UNCLASSIFIED

AD NUMBER

ADB142350

LIMITATION CHANGES

TO:

Approved for public release; distribution is unlimited.

FROM:

Distribution authorized to U.S. Gov't. agencies only; Test and Evaluation; FEB 1990. Other requests shall be referred to David Taylor Research Center, Bethesda, MD 20084-5000.

AUTHORITY

NSWC ltr dtd 10 May 1995

THIS PAGE IS UNCLASSIFIED

David Taylor Research Center

Bethesda, Maryland 20084-5000

NTIC FILE COPY

DTRC SHD-1322-01 February 1990 Ship Hydromechanics Department Departmental Report

AD-B142 350

HYDRODYNAMIC TOWING EVALUATION OF THE USS SKATE (SSN-578)

by

Stephen A. McCauley Raymond P. Para



Distribution limited to U.S. Government agencies only; test and evaluation; February 1990. Other requests for this document shall be referred to Code 15, David Taylor Research Center, Bethesda, MD 20084-5000.



90 04 12 111

MAJOR DTRC TECHNICAL COMPONENTS

CODE 011 DIRECTOR OF TECHNOLOGY, PLANS AND ASSESSMENT

- 12 SHIP SYSTEMS INTEGRATION DEPARTMENT
- 14 SHIP ELECTROMAGNETIC SIGNATURES DEPARTMENT
- 15 SHIP HYDROMECHANICS DEPARTMENT
- 16 AVIATION DEPARTMENT
- 17 SHIP STRUCTURES AND PROTECTION DEPARTMENT
- **18 COMPUTATION, MATHEMATICS & LOGISTICS DEPARTMENT**
- **19 SHIP ACOUSTICS DEPARTMENT**
- 27 PROPULSION AND AUXILIARY SYSTEMS DEPARTMENT
- 28 SHIP MATERIALS ENGINEERING DEPARTMENT

DTRC ISSUES THREE TYPES OF REPORTS:

1. DTRC reports, a formal series, contain information of permanent technical value. They carry a consecutive numerical identification regardless of their classification or the originating department.

2. Departmental reports, a semiformal series, contain information of a preliminary, temporary, or proprietary nature or of limited interest or significance. They carry a departmental alphanumerical identification.

3. Technical memoranda, an informal series, contain technical documentation of limited use and interest. They are primarily working papers intended for internal use. They carry an identifying number which indicates their type and the numerical code of the originating department. Any distribution outside DTRC must be approved by the head of the originating department on a case-by-case basis.

UNCLA	ISS:	IFIED	

SECURITY CLASSIFICATION OF THIS PAGE

Is REPORT SECURITY CLASSIFICATION UNICLASSIFICATION AUTHORITY ID. RESTRICTIVE MARKINGS 2a SECURITY CLASSIFICATION AUTHORITY 3. DISTRIBUTION/AVAILABILITY OF REPORT (See Reverse Side) 2b DECLASSIFICATION AUTHORITY 3. DISTRIBUTION/AVAILABILITY OF REPORT (See Reverse Side) 2b DECLASSIFICATION AUTHORITY 3. DISTRIBUTION/AVAILABILITY OF REPORT (See Reverse Side) 2c DECLASSIFICATION AUTHORITY 3. DISTRIBUTION/AVAILABILITY OF REPORT (See Reverse Side) 2c DECLASSIFICATION REPORT NUMBER(S) 5. MONITORING ORGANIZATION REPORT NUMBER(S) 2c DEVICE STREAMING CORGANIZATION 66. OFFICE SYMBOL (M applicable) 2c ADDRESS (Chy, State, and ZIP Code) 7b. ADDRESS (Chy, State, and ZIP Code) 2c ADDRESS (Chy, State, and ZIP Code) 8b. OFFICE SYMBOL (M applicable) 9. PROCENT INSTRUMENT IDENTIFICATION NUMBER 2c ADDRESS (Chy, State, and ZIP Code) 8b. OFFICE SYMBOL (M applicable) 9. PROCENT INSTRUMENT IDENTIFICATION NUMBER 2c ADDRESS (Chy, State, and ZIP Code) 8b. OFFICE SYMBOL (M applicable) 9. PROCENT INSTRUMENT IDENTIFICATION NUMBERS 2c ADDRESS (Chy, State, and ZIP Code) 8b. OFFICE SYMBOL (M applicable) 9. ROOKCE OF FUNDING NUMBERS 2c ADDRESS (Chy, State, and ZIP Code) 9. STATE (SSN-578) 10. SOURCE OF FUNDING NUMBERS 3c ADDRESS (Chy, State, and ZIP Code) 9. STATE (SSN-578) 11. THE (mol		REPORT	DOCUMENTATIO	N PAGE		6	orm Approved OMB No. 0704-0188
22. SECURITY CLASSIFICATION AUTHORITY 3. DISTRIBUTION / AVAILABILITY OF REPORT 23. DECLASSIFICATION AUTHORITY 3. DISTRIBUTION / AVAILABILITY OF REPORT 24. PERFORMING ORGANIZATION REPORT NUMBER(S) 5. MONITORING ORGANIZATION REPORT NUMBER(S) 25. DECLASSIFICATION REPORT NUMBER(S) 5. MONITORING ORGANIZATION REPORT NUMBER(S) 26. DEVID TRY OR SEGARCH Center (ff applicable) 26. DETECT SYMBOL (ff applicable) 27. NAME OF FUNDING / SPONSORING (ff applicable) 28. ADDRESS (Gry, State, and 20° Code) 3. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER 27. NAME OF FUNDING / SPONSORING (ff applicable) 28. ADDRESS (Gry, State, and 20° Code) 3. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER 28. ADDRESS (Gry, State, and 20° Code) 15. OFRICE SYMBOL 28. ADDRESS (Gry, State, and 20° Code) 15. OFRICE SYMBOL 29. PROCUREMENT AVAILABILITY OF REPORT (Graphicable) 235R 10. SOURCE OF FUNDING NUMBERS Boor 400 29. PROCUREMENT AVAILABILITY OF REPORT (Graphicable) 16. SOURCE OF FUNDING NUMBERS 29. REPORT THE SECONTY CLASSIFICATION 10. DATE OF REPORT (Graphicable) 29. PROCURATION TOW FUNCTIONE EVALUATION OF THE USS SKATE (SSN-578) 17. DATE OF REPORT (Graphicable) 29. FERSONAL AUTHORIS) MO	1a. REPORT SECURITY CLASS UNCLASSIFIED	IFICATION		16. RESTRICTIVE	MARKINGS		
26. DECLASSIFICATION / DOWNGRADING SCHEDULE (See Reverse Side) 27. PERFORMING ORGANIZATION REPORT NUMBER(S) 5. MONITORING ORGANIZATION REPORT NUMBER(S) 28. NAME OF PERFORMING ORGANIZATION REPORT NUMBER(S) 5. MONITORING ORGANIZATION REPORT NUMBER(S) 28. NAME OF PERFORMING ORGANIZATION 60. OFFICE SYMBOL (P applicable) 72. NAME OF MONITORING ORGANIZATION 28. NAME OF PUNDING /SPONSORING ORGANIZATION 60. OFFICE SYMBOL (P applicable) 72. NAME OF MONITORING ORGANIZATION 28. NAME OF PUNDING /SPONSORING ORGANIZATION 90. OFFICE SYMBOL (P applicable) 72. NAME OF MONITORING ORGANIZATION NUMBER 29. RECUREMENT INSTRUMENT IDENTIFICATION NUMBER 98. OFFICE SYMBOL (P applicable) 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER 20. Sama and ZIP Code) 90. OFFICE SYMBOL (P applicable) 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER 20. SADDRESS (GR), State, and ZIP Code) 9. DOFFICE SYMBOL (P applicable) 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER 20. SADDRESS (GR), State, and ZIP Code) 9. DOFFICE SYMBOL (P applicable) 10. SOURCE OF FUNDING NUMBERS 20. COLL 11. THE (Inclust 20 Code) 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER 10. SOURCE OF FUNDING NUMBERS 20. THE DET MET COMTING EVALUATION OF THE USS SKATE (SSN-578) 10. SOURCE OF FUNDING NUMBERS 10. SOURCE OF FUNDING NUMBERS	28. SECURITY CLASSIFICATIO	N AUTHORITY		3. DISTRIBUTION	AVAILABILITY	OF REPORT	
(See Reverse Side) 4. PERFORMING ORGANIZATION REPORT NUMBER(S) DTRC SHD-1322-01 5. NAME OF PERFORMING ORGANIZATION REPORT NUMBER(S) David Taylor Research Center 1541 5. ADDRESS (Gr), State, and ZP Code) 8. NAME OF PERFORMING ORGANIZATION 8. NAME OF PERFORMING ORGANIZATION 8. NAME OF FUNCION (SPONSORING ORGANIZATION (Prophysicable)) 7. ADDRESS (Gr), State, and ZP Code) 8. NAME OF FUNCING SPONSORING ORGANIZATION (Prophysicable) 7. ADDRESS (Gr), State, and ZP Code) 8. NAME OF FUNCING SPONSORING ORGANIZATION NUMBER 7. ADDRESS (Gr), State, and ZP Code) 8. ADDRESS (Gr), State, and ZP Code) 7. TO COGAN 8. CODRESS (Gr), State, and ZP Code) 8. CADDRESS (Gr), State, and ZP Code) 8. CADRESS (Gr), State, and ZP Code) 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER 11. TITLE (Proton ADDRESS (Gr), State, and ZP Code) 12. PAGE COLOR 13. TIME OF REPORT 13. THE OF REPORT 14. DETEMENTAL	26. DECLASSIFICATION / DOW	NGRADING SCHED	JLE	4			
4. PERFORMING ORGANIZATION REPORT NUMBER(5) 5. MONITORING ORGANIZATION REPORT NUMBER(5) DTRC SHD-1322-01 6. OFFICE SYMBOL Ga NAME OF REFORMING ORGANIZATION 66. OFFICE SYMBOL Bethesda, Maryland 20084-5000 1541 Bethesda, Maryland 20084-5000 72. NAME OF MONITORING ORGANIZATION Bethesda, Maryland 20084-5000 74. NAME OF MONITORING ORGANIZATION Bethesda, Maryland 20084-5000 75. ADDRESS (CRy, State, and ZIP Code) Bethesda, Maryland 20084-5000 75. ADDRESS (CRy, State, and ZIP Code) Bethesda, Maryland 20084-5000 75. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER Pearl Harbor, HI 9680 75. DDRESS (CRy, State, and ZIP Code) Box 400 Pearl Harbor, HI 96860 Pearl Harbor, HI 96860 96. OFFICE SYMBOL (# applicable) 11. TITLE (Include Security Classification) 10. SOURCE OF FUNDING NUMBERS YPRODYNAMIC TOWING EVALUATION OF THE USS SKATE (SSN-578) 12. PERSONAL AUTHORS() 12. PERSONAL AUTHORS() 16. SUBJECT TERMS (Continue on reverse if maccesary and dentify by block number) 715 SUPERMENTARY NOTATION 17 18. SUBJECT TERMS (Continue on reverse if maccesary and dentify by block number) 76 ADDRESS (CRy, State, and 2000 MICH (SSN 5778) 17				(See Rev	verse Side)	
DTRC SHD-1322-01 66. OFFICE SYMBOL (If Applicable) 72. NAME OF MONITORING ORGANIZATION David Taylor Research Center David Taylor Research Center 1541 72. NAME OF MONITORING ORGANIZATION 66. ADDRESS (CRy, State, and ZIP Code) 1541 76. ADDRESS (CRy, State, and ZIP Code) 8e heads, Maryland 20084-5000 8b. OFFICE SYMBOL (If Applicable) 76. ADDRESS (CRy, State, and ZIP Code) 8e. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If Applicable) 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER Pearl Harbor Naval Shipyard 235R 8b. OFFICE SYMBOL (If Applicable) 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER Box 4000 Factors 10. SOURCE OF FUNDING NUMBERS WOOK UN ACCESSION Pearl Harbor, HI 96860 10. SOURCE OF FUNDING NUMBERS WOOK UN ACCESSION PCCalley, Stephan A. and Para, Raymond P. 12. FROMA LUTHORGY 18. DATE OF REPORT (Year, Month, Day) 15. PAGE COUNT PEDUary 1990 17. 13b. TIME COVERED Towing Characteristics Submarine Towing Stabil Hydrodynamic Performance 19. ADSTRUCT (Continue on reverse if Accessary and identify by block number) 17. 19. ADSTRUCT (Continue on reverse if Accessary and identify by block number) 17. 19. ADSTRUCT (Continue on reverse if Accessary and identify by block number) 17.	4. PERFORMING ORGANIZAT	ION REPORT NUMB	ER(S)	5. MONITORING	ORGANIZATION	REPORT NUMB	ER(S)
Ga. NAME OF PERFORMING ORGANIZATION David Taylor Research Center Gb. OFFICE SYMBOL (# applicable) 1541 72. NAME OF MONITORING ORGANIZATION Gc. ADDRESS (Chy, State, and ZIP Code) 1541 75. ADDRESS (Chy, State, and ZIP Code) Be thesda, Maryland 20084-5000 Bb. OFFICE SYMBOL (# applicable) 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER ORGANIZATION Bb. OFFICE SYMBOL (# applicable) 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER Pearl Harbor Naval Shipyard Bb. OFFICE SYMBOL (# applicable) 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER Box 400 Restand Procession 10. SOURCE OF FUNDING NUMBERS Procession 10. SOURCE OF FUNDING NUMBERS PROCEASE (Chy, State, and ZP Code) Box 400 Pearl Harbor, HI 96860 10. SOURCE OF FUNDING NUMBERS PROCEASE (Chy, State, and ZP Code) 10. SOURCE OF FUNDING NUMBERS PROCEASE (Chy, State, and ZP Code) 11. TITLE (Inductive Security Classification) TO SOURCE OF FUNDING NUMBERS Procease (Charles) 10. SOURCE OF FUNDING NUMBERS Provide Security Classification) 12. FERSONAL AUTHOR(S) Pepartimental IB. SUBJECT TERMS (Continue on reverse (I necessary and identify by Moch number) 11. SUBJECT TERMS (Continue on reverse (I necessary and identify by Moch number) 13. TYPE OF REPORT IB. SUBJECT TERMS (Continue on reverse (I necessary and identify by Moch number) 17. 14. DATE OF REPORT (Vear, Morth, Day) I	DTRC SHD-1322-	01					
David Taylor Research Center Ut appricately 6c ADDRESS (GR, State, and ZIP Code) 1541 6c ADDRESS (GR, State, and ZIP Code) 7b. ADDRESS (GR, State, and ZIP Code) 8e thesda, Maryland 20084-5000 8b. OFFICE SYMBOL (If applicable) 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER (ADDRESS (GR, State, and ZIP Code) 8e. ADDRESS (GR, State, and ZIP Code) 10. SOURCE OF FUNDING NUMBERS (DR, State, and ZIP Code) 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER (If applicable) 8e. ADDRESS (GR, State, and ZIP Code) 235R 10. SOURCE OF FUNDING NUMBERS (DR, State, and ZIP Code) 8e. ADDRESS (GR, State, and ZIP Code) 10. SOURCE OF FUNDING NUMBERS (DR, State, and ZIP Code) WORK UN (If applicable) 8e. ADDRESS (GR, State, and ZIP Code) 10. SOURCE OF FUNDING NUMBERS (DR, State, and ZIP Code) WORK UN (If applicable) 11. TITLE (Include Security Classification) 10. SOURCE OF FUNDING NUMBERS (DR, State, and ZIP Code) WORK UN (If applicable) 12. PERSONAL AUTHOR(S) MCCauley, Stephan A. and Para, Raymond P. 13. TYPE OF REPORT (DR The Code) 14. DATE OF REPORT (rese. Month, Day) 15. PAGE COUNT 17 13. TYPE OF REPORT (DR Characteristics Submarine Towing Stabil (If Code) 16. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) Towing Characteristics Submarine Towing Stabil Rydrodynamic Performance 13. ABSTRACT (Continue on reverse if Accessary and identify by block number) Towing Characteristics Submarine Towing Stabil Rydrodynamic Perf	6a. NAME OF PERFORMING	ORGANIZATION	6b. OFFICE SYMBOL	7a. NAME OF M	ONITORING OR	SANIZATION	
6C. ADDRESS (City, State, and ZIP Code) 10.342 7b. ADDRESS (City, State, and ZIP Code) 8e thesda, Maryland 20084-5000 8e. NAME OF FUNDING /SPONSORING OKGANIZATION ACADRESS (City, State, and ZIP Code) 9e. ADDRESS (City, State, and ZIP Code) 10. SUPLEMENTARY NOTATION 11. TITLE (Inclusive Security Classification) 12. PERSONAL AUTHOR(S) 13e. STPPECHENTARY NOTATION 17 13a. STPE OF REPORT 13b. SUPLEMENTARY NOTATION 17 17 17 17 17 17	David Taylor Rese	arch Center	(" applicable)				
Be thesda, Maryland 20084-5000 Bs. NAME OF FUNDING SPONSORING ORGANATION Pearl Harbor Naval Shipyard Caboress (Chy, State, and ZiP Code) Dox 400 Pearl Harbor, HI 96860 II. THUE (Include Security Classification) HYDRODYNAMIC TOWING EVALUATION OF THE USS SKATE (SSN-578) II. THUE (Include Security Classification) HYDRODYNAMIC TOWING EVALUATION OF THE USS SKATE (SSN-578) II. THUE (Include Security Classification) HYDRODYNAMIC TOWING EVALUATION OF THE USS SKATE (SSN-578) II. THUE (Include Security Classification) HYDRODYNAMIC TOWING EVALUATION OF THE USS SKATE (SSN-578) II. THUE (Include Security Classification) HYDRODYNAMIC TOWING EVALUATION OF THE USS SKATE (SSN-578) II. FROM A AUTHOR(S) MCCauley, Stephan A. and Para, Raymond P. II. A TYPE OF REPORT III. III. TIME COVERED IS SUPPLIEMENTARY NOTATION III. COSATI CODES III. B. SUBJECT TERMS (Continue on reverse If necessary and identify by block number) III. B. SUBJECT TERMS (Continue on reverse If necessary and identify by block number) III. ASSTRACT (Continue on reverse If necessary and identify by block number) An experimental evaluation was conducted to investigate the surface tow characteristics of the USS SKATE (SSN-578). A 1/14.198-scale model was towed in David Taylor Research Center (VTRC) deep-water towing Basin using a single towpoin and several sternplane set at 25 deg trailing edge up. Keywords: Nuclear powered submat Submarine Models; Towied bedies; Seale models; Seale models; Hydrodynamic 540 Hydrodynamic Confron Sur Faces Sperformance. (EDC)	6c. ADDRESS (City, State, an	d ZIP Code)	1 1241	76. ADDRESS (C	ty, State, and Z	IP Code)	
Bethesda, Maryland 20084-5000 Sa NAME OF FUNDING (SPONSORING ORGANIZATION ORGANIZATION Pearl Harbor Naval Shipyard Sb. OFFICE SYMBOL (M spoktable) 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER Pearl Harbor, HI 96860 Box 400 Pearl Harbor, HI 96860 10. SOURCE OF FUNDING NUMBERS PEOGRAM ELEMENT NO 10. SOURCE OF FUNDING NUMBERS PROJECT WORK UN NO. T1. TITLE (include Security Classification) 10. SOURCE OF FUNDING NUMBERS PEOGRAM PEOGRAM PEOGRAM IND. 10. SOURCE OF FUNDING NUMBERS NO. WORK UN ACCESSOR SOTOA: 11. TITLE (include Security Classification) 11. TITLE (include Security Classification) 11. TITLE (include Security Classification) 12. PERSONAL AUTHON(S) MCCauley, Stephan A. and Para, Raymond P. 13. TYPE OF REPORT 11. Date Covered 14. Date OF REPORT (Vasr, Month, Day) 15. PAGE COUNT Pebruary 1990 12. PERSONAL AUTHON(S) MCCauley, Stephan A. and Para, Raymond P. 13. TYPE OF REPORT 14. Date OF REPORT (Vasr, Month, Day) 15. PAGE COUNT 17 13. TYPE OF REPORT 11. Bit. TIME COVERED 14. Date OF REPORT (Vasr, Month, Day) 15. PAGE COUNT 17 14. Date Stephental 13. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) 17 15. ASSTRUCT (Continue on reverse if necessary and identify by block number) 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) 19. ASSTRUCT (Continue on reverse if necessary and identify by bl							
Ba. NAME OF FUNDING / SPONSORING ORGANIZATION Bb. OFFICE SYMBOL (If applicable) 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER (If applicable) Pearl Harbor Naval Shipyard 235R Box ADDRESS (Gry, State, and ZIP Code) 235R Box 400 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER PROCECT Para Harbor, HI 96860 10. SOURCE OF FUNDING NUMBERS PROGRAM PROJECT TASK PROMECOREPORT TaSK ADDRESS (Con	Bethesda, Marylan	d 20084-500	0				
ORGANIZATION (# applicable) Pearl Harbor Naval Shipyard 235R Ex ADDRES (for, State, and ZiP Code) 235R Box 400 PROGRAM PROGRAM PROGRAM PROGRAM PROGRAM PROGRAM PROGRAM PROGRAM PROGRAM PROGRAM PROGRAM Box 400 PROGRAM Program PROGRAM PROMOUSE PROGRAM Box 400 PROGRAM Pearl Harbor, HI 96860 PROGRAM 11. THLE (include Security Classification) McCauley, Stephan A. and Para, Raymond P. 12. PERSONAL AUTHOR(S) McCauley, Stephan A. and Para, Raymond P. 13. TYPE OF REPORT PROM To	8a. NAME OF FUNDING / SPC	NSORING	Bb. OFFICE SYMBOL	9. PROCUREMEN	T INSTRUMENT	IDENTIFICATION	NUMBER
Pearl Harbor Naval Shipyard 235K BC ADDRESS (CRy, State, and ZiP Code) 10 SOURCE OF FUNDING NUMBERS Box 400 PROGRAM Pearl Harbor, HI 96860 10 SOURCE OF FUNDING NUMBERS III. THLE (include Security Classification) HYDRODYNAMIC TOWING EVALUATION OF THE USS SKATE (SSN-578) 12. FERSONAL AUTHOR(5) McCauley, Stephan A. and Para, Raymond P. 13. TYPE OF REPORT 13. TYPE OF REPORT 13. TYPE OF REPORT 13. TYPE OF REPORT 14. DATE OF REPORT (Year, Month, Day) 15. PAGE COUNT Peartmental 13. TYPE OF REPORT 14. DATE OF REPORT (Year, Month, Day) 15. PAGE COUNT Peartmental 16. SUBJECT TERMS (Continue on reverse if mecessary and identify by Mock number) 17. COSATI CODES 18. SUBJECT TERMS (Continue on reverse if mecessary and identify by Mock number) 17. 18. SUBJECT TERMS (Continue on reverse if mecessary and identify by Mock number) 19. Astract (Continue on reverse if mecessary and identify by Mock number) 19. Astract (Continue on reverse if mecessary and identify by Mock number) 19. An experimental evaluation was conducted to investigate the	ORGANIZATION		(If applicable)				
CONNECTION, State, and Dar Code 10. SUDACE OF PUNIONS NUMBERS Pearl Harbor, HI 96860 PROGRAM Pearl Harbor, HI 96860 PROGRAM 11. TITLE (include Security Classification) IVDRODYNAMIC TOWING EVALUATION OF THE USS SKATE (SSN-578) 12. PERSONAL AUTHOR(S) McCauley, Stephan A. and Para, Raymond P. 13a. TYPE OF REPORT 13b. TYPE OF REPORT 13b. TYPE OF REPORT 17 17. COSATI CODES 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) 17. 17. COSATI CODES 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) 17. 17. 17. 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Con	Pearl Harbor Nava	1 Shipyard	235R	10 5011055 05		CBC	
Pearl Harbor, HI 96860 ELEMENT NO. NO. NO. SCCESSION 50704: 11. TITLE (Include Security Classification) INC. NO. SCCESSION 50704: 11. TITLE (Include Security Classification) INC. SOTO4: 12. PERSONAL AUTHOR(S) McCauley, Stephan A. and Para, Raymond P. INC. SOTO4: 13. TYPE OF REPORT II. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) IT 15. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) Towing Characteristics Submarine Towing Stabil 19. ASSTRACT (Continue on reverse if necessary and identify by block number) INCLASSTRACT (Continue on reverse if necessary and identify by block number) 19. ASSTRACT (Continue on reverse if necessary and identify by block number) INCLASSTRACT (Continue on reverse if necessary and identify by block number) 19. ASSTRACT (Continue on reverse if necessary and identify by block number) INCLASSTRACT (Continue on reverse if necessary and identify by block number) <	Box 400	2/7 (000)		PROGRAM	PROJECT	TASK	WORK LINIT
50704: 11. TITLE (Include Security Classification) HYDRODYNAMIC TOWING EVALUATION OF THE USS SKATE (SSN-578) 12. FERSONAL AUTHOR(S) MCGauley, Stephan A. and Para, Raymond P. 13a. TYPE OF REPORT TO To To Towing Characteristics Submarine Towing Stabil Towing Characteristics Submarine Towing Stabil Towing Characteristics Submarine Towing Stabil Hydrodynamic Performance 19. ABSTRACT (Continue on reverse if necessary and identify by block number) An experimental evaluation was conducted to investigate the surface tow characteristics of the USS SKATE (SSN-578). A 1/14.198-scale model was towed in the satisfactorily towed with an additional 50% prevents sternplane area aft and the sternplane configurations. The results indicate that the SSN-578 can satisfactorily towed with an additional 50% prevents sternplane area aft and the sternplane set at 25 deg trailing edge up. <i>Kcywords: Wackar powered submarine Submarine Configurations Scale models: Hydrodynamic Stabilional Sole for mance (EDC)</i> 20. DISTRIBUTION / AVAILABILITY OF ABSTRACT 20. DISTRIBUTION / AVAILABILITY OF ABSTRACT 20. DISTRIBUTION / AVAILABILITY OF ABSTRACT	Pearl Harbor. HI	96860		ELEMENT NO.	NO.	NO.	ACCESSION NO
11. TITLE (Include Security Classification) HYDRODYNAMIC TOWING EVALUATION OF THE USS SKATE (SSN-578) 12. PERSONAL AUTHON(S) MCCauley, Stephan A. and Para, Raymond P. 13. TYPE OF REPORT 13. TYPE OF REPORT 13. TYPE OF REPORT 13. TYPE OF REPORT 14. DATE OF REPORT 15. TYPE OF REPORT 16. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) 17. COSATI CODES 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) 17. COSATI CODES 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) An experimental evaluation was conducted to investigate the surface tow characteristics of the USS SKATE (SSN-578). A 1/14.198-scale model was towed in pavid Taylor Research Center (OTRC) deep-water towing basin using a single towpoil and several sternplane configurations. The results indicate that the SSN-578 can satisfactorily towed with an additional 50 persons ternplane area aft and the sternplane set at 25 deg trailing edge up. Kcywoords: Muchar powered submat Submarine Models; Towled bodies; Scale models: Hud rody no mic sta Hud rodynamic Control surfaces performance. (EDC) 20. DISTRIBUTION/AVAILABILITY OF ABSTRACT DICL USERS 21. ABSTRACT SECURITY CLASSIFICATION							507042
INDERODYNAMIC TOWING EVALUATION OF THE USS SKATE (SSN-578) 12. PERSONAL AUTHOR(S) MCCauley, Stephan A. and Para, Raymond P. 13a. TYPE OF REPORT 13b. TIME COVERED FROM 14. DATE OF REPORT (Year, Month, Day) 15. PAGE COUNT Departmental FROM TO February 1990 17 15. SUPPLEMENTARY NOTATION 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) Toving Characteristics Submarine Towing Stabil Hydrodynamic Performance 17. COSATI CODES 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) Towing Characteristics Submarine Towing Stabil 17. COSATI CODES 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) Towing Characteristics Submarine Towing Stabil 18. ABSTRACT (Continue on reverse if necessary and identify by block number) Towing Characteristics Submarine Towing Stabil 19. ABSTRACT (Continue on reverse if necessary and identify by block number) An experimental evaluation was conducted to investigate the surface tow characteristics of the USS SKATE (SSN-578) A 1/14.198-scale model was towed in David Taylor Research Center (DTRC) deep-water towing basin using a single towpoin and several sternplane configurations. The results indicate that the SSN-578 can satisfactorily towed with an additional 50 prevents sternplane area aft and the sternplane set at 25 deg trailing edge up. <i>Mcguords</i> : Wuclear powered submo Submorive models; Towed bodies; Seale models; Hydrodynamic sta Hyd	11. TITLE (Include Security C	lassification)					
12. PERSONAL AUTHORS; 13. TYPE OF REPORT 13. TIME COVERED 14. DATE OF REPORT 15. PAGE COUNT 15. SUPPLEMENTARY NOTATION 16. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) 17. COSATI CODES 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT SECURITY CLASSIFICATION 19. David Taylor Research Center (DTRC) deep-water towing basin using a single towpoit and several sternplane set at 25 deg trailing edge up. Keywords:	TOUTN TOUTN	G EVALUATION	OF THE USS SKA	TE (SSN-578)		
McCauley, Stephan A. and Para, Raymond P. 13a. TYPE OF REPORT 13b. TIME COVERED 14. DATE OF REPORT (Year, Month, Day) 15. PAGE COUNT Departmental FROM TO February 1990 17 16. SUPPLEMENTARY NOTATION 16. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) 17 17. COSATI CODES 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) 17. GROUP SUB-GROUP 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) 17. GROUP SUB-GROUP 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) 17. GROUP SUB-GROUP 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if hecessary and identify by block number) Towing Characteristics Submarine Towing Stabil 19. ABSTRACT (Continue on reverse if hecessary and identify by block number) An experimental evaluation was conducted to investigate the surface tow characteristics of the USS SKATE (SSN-578). A 1/14.198-scale model was towed in David Taylor Research Center (DTRC) deep-water towing basin using a single towpoint and several sternplane configurations. The results indicate that the SSN-578 can satisfactorily towed with an additional 50/percent sternplane area aft and the sternplane set at 25 deg trailing edge up. Keywords: Muclear powered submar Sub	12. PERSONAL AUTHOR(S)						
13a. TYPE OF REPORT 13b. TIME COVERED 14. DATE OF REPORT (Yeer, Month, Day) 15. PAGE COUNT Departmental FROM TO February 1990 17 16. SUPPLEMENTARY NOTATION 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) 17 Towing Characteristics Submarine Towing Stabil Hydrodynamic Performance 19. ABSTRUCT (Continue on reverse if necessary and identify by block number) Towing Characteristics Submarine Towing Stabil Hydrodynamic Performance 19. ABSTRUCT (Continue on reverse if necessary and identify by block number) An experimental evaluation was conducted to investigate the surface tow characteristics of the USS SKATE (SSN-578). A 1/14.198-scale model was towed in David Taylor Research Center (DTRC) deep-water towing basin using a single towpoil and several sternplane configurations. The results indicate that the SSN-578 can satisfactorily towed with an additional 50% persons sternplane area aft and the sternplane set at 25 deg trailing edge up. Kcywords: Nuclear powered submar Submarine Confront surfaces performance. (EDC) 20. DISTRIBUTION/AVAILABILITY OF ABSTRACT Duncussification 21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED 2	McCauley, Step	han A. and P	ara, Raymond P.				
Departmental FROMTO	13a. TYPE OF REPORT	136. TIME C	OVERED	14. DATE OF REPO	ORT (Year, Mont	h, Day) 15. PA	GE COUNT
10. SUPPLEMENTARY NOTATION 17. COSATI CODES 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT Second on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT Second on reverse if necessary and identify by block number) 19. ABSTRACT Second on reverse if necessary and identify by block number) 19. ABSTRACT Second on reverse if necessary and identify by block number) 19. ABSTRACT Second on reverse if necessary and identify by block number) 19. ABSTRACT Second on reverse if necessary and identify by block number) 20. DISTRIBUTION / AVAILABILI	Departmental	FROM	10	February 1	990		17
17. COSATI CODES 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) Towing Characteristics Submarine Towing Stabil Hydrodynamic Performance 19. ABSTRACT (Continue on reverse if necessary and identify by block number) An experimental evaluation was conducted to investigate the surface tow characteristics of the USS SKATE (SSN-578). A 1/14.198-scale model was towed in David Taylor Research Center (DTRC) deep-water towing basin using a single towpoin and several sternplane configurations. The results indicate that the SSN-578 can satisfactorily towed with an additional 50% persons sternplane area aft and the sternplane set at 25 deg trailing edge up. Keywords: Nuclear powered submos Submorine Models; Towed bedies; Seale models; Hydrodynamic sta Hydrodynamic Control surfaces performance. (EDC) 20. DISTRIBUTION/AVAILABILITY OF ABSTRACT DUNCLASSIFICUMULMITED EF SAME AS RPT. DOTIC USERS 21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFICUMULMITED EF SAME AS RPT. DOTIC USERS 22a. NAME OF RESPONSIBLE INDIVIDUAL Stephan A. McCauley 21. ABSTRACT SECURITY CLASSIFICATION OF THIS PAG 22b. TELEPHONE (Include Area Code) 22c. OFFICE SYMBOL (202) 227-2030 22b. TELEPHONE (Include Area Code) 22c. OFFICE SYMBOL (202) 227-2030	J			201			
FIELD GROUP SUB-GROUP Towing Characteristics Submarine Towing Stabil Hydrodynamic Performance Hydrodynamic Performance 19. ABSTRACT (Continue on reverse if necessary and identify by block number) An experimental evaluation was conducted to investigate the surface tow characteristics of the USS SKATE (SSN-578). A 1/14.198-scale model was towed in David Taylor Research Center (DTRC) deep-water towing basin using a single towpoin and several sternplane configurations. The results indicate that the SSN-578 can satisfactorily towed with an additional 50% percent sternplane area aft and the sternplane set at 25 deg trailing edge up. Keywords: Wuclear powered submar Submarine Models; Towed bodies; Seale models: Hydrodynamic stabil Hydrodynamic Control surfaces performance. (EDC) 20. DISTRIBUTION/AVAILABILITY OF ABSTRACT 21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED/UNLIMITED EF SAME AS RPT. Dotic USERS 22a. NAME OF RESPONSIBLE INDIVIDUAL 21. ABSTRACT SECURITY CLASSIFICATION Stephan A. McCauley 220. DISTRIBUTION/AVAILABILITY OF ABSTRACT 22a. NAME OF RESPONSIBLE INDIVIDUAL 221. DOTIC USERS 22a. NAME OF RESPONSIBLE INDIVIDUAL 221. ABSTRACT SECURITY CLASSIFICATION 220. DISTRIBUTION AVAILABILITY OF ABSTRACT 221. DOTIC USERS 222. NAME OF RESPONSIBLE INDIVIDUAL 221. TELEPHONE (include Area Code) 222. OFFICE SYMBOL (202) 227-2030 220. TELEPHONE (include Area Code) 1541 1541<	17. COSATU	CODES	18. SUBJECT TERMS	Continue on reven	e if pecestary a	nd identify by h	lock number)
Hydrodynamic Performance Hydrodynamic Performance 19. ABSTRACT (Continue on reverse if necessary and identify by block number) An experimental evaluation was conducted to investigate the surface tow characteristics of the USS SKATE (SSN-578). A 1/14.198-scale model was towed in David Taylor Research Center (DTRC) deep-water towing basin using a single towpoin and several sternplane configurations. The results indicate that the SSN-578 can satisfactorily towed with an additional 50% sereent sternplane area aft and the sternplane set at 25 deg trailing edge up. Keywords: Nuclear powered subma Submarine Models; Towed bodies; Scale models; Hydrodynamic sta Hydrodynamic Control surfaces performance. (EDC) 20. DISTRIBUTION/AVAILABILITY OF ABSTRACT DuvicLassifieDunulmiTED EF same as RPT. Dotic users 21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIEDUNULMITED EF same as RPT. Distribution/Availability of ABSTRACT 21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIEDUNULMITED EF SAME AS RPT. DISTRIBUTION/AVAILABILITY OF ABSTRACT 21. Distribution/Availability of ABSTRACT 20. DISTRIBUTION/AVAILABILITY OF ABSTRACT 20. TELEPHONE (include Area Code) 22. OFFICE SYMBOL 22. TELEPHONE (include Area Code) 22. OFFICE SYMBOL <td>FIELD / GROUP</td> <td>SUB-GROUP</td> <td>Towing Cha</td> <td>racteristic</td> <td>s Subm</td> <td>arine Towi</td> <td>ng Stability</td>	FIELD / GROUP	SUB-GROUP	Towing Cha	racteristic	s Subm	arine Towi	ng Stability
19. ABSTRACT (Continue on reverse if necessary and identify by block number) Image: Stephan A. MCCauley 19. ABSTRACT (Continue on reverse if necessary and identify by block number) Image: Stephan A. MCCauley 19. ABSTRACT (Continue on reverse if necessary and identify by block number) Image: Stephan A. MCCauley 19. ABSTRACT (Continue on reverse if necessary and identify by block number) Image: Stephan A. MCCauley 19. ABSTRACT (Continue on reverse if necessary and identify by block number) Image: Stephan A. MCCauley 19. ABSTRACT (Continue on reverse if necessary and identify by block number) 19. ABSTRACT (Continue on reverse if necessary and identify by block number) Image: Stephan A. MCCauley 19. ABSTRACT SECURITY CLASSIFICATION of THIS PAGE			Hydrodynam	ic Performan	nce		
19. ABSTRACT (Continue on reverse if necessary and identify by block number) An experimental evaluation was conducted to investigate the surface tow characteristics of the USS SKATE (SSN-578). A 1/14.198-scale model was towed in David Taylor Research Center (DTRC) deep-water towing basin using a single towpoil and several sternplane configurations. The results indicate that the SSN-578 can satisfactorily towed with an additional 50% persons sternplane area aft and the sternplane set at 25 deg trailing edge up. Keywords: Waclear powered submit Submarial Models; Towed bodies; Scale models; Hydrodynamic sta Hydrodynamic Control surfaces performance. (EDC) 20. DISTRIBUTION / AVAILABILITY OF ABSTRACT Date of RESPONSIBLE INDIVIDUAL 21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED 22. NAME OF RESPONSIBLE INDIVIDUAL 21. ABSTRACT SECURITY CLASSIFICATION 22. DISTRIBUTION / AVAILABILITY OF ABSTRACT DOTIC USERS <							
20. DISTRIBUTION / AVAILABILITY OF ABSTRACT 21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED/UNLIMITED SAME AS RPT. DTIC USERS 22a. NAME OF RESPONSIBLE INDIVIDUAL 22b. TELEPHONE (include Area Code) 22c. OFFICE SYMBOL Stenhan A. McCauley (202)227-2030 1541 ID Form 1473, JUN 86 Previous editions are obsolete. SECURITY CLASSIFICATION OF THIS PAG							
22a. NAME OF RESPONSIBLE INDIVIDUAL 22b. TELEPHONE (Include Area Code) 22c. OFFICE SYMBOL Stenhan A. McCauley (202)227~2030 1541 DD Form 1473, JUN 86 Previous editions are obsolete. SECURITY CLASSIFICATION OF THIS PAG	An e characteristic David Taylor R and several st satisfactorily sternplane set Submorive m Hydrodyna.	xperimental s of the USS esearch Cent ernplane cor towed with at 25 deg t odds; Tou mic confi	evaluation was SKATE (SSN-578 er (DTRC) deep- figurations. T an additional S railing edge up Wed bodies; S tol surfac.	conducted to b). A 1/14. water towing the results to percents be Keywood Scale wood es perfe	o investig 198-scale g basin us indicate t ternplane As: Wucle hels: Hu bermane	ate the su model was ing a sing hat the SS area aft a or power ydrodyna ce. (ED	rface towing towed in the le towpoint N-578 can be nd the ed submark muic stabu
Stephan A. McCauley I (202)22/~2030 I 1241 DD Form 1473, JUN 86 Previous editions are obsolete. SECURITY CLASSIFICATION OF THIS PAG	An e characteristic David Taylor R and several st satisfactorily sternplane set Submorive M Hydrodyna 20. DISTRIBUTION/AVAILABI	xperimental s of the USS esearch Cent ernplane con towed with at 25 deg t odd(s; Tou mic confi uity OF ABSTRACT ED ES SAME AS	evaluation was SKATE (SSN-578 er (DTRC) deep- figurations. T an additional 5 railing edge up Ved bodies; S rol surfac. RPT. ODTIC USERS	conducted to A 1/14. water towing the results by persons Requose es perfe 21. ABSTRACT SE UNCLASSI	o investig 198-scale g basin us indicate t ternplane ds: Wucle dels: Hu bels: Hu bels: Hu contrologic curity classif FIED	ate the su model was ing a sing hat the SS area aft a or power ydrodyna ce. (ED	rface towing towed in the le towpoint N-578 can be nd the ed submark mic stabu
JU FORTH 14/5, JUN 80 Previous editions are obsolete. SECURITY CLASSIFICATION OF THIS PAG	20. DISTRIBUTION / AVAILABI UNCLASSIFIED/UNLIMITI 22. NAME OF RESPONSIBLE	xperimental s of the USS esearch Cent ernplane cor towed with at 25 deg t odds; Tou mic Confi Mic Confi UTY OF ABSTRACT ED SAME AS INDIVIDUAL	evaluation was SKATE (SSN-578 er (DTRC) deep- an additional 5 trailing edge up Wed bodies; S tol surfac. RPT. OTIC USERS	conducted to A 1/14. water towing the results of percents be Keyword Scale mode es perfe 21. ABSTRACT SE UNCLASSI 22b. TELEPHONE	o investig 198-scale g basin us indicate t ternplane ds: Wucle dels: Hu bernance curity classif FIED finclude Area Co	ate the su model was ing a sing hat the SS area aft a or power ydrodyng ce. (ED ication	rface towing towed in the le towpoint N-578 can be nd the ed submarine nuc stabu
	An e characteristic David Taylor R and several st satisfactorily sternplane set Submorive M Hydrodyna 20. DISTRIBUTION/AVAILABI ☐ UNCLASSIFIED/UNLIMIT 22a. NAME OF RESPONSIBLE Stenban A. McCau	xperimental s of the USS esearch Cent ernplane cor towed with at 25 deg t odds; Tou mic Confi unc Confi UTY OF ABSTRACT ED SAME AS INDIVIDUAL Ley	evaluation was SKATE (SSN-578 er (DTRC) deep- figurations. T an additional S railing edge up Wed bodies; S rol surfac. RPT. OTIC USERS	conducted to A 1/14. water towing the results of percents b. Keyword cale wood cale cale wood cale cale wood cale cale wood cale cale wood cale cale wood cale cale cale wood cale cale cale cale cale cale cale cale	o investig 198-scale g basin us indicate t ternplane ds: Wucle dels: Ho FIN and CURITY CLASSIF FIED (Include Area Co 2030	ate the su model was ing a sing hat the SS area aft a or power ydrodyna ce. (ED ication de) 22c. Office 1541	rface towing towed in the le towpoint N-578 can be nd the ed submark muic stabu

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

BLOCK #3:

Distribution **Chiefe** to U.S. Government agencies only; test and evaluation; February 1990. Other requests for this document shall be referred to Code 15, David Taylor Research Center, Bethesda, Maryland 20084-5000.

NTIS	CRA&I	п.
DTIC	TAB	N
Unanr	ounced	ō
Justiti	calion	
Bv		
Distrib	ution /	
		0. I
م 	манаольту	Loges
Dist	Avell and Specia	1 / or
2-2		
50		

DD Form 1473, JUN 86 (Reverse)

DIIC COPY

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

CONTENTS

	-	-	-
	ж.	P	
-	-	-	-

ABSTRACT	1
ADMINISTRATIVE INFORMATION	1
INTRODUCTION	1
MODEL DESCRIPTION	2
PROCEDURE	2
INSTRUMENTATION	5
RESULTS AND DISCUSSION	8
CONCLUSIONS	10

FIGURES

1.	Model of the USS SKATE (SSN-578)	3
2.	Towpoint location used in the SSN-578 evaluation	3
3.	SSN-578 submarine model with sternplane extensions aft	6
4.	SSN-578 submarine model with sternplane extensions outboard	6
5.	SSN-578 submarine model with vertical end plates on the sternplane tips	7
6.	SSN-578 submarine model without sternplane extensions	7
7.	Horizontal towline angle as a function of elapsed time for 4 sternplane configurations at 7 kn (3.6 m/s)	11
8.	Horizontal towline angle as a function of elapsed time for 4 sternplane configurations at 10 kn (5.14 m/s)	11
9.	Horizontal towline angle as a function of elapsed time for two GM values at 7 kn (3.6 m/s)	12
10.	Horizontal towline angle as a function of elapsed time for two GM values at 10 km (5.14 m/s) .	12

TABLES

Page

1.	Ballast conditions for the SSN-578 submarine model	4
2.	Horizontal towline angle for various speeds, sternplane angles, and sternplane configurations at a GM of 1.06 ft (0.32 m)	9
3.	Horizontal towline angle and towline tension for various speeds at a GM of 0.85 ft (0.26 m), extensions aft, and a sternplane angle of 25 deg TEU	9
4.	Towline tension for various speeds, sternplane angles, and sternplane configurations at a GM of 1.06 ft (0.32 m)	13

ABSTRACT

An experimental evaluation was conducted to investigate the surface towing characteristics of the USS SKATE (SSN-578). A 1/14.198-scale model was towed in the David Taylor Research Center deep-water towing basin using a single towpoint and several sternplane configurations. The results indicated that the SSN-578 can be satisfactorily towed with an additional 50 percent sternplane area aft and the sternplane set at 25 deg trailing edge up.

ADMINISTRATIVE INFORMATION

This project was sponsored by the Pearl Harbor Naval Shipyard through Work Request WR21512 of 26 November 1986 with the Naval Sea Systems Command, (NAVSEA) Code 55W31, the technical point of contact. This work was performed by the David Taylor Research Center under Work Unit 1-1541-113.

INTRODUCTION

At the request of the Naval Sea Systems Command, the David Taylor Research Center (DTRC) undertook a program to investigate the surface towing characteristics of the SSN-578 submarine. Submarines under surface tow often display undesirable tow characteristics such as yawing and extreme kiting to one side. The classic description of a stable tow has the tow positioned directly astern of the tug. As the tow yaws and moved further outboard from a centerline position behind the tug, the situation can become difficult, if not unacceptable. Several basin evaluations have looked at stabilizing efforts for a submarine under tow. ^{1.2}

^{&#}x27;Para, R. P., "A Stability Investigation of Various Towing Configurations and Stabilizing Devices for a Modified SSBN-598 Class Submarine," DTNSRDC Report SPD-0202-06 (Mar 1982).

²Para, R. P., "Hydrodynamic Towing Evaluation of the USS DOLPHIN (AGSS-555)," DTNSRDC Report SPD-0906-01 (Jul 1979).

The purpose of this effort was to determine the best towing configuration for the submarine and to present the results of these evaluations. This report describes the model and the experimental procedure. Towline tension and towline angles are presented as a function of speed for various sternplane configurations.

MODEL DESCRIPTION

An 18.85 ft (5.75 m) long free-flooding mahogany model of the USS SKATE was used for the basin evaluation. The model has a linear scale ratio of 14.198. The model is shown in Fig. 1 with its ballast conditions listed in Table 1. The sail was not fitted to the model since during a surface tow it is completely out of the water and therefore does not have any hydrodynamic effect on the stability of the submarine. A single towpoint was used with a full scale location of 23.83 ft (7.20 m) above the baseline (ABL) and on the forward perpendicular. The model towpoint is shown in Fig 2. The screw eye shown on the top of the model was only used for handling purposes.

PROCEDURE

The model was statically trimmed for surface towing by ballasting to waterline 1 with a trim of 4.66 ft (1.42 m) down by the stern and waterline 2 with a trim of 4.01 ft (1.22 m) down by the stern. Roll incline tests were then conducted to obtain the two required metacentric heights (GM) of 1.06 ft (0.32 m) and 0.85 ft (0.25 m). The tow tests were conducted in the deepwater basin at DTRC. The basin is 22 ft (6.7 m) deep, 51 ft (15.5 m) wide, and has an approximate run length of 800 ft (243.8 m). The model was towed at equivalent full-scale speeds of 4, 7 and 10 kn (2.06, 3.6, and 5.14 m/s). The length of the nylon towline used was 16 ft (4.88 m) and had a diameter of



PSD 16136-12-86-1

Fig. 1. Model of the USS SKATE (SSN-578).





Ship Characteristics	Full Scale	Model
Displacement	2,215 Tons (SW) (2,250,948 Kg)	1,686 lbs (FW) (765 Kg)
Mean Draft	17.75 ft (5.4 m)	15 in. (0.38 m)
WATERLINE 1		
GM Required	1.06 ft (0.32 m)	0.89 in. (0.023 m)
Draft (FWD)	16.3 ft (4.97 m)	13.78 in. (0.35 m)
Draft (AFT)	19.44 ft (5.93 m)	16.43 in. (0.42 m)
WATERLINE 2		
GM Required	0.85 ft (0.26 m)	0.72 in. (0.018 m)
Draft (FWD)	16.5 ft (5.03 m)	13.95 in. (0.35 m)
Draft (AFT)	19.2 ft (5.85 m)	16.23 in. (0.41 m)

Table 1. Ballast conditions for the SSN 578 submarine model.

1/8 in. (0.003 m). Only one towline length was used, since earlier basin tests have shown that various towline lengths³ do not affect the towing behavior of the model.

Once the carriage reached the desired speed, the model was displaced to one side of the tow carriage's centerline and then allowed to seek its equilibrium position. The towing stability was evaluated at sternplane settings of 0, 10, and 25 deg trailing edge up (TEU). The following four sternplane configurations were evaluated:

- 1. Additional 50 percent sternplane area aft (Fig. 3),
- 2. Additional 50 percent sternplane area outboard (Fig. 4),
- 3. Vertical end plates on the sternplane tips (Fig. 5), and
- 4. Sternplanes with no extensions (Fig. 6).

INSTRUMENTATION

The instrumentation located at the gimbal towpoint consisted of:

1. An angle potentiometer to measure the horizontal towline angle, defined as the towline angle relative to the direction of tow, projected onto a horizontal plane. The potentiometer has a range of 60 deg port and starboard with a system accuracy of ± 0.5 deg.

2. A 50 lb (222 N) capacity ring gage dynamometer to provide measurements of towing tension with a system accuracy of \pm 0.25 lb (1 N). The full scale accuracy translates to \pm 735 lb (3270 N).

³Mirabella, J. V., "Investigation of Techniques for Submarine Towing," DTNSRDC Report 432-H-01 (Jun 1971).



Fig. 3. SSN-578 submarine model with sternplane extensions aft.



PSD 16137-12-86-1

Fig. 4. SSN-578 submarine model with sternplane entensions outboard.



PSD 16136-12-86-10

Fig. 5. SSN-578 submarine model with vertical end plates on the sternplane tips.



PSD 16136-12-86-11



Additional instrumentation consisted of a magnetic pickup on the towing carriage to provide measurements of speed with a model accuracy of \pm 0.01 kn and a full-scale accuracy of \pm 0.04 kn. For all measurements, data readout was provided by an eight-channel stripchart recorder and an HP9836 computer.

RESULTS AND DISCUSSION

The test results are presented as full-scale values. The towline tension was scaled by: $\rho_{sea} = \lambda^3$

P fresh

where ρ_{sea} is the density of sea water at 59 deg E,

 ρ_{fresh} is the density of the basin water at 68 deg F., and

 λ is the linear scale ratio.

For all conditions and speeds when the model was deflected to port or starboard it did not exhibit a preference for either side of the centerline. The horizontal towline angle measurements taken after the model had reached an equilibrium condition are presented in Table 2 for various speeds, sternplane angles, sternplane extensions, and a GM of 1.06 ft (0.32 m). The horizontal towline angle and towline tension are presented for various speeds, for a GM of 0.85 ft (0.26 m) with extensions aft and a sternplane angle of 25 deg TEU in Table 3.

The SSN-578 model without extensions exhibited undesirably large horizontal towline angles at speeds of 4, 7, and 10 kn (2.06, 3.6, and 5.14 m/s). With the sternplane angle set to 25 deg TEU, the horizontal towline angle was reduced with the addition of either sternplane extensions aft, extensions outboard, or vertical end plates for all speeds tested.

Carriage Speed Kn (m/s)	1. Exter At	nsions Et	2. Ext Out	ensions board	3. Ver (End	tical Plates)	4. N Exten	io sions
Sternplane angle (deg) TEU	10	25	10	25	10	25	0	5
			Но	rizontal	Towline	Angles (d	eg)	
4 (2.06)	46 <u>+</u> 12	4.5	42	23	>50	12	Unsteady ±12	20±10
7 (3.6)	10	2	19	10	22	5	40	Unstable 0±10
10 (5.14)	12	13	13	2 <u>±</u> 6	10	14	Unsteady 40±20	Unstable 0

1

...

Table 2. Horizontal towline angles for various speeds, sternplane angles, and sternplane configurations at a GM of 1.06 ft (0.32 m).

Table 3. Horizontal towline angle and towline tension for various speeds at a GM of 0.85 ft (0.26 m) extension aft, and a sternplane angle of 25 deg TEU.

Speed Kn (m/sec)	Angle deg	Tension lbs (N)
4 (2.06)	14	7,100 (31,400)
7 (3.6)	7	13,800 (61,400)
10 (5.14)	3	27,900 (124,200)

For all three sternplane configurations with extensions and a 10 deg sternpane angle, an acceptable horizontal towline angle range of \pm 15 deg was not acheived until the model reached a speed of 7 kn (3.6 m/s). When the sternplane angle was increased to 25 deg, the horizontal towline angle damped within the acceptable range for all configurations except extensions outboard at 4 kn (2.06 m/s). Horizontal towline angle as a function of time for a sternplane angle of 25 deg TEU, for all configurations, is presented in Figs. 7 and 8. The effect of GM on the horizontal towline angle is shown as a function of elapsed time in Figs. 9 and 10.

Towline tension is presented as a function of speed, sternplane angle and sternplane configuration in Table 4. The effect of sternplane angle and sternplane configuration on the towline tension is seen to be minimal.

CONCLUSIONS

The following conclusions are reached based on the results of this towing evaluation:

 The SSN-578 with no extensions and a zero deg sternplane setting creates an undesirable tow at all speeds.

2. Adding extensions to the sternplanes improved the submarine's towing performance with the best results obtained with the sternplane extensions aft.

3. The sternplane angle should be set to an angle of 25 deg trailing edge up.

4. The GM should be between 0.85 ft (0.26 m) and 1.06 ft (0.32 m) fullscale.



**









Fig. 9. Horizontal towline angle as a function of elasped time for 2 GM values at 7 kn (3.6 m/s).



Fig. 10. Horizontal towline angle as a function of elasped time for 2 GM values at 10 kn (5.14 m/s).

V

Towline tension for various speeds, sternplane angles, and sternplane configurations at a GM of 1.06 ft (0.32 m). Table 4.

v

Speed (Kts)	Ext.	ensions Aft b(N)	Exte Out	ensions tboard > (N)	Vertic. Pl. 1b	al End ates (N)	Exte Ib	o nsion (N)
	10*	25°	10	25*	10°	25°	0°	25°
4	6,800 (30,000)	4,400 (19,600)	7,000 (31,400)	7,300 (32,700)	8,800 (39,200)	12,300 (54,900)	5,000 (22,200)	6,500 (28,700)
2	12,600 (56,200)	12,300 (54,900)	11, 800 (52,300)	15,300 (67,900)	11,800 (52,300)	12,300 (54,900)	14,700 (65,400)	11,800 (52,300)
10	25,900 (115,000)	27,900 (124,200)	23,500 (104,600)	30,900 (137,300)	22,900 (102,000)	27,000 (120,300)	30,600 (135,900)	26,500 (117,600)