
PART II--COMPUTATION SHEET

Exercise Date_____
Time_____

A. System Performance

Track leg No.	Standard course error E_{sc}	Observed course error E_{oc}	System course performance factor $F_c=(E_{oc}/E_{sc})^2$	Standard speed error E_{ss}	Observed speed error E_{os}	System speed performance factor $F_s=(E_{os}/E_{ss})^2$
1						
2						
3						
4						
5						
6						
7						
8						

Total Number Track Legs N_____

ΣE_{oc}_____ ΣF_c_____

Course bias $M_c = (\Sigma E_{oc}/N)$_____

Speed bias $M_s = (\Sigma E_{os}/N)$_____

ΣE_{os}_____ ΣF_s_____ ΣF_c_____

System Performance Factor $\Sigma F_s + \Sigma F_c$_____

Scoring table entry number (2N)_____

System performance score_____

Note: All summations indicated are algebraic sums.

Figure 11

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EXERCISE TRACKING DATA SHEET
PART II--COMPUTATION SHEET

Exercise Date _____
Time _____

B. Operator Performance

Track Leg number	Standard course error E_{sc}	Observed course error minus course bias $(E_{oc} - M_c)$	Operator course performance factor $F_{oc} = (\frac{E_{oc} - M_c}{E_{sc}})^2$	Standard speed error E_{ss}	Observed speed error minus speed bias $(E_{os} - M_s)$	Operator speed performance factor $F_{os} = (\frac{E_{os} - M_s}{E_{ss}})^2$
1						
2						
3						
4						
5						
6						
7						
8						

$\Sigma F_{oc} =$ _____

$\Sigma F_{os} =$ _____

$\Sigma F_{oc} =$ _____

Operator Performance Factor $\Sigma F_{os} + \Sigma F_{oc} =$ _____

Scoring Table Entry Number (2N-2) _____

Operator Performance Score _____

Note: All summations indicated are algebraic sums.

Figure 11

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Sonar Op

Reacquis
tion num
ber (N)

Notes:

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Table I

Scoring Table

n \ Score	99	95	90	80	70	60	50	Score \ n
1	0.00016	0.00393	0.0158	0.0642	0.148	0.276	0.455	1
2	0.0201	0.103	0.211	0.446	0.713	1.022	1.386	2
3	0.115	0.352	0.584	1.005	1.424	1.869	2.366	3
4	0.297	0.711	1.064	1.649	2.195	2.753	3.357	4
5	0.554	1.145	1.610	2.343	3.000	3.656	4.351	5
6	0.872	1.635	2.204	3.070	3.828	4.570	5.348	6
7	1.239	2.167	2.833	3.822	4.671	5.493	6.346	7
8	1.646	2.733	3.490	4.594	5.527	6.423	7.344	8
9	2.088	3.325	4.168	5.380	6.393	7.357	8.343	9
10	2.558	3.940	4.865	6.179	7.267	8.296	9.342	10
11	3.053	4.575	5.578	6.989	8.148	9.237	10.341	11
12	3.571	5.226	6.304	7.807	9.034	10.182	11.340	12
13	4.107	5.892	7.042	8.634	9.926	11.129	12.340	13
14	4.660	6.571	7.790	9.467	10.821	12.079	13.339	14
15	5.229	7.261	8.547	10.307	11.721	13.030	14.339	15
16	5.812	7.962	9.312	11.152	12.624	13.983	15.338	16
17	6.408	8.672	10.085	12.002	13.531	14.937	16.338	17
18	7.015	9.390	10.865	12.857	14.440	15.893	17.338	18
19	7.633	10.117	11.651	13.716	15.352	16.850	18.338	19
20	8.260	10.851	12.443	14.578	16.266	17.809	19.337	20
21	8.897	11.591	13.240	15.445	17.182	18.768	20.337	21
22	9.542	12.338	14.041	16.314	18.101	19.728	21.337	22
23	10.196	13.091	14.848	17.187	19.021	20.689	22.337	23
24	10.856	13.848	15.659	18.062	19.943	21.651	23.337	24
25	11.524	14.611	16.473	18.940	20.867	22.614	24.337	25
26	12.198	15.379	17.292	19.820	21.792	23.578	25.336	26
27	12.879	16.151	18.114	20.703	22.719	24.543	26.336	27
28	13.565	16.928	18.939	21.588	23.647	25.508	27.336	28
29	14.256	17.708	19.768	22.475	24.577	26.474	28.336	29
30	14.953	18.493	20.599	23.364	25.508	27.440	29.336	30
F factors for n > 30 (see note)	-2.32635	-1.64485	-1.28155	-.84162	-.52440	-.25335	0	

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Table I (Continued)

Score / n	50	40	30	20	10	5	1	Score / n
1	0.455	0.708	1.074	1.642	2.706	3.841	6.635	1
2	1.386	1.833	2.408	3.219	4.605	5.991	9.210	2
3	2.366	2.945	3.665	4.642	6.251	7.815	11.341	3
4	3.357	4.044	4.878	5.989	7.779	9.488	13.277	4
5	4.351	5.132	6.064	7.289	9.236	11.070	15.086	5
6	5.348	6.211	7.231	8.558	10.645	12.592	16.812	6
7	6.346	7.283	8.383	9.803	12.017	14.067	18.475	7
8	7.344	8.350	9.524	11.030	13.362	15.507	20.090	8
9	8.343	9.414	10.656	12.242	14.684	16.919	21.666	9
10	9.342	10.473	11.781	13.442	15.987	18.307	23.209	10
11	10.341	11.530	12.899	14.631	17.275	19.675	24.725	11
12	11.340	12.584	14.011	15.812	18.549	21.026	26.217	12
13	12.340	13.637	15.119	16.985	19.812	22.362	27.688	13
14	13.339	14.687	16.222	18.151	21.064	23.685	29.141	14
15	14.339	15.735	17.322	19.311	22.307	24.996	30.578	15
16	15.338	16.781	18.418	20.465	23.542	26.296	32.000	16
17	16.338	17.826	19.511	21.615	24.769	27.587	33.409	17
18	17.338	18.869	20.601	22.760	25.989	28.869	34.805	18
19	18.338	19.911	21.689	23.900	27.204	30.144	36.191	19
20	19.337	20.952	22.775	25.038	28.412	31.410	37.566	20
21	20.337	21.992	23.858	26.171	29.615	32.671	38.932	21
22	21.337	23.031	24.939	27.301	30.813	33.924	40.289	22
23	22.337	24.069	26.018	28.429	32.007	35.172	41.638	23
24	23.337	25.106	27.096	29.553	33.196	36.415	42.980	24
25	24.337	26.143	28.172	30.675	34.382	37.652	44.314	25
26	25.336	27.180	29.246	31.795	35.563	38.885	45.642	26
27	26.336	28.216	30.319	32.912	36.741	40.113	46.963	27
28	27.336	29.251	31.391	34.027	37.916	41.337	48.278	28
29	28.336	30.286	32.461	35.139	39.087	42.557	49.588	29
30	29.336	31.320	33.530	36.250	40.256	43.773	50.892	30
F factors for n > 30 (see note)	0	.25335	.52440	.84162	1.28155	1.64485	2.32635	

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Note 1: For values of n greater than 30, table values may be approximated by the formula $(F + \sqrt{2n-1})^2/2$, where F takes on the values shown on the bottom of the table.

Note 2: This table is derived from "Handbook of Mathematical Function, with Formulas, Graphs and Mathematical Tables," edited by M. Abramowitz, and I. A. Stegun, U. S. Department of Commerce, National Bureau of Standards, Applied Mathematics Series 55. Table values were taken from Table 26.8, Percentage Points of the χ^2 Distribution or were interpolated from Table 26.7, Probability Integral of χ^2 Distribution, Incomplete Gamma Function and Cumulative Sums of the Poisson Distribution.

Sonar Operator Tracking Summary
Part I - System Performance

Sonar Operator's Name_____

Exercise Date	Number of Track Legs Evaluated (N)	Exercise System Performance Factor $\left(\sum \frac{E_o}{E_s}\right)$	Scoring Table Entry Number (2N)	Exercise System Performance Score	Cummulative System Performance Factor $\sum\left(\sum \frac{E_o}{E_s}\right)$	Cummulative Scoring Table Entry No. $\sum(2N)$	Cummulative System Performance Score

Figure 12

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Sonar Operator Tracking Summary
Part II - Operator Performance
(System Errors - Bias)

Sonar Operator's Name_____

Exercise Date	Number of Track Legs Evaluated (N)	Exercise Operator Performance Factor $\sum\left(\frac{E_o-m}{E_s}\right)$	Exercise Table Entry Number (2N-2)	Exercise Operator Performance Score	Cummulative Operator Performance Factor $\sum\left(\sum\frac{E_o-m}{E_s}\right)$	Cummulative Scoring Table Entry Number (2N-2)	Cummulative Operator Performance Score

Figure 12

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d. Computation and scoring

1) Performance on a given leg
2) Performance for the exercise
3) Statistical adequacy of the sample

a) Number of target legs
b) Variations in target aspect

4) Use of E_o/E_s and $(E_o/E_s)^2$ nomograms
5) Use of the scoring tables
6) Eliminating system bias

2. Completing the Sonar Operator Tracking Summary

a. Completing the data

b. Computing the cumulative tracking performance score including system bias

c. Computing the cumulative tracking performance score without system bias

d. Maintaining the operator tracking performance log

3. Sample Problems

(The procedure to be followed will be expanded in the Standards Guide. In summary, it is as follows:

Step 1

Complete the target data entries in the Exercise Tracking Data Sheet, using reconstruction data from the target.

Step 2

Select the appropriate measurement time for each course leg of the target track. Enter target range, estimated target course and estimated target speed.

Step 3

Read the standard course error and standard speed error values for each track leg from the appropriate curves (samples, Figures 6, 7, 8 and 9) using magnitude of last course or speed change, time since last course or speed change, and target range as inputs.

Step 4

Compute the solution course error and solution speed error for each leg at the selected measurement time. Compute the mean course solution error and the mean speed solution error for all track legs in the exercise.

Step 5

Compute the square of the ratio of actual error to standard error $(E_o/E_s)^2$ for the course and for the speed on each track leg using either a slide rule or the nomogram provided (Figure 10). Compute the sum of all these squared ratios.

Step 6

Enter the scoring table (Table I) with the total number of samples used (twice the number of track legs evaluated) and the sum of the squared ratios. Read the score from the column headings, interpolating. This is the tracking performance score for the entire system, including the operator.

Step 7

Compute the square of the ratio of (actual error minus mean error) to (standard error); that is, $(E_o\text{-}m)/E_s$, for course and speed on each track leg as in Step 5. Compute the sum of all these squared ratios.

Step 8

Enter the scoring table (Table I) with two less than the total number of samples used (twice the number of track legs evaluated minus two) and the sum of the squared ratios. Read the score from the column headings, interpolating. This is the tracking

performance score for the sonar operator (system error minus system bias))

E. Tactical Effects of Sonar Operator Tracking Error Levels

1. Splash Point Errors to be Expected with Zero Sonar Operator Tracking Errors

   a. ASROC
   b. DASH

2. Splash Point Errors to be Expected with Standard Sonar Operator Tracking Error Levels

   a. ASROC
   b. DASH

3. Tradeoff Factors in Determining Weapon Launch Time or Need for Multiple Launch

   a. Target range

   b. Tracking time on current target leg

   c. Sonar operator tracking proficiency

   d. Acceptable levels versus expected levels of splash point error

DUNLAP and ASSOCIATES, INC.

DARIEN, CONNECTICUT 06820
One Parkland Drive
Area Code 203 655-3971
In N.Y.C., WYandotte 3-2464
Executive Offices

WASHINGTON, D.C. 20007
1050 Thirty-First Street, N.W.
Area Code 202 333-0100

BEDFORD, MASSACHUSETTS 01730
363 The Great Road
Area Code 617 275-7810

SANTA MONICA, CALIFORNIA 90404
1454 Cloverfield Boulevard
Area Code 213 393-0166

MANHATTAN, KANSAS 66502
200 Research Drive
Area Code 913 539-3565