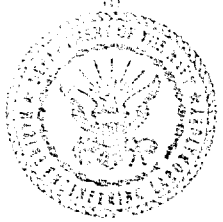

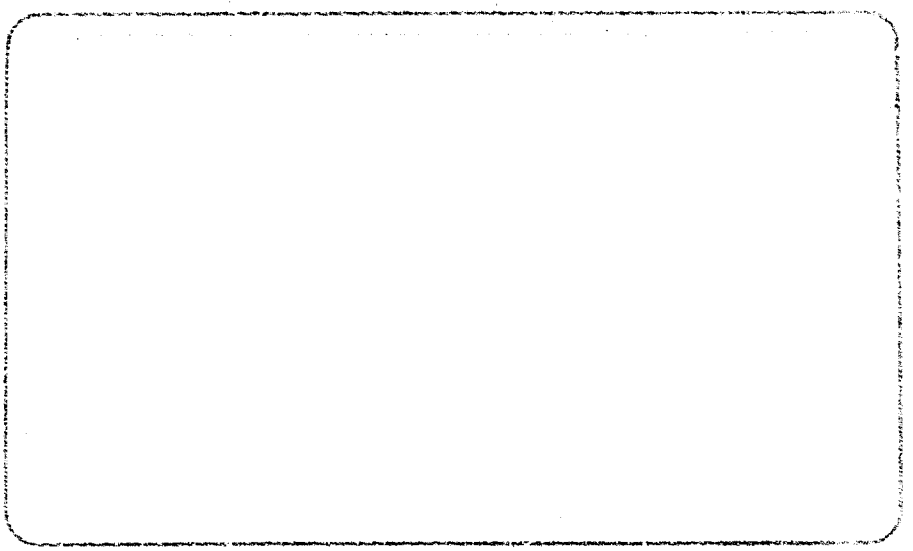

U. S. NAVY

MARINE ENGINEERING LABORATORY

Annapolis, Md.

Dedicated To PROGRESS IN MARINE ENGINEERING

Evaluation of Functional Performance
of an Integrated Ship Control
Conning Console by Operator Personnel

Assignment 62 110
MEL R&D Report 333/65
May 1966

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ABSTRACT

The adequacy of the human engineering for a ship control conning console static mock-up was evaluated by six naval officers and three enlisted personnel. The console was designed for two operators - conning officer and conning assistant. Each officer was instructed to simulate three maneuvers: man-overboard, replenishment at sea, and maneuvering in restricted waters. He criticized the adequacy of the mock-up in light of the criteria established by the human engineering team by pointing out omissions, overinclusions, faulty layout, and desired substitutions. Two members of the team observed and took notes. The enlisted personnel were also questioned as to their evaluative comments at the conning assistant's position. Comments of both officers and enlisted men were analyzed and a list of recommendations was made. The subjects approved the ship control console concept and were in favor of its automatic features as long as a human override was available. Seating the conning officer and assigning both helm and throttle to the conning assistant alone were disapproved. The results of this experiment, combined with continuing system development efforts, will be used as a basis for refining the conning console design. A prototype operational configuration will be constructed and tested in a simulated environment.

ADMINISTRATIVE INFORMATION

This report is a part of SS-22-07X, Task 10595, MEL Assignment 62 110. Assignment 62 110 is concerned with the SEA HAWK - Integrated Combat System Program to upgrade the operability of a proposed ship control conning console system 4+ of reference (a).

Dr. J. C. Townsend, Catholic University of America, Washington, D. C., acted as consultant on this assignment.

REFERENCES

(a) SEA HAWK Ship Control Group, "SEA HAWK Preliminary Cost-Effectiveness Study on Ship Control Subsystems," MEL R&D Rept 53/64, Assigt 62 110, 22 May 1964
(b) Gawitt, M. A., and H. S. Markham, "Preliminary Performance Specifications, ICS Ship-Control Conning Console," MEL Rept 364/65, Feb 1966

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EVALUATION OF FUNCTIONAL PERFORMANCE OF AN INTEGRATED SHIP CONTROL CONNING CONSOLE BY OPERATOR PERSONNEL

1.0 INTRODUCTION

As a part of the ship control and integrated command systems study, a ship control conning console mock-up was constructed at MEL and received human engineering evaluation. Several objectives of this evaluation require exposition.

1.1 Primary Purpose. The primary purpose of this evaluation was to test the human engineering adequacy of the preliminary-design ship conning console. The console mock-up was the specific result of MEL human factors work which was carried out as a result of earlier MEL SEA HAWK-Integrated Control Systems (ICS) studies. The early stages of this effort included the study of concepts employed by the U.S. Maritime Commission, U.S. Coast Guard, and the Royal Canadian Navy. These studies were also accompanied by the construction and examination of several control console mock-ups employing the more desirable features of each. As the MEL systems studies progressed, the console concepts and design criteria were modified accordingly. The console mock-up that was evaluated is the result of these earlier studies. The console had been, previous to the evaluation, human engineered according to basic principles. However, it was felt that only as the result of an evaluation by operational personnel could the adequacy of the layout of the console be tested. To provide a suitable environment for the console, a mock-up of the bridge of a Type 1052 destroyer was constructed. This present evaluation was carried out under the condition that the overall command of the ship may reside elsewhere than on the bridge, and therefore the console must be judged from the ship control point of view rather than from the command aspect.

1.2 Secondary Purpose. A second purpose of the evaluation was to identify those omissions, over-inclusions, and desired substitution of controls, displays, layout configurations, and available functions that would correct the design in a subsequent revised human engineering effort planned to follow immediately.

1.3 Ultimate Objective. A third purpose was to develop a rationale for the final human engineered design. From sound principles of human engineering and the comments of the operational personnel serving as evaluators, this rationale was developed in support of the final console design.

1.4 Scope. Although the evaluation deals almost entirely with the ship control console, it was inevitable that comments would be offered by operational personnel concerning the relation of the console to other aspects of the bridge which houses it. Therefore, although an evaluation of the entire bridge was unplanned, comments concerning the console-bridge, ship command-ship control, and ship-ship interfaces are included and discussed in this report.

The evaluation is not to be considered as a formal experiment, for no manipulation involving experimental and control groups took place. Rather, the evaluation had to do with the observation and recording of the performance of skilled ship control personnel in relation to simulated ship control activities selected so as to exercise the design and layout of the ship control console. It is to be emphasized, however, that the evaluation was conducted under controlled conditions and was designed so as to solicit information of use in evaluating the console in as unequivocal a manner as was practicable.

The results of this evaluation will serve as a basis for developing the final console design. It is anticipated that such a finalized human engineered console design will be translated into prototype hardware. The prototype thus produced will be given a further evaluation at a shore-based installation and later aboard a ship under actual sea duty conditions.

2.0 EQUIPMENT DESCRIPTION

The equipment evaluated here as to its human engineering aspects is known as the ship control console, System 4+. This designation is explained in paragraph 2.3 below. The console seats two: the conning officer at the right and the conning assistant (helmsman) at the left. The console is located on the

center line and a little forward of center in a bridge mock-up of the Destroyer Escort (DE) 1052 class. All man-machine decisions were based upon the utilization of the console in that context.

For the purpose of this evaluation, the responsibility of the conning officer was defined as the safe conduct of the ship by appropriate course and speed control maneuvers. Experience as officer of the deck was regarded as sufficient qualification. Experience as a destroyer helmsman qualified for the position of conning assistant. Further description of the duties of conning officer and conning assistant is available in references 2 and 6 in Appendix C.

2.1 The Bridge. The bridge used in the evaluation was a full-scale model complete with one wing which contained a pelorus. Large, rectangular windows were located in front of the console, giving a simulated view complete with glare in the direction of the bow. The rear bulkhead was painted so as to simulate windows, two doorways, and a sliding door leading to the chart room. No controls and displays were simulated on the bulkhead. Two swivel chairs, located within the bridge and at the two forward corners, provided seats for the captain or other observers. Within reach of each of these seats were binocular holders and communication equipment. A railing extended across the forward bulkhead and along the sides of the bridge's interior as far aft as the rear bulkhead.

A drafting table, used to simulate a chart and navigation table, was located in the after-port corner of the bridge.

2.2 The Console. The console is pictured in Figures 1 through 4. The console was painted a medium blue. The rear of the console contained simulated access panels. The television screen showed a view of the Severn River with its usual river traffic.

2.3 Design Concepts. The concepts employed in the design of the 4+ system ship control console evaluated here represent a state of design in excess of System 4 (the system numbers are described in reference 4 of Appendix C) but not as comprehensive as System 5; thus the designation, System 4+. In describing the various systems, a continum of increasing computerization exists from the currently existing system consisting of present-day DE equipment with manual control (System 1) to the future System 6, where as many ship control tasks as possible will be relegated to a digital computer.

The concepts, equipment, and simulated actions incorporated in the console evaluated were:

- Direct Throttle Control - direct actuator control of engine speed by conning station.
- Environment Engineering of Conning Station - completely human engineered environment.
- Functional Grouping of Displays - grouping of all indicators required for decisions in their respective areas.
- Computer-Assisted Trial Maneuver Solutions - solutions based on manually inserted data.
- Alpha-Numeric Plan Position Indicator (PPI) Display - PPI with contact identification symbols.
- Computer-Actuated Fixed Course and Speed - automatic course and speed keeping for manual settings of course and speed.
- Preprogrammed Computer Actuated Maneuvers - automatic control for preprogrammed navigation and tactical maneuvers.
- True-Relative Motion PPI Display - synthetically generated relative or true motion vectors.
- Quickening for Conning Assistant - quickened heading display for course keeping.
- Closed-Circuit Television Surveillance - instrumented display for close-range information independent of direct visual perception.

- Centrally Grouped Speed and Heading Control - functional integration of heading and speed control.
- Lookouts - visual and audible surveillance.
- Automatic Closest Point of Approach (CPA) Determination - computer calculation and presentation of CPA data.
- Auxiliary Heading and Speed Controls - speed and heading control inputs may be received from other control systems.
- Voice Transmission of Commands - communication by human and phone links.
- After Steering Standby - watch stander in after steering for steering casualties (as required).
- Computer Monitor of Damage Status - utilization of computer storage for damage control intelligence.
- Unaided Manual Steering - conventional steering procedures.
- Computer Storage of Incoming Data - facility for demand recall and simultaneous presentation of earlier data transmissions.
- Processed Weather Display - weather data enhanced for predictive purposes.
- Automatic Alarms - computer actuated malfunction and hazard alarms.
- Manual Calculations - conventional procedures for solution of maneuvering problems, etc.
- Automatic Computer Check - periodic self-check of computer functioning.
- Manual Alarm Controls - manually actuated alarms.
- Status Displays - ship status, destination, navigation, and weather.
- Station Keeping Display.
- Track Display.
- Rudder, Course, Speed, Revolution per Minute Display.
- Transfer of Conn Control Switches.
- Quickened Speed Display.
- Ship Lights Display - showing which lights are energized.
- Fog Horn Control Switch.
- Revolution per Minute Vernier Control.
- Windshield Wipers, Washers, and Deicing Controls.
- Time Display - both Greenwhich Mean Time (GMT) and local time.
- Ordered Course and Speed Display.
- Recommended Course and Speed Display.

- Sound Powered Phones (SPP).
- Intercom.
- Propulsion Controls.

2.4 Components Evaluated in this Study. The specific components physically included in the System 4+ console evaluated in this study were:

- Conning Officer's Position.
  - . Sound powered telephones
  - . Intercom
  - . Ship-to-ship communications
  - . Control mode selection switch
  - . Closed-circuit television, with controls
  - . Track ball controls
  - . Keyboard input to computer
  - . Alarms
  - . Own ship rudder angle, course and speed displays
  - . Damage control status displays
  - . Station keeping data displays
  - . CPA data display
  - . Track display
  - . Command functions including transfer of conns, switch, plus recommended course and speed display
  - . Ship status display
  - . Weather display
  - . Destination display
  - . Navigation display.
- Conning Assistant's Position.
  - . Sound powered telephones
  - . Intercom
  - . Ship lights display
  - . Fog horn controls
  - . Rudder angle control and display

- Course compass
- Course quickened display
- Port and starboard shaft revolution per minute indicators
- Speed (log) readout
- Throttle (speed, revolution per minute) control
- Throttle quadrant
- Revolution per minute fine adjust control
- Time (GMT and local) display
- Ordered course
- Ordered speed
- Propulsion controls
- Helm wheel.

3.0 DESIGN OF THE EVALUATION

In this section, the procedures, the procedure materials, the subjects, the physical and psychological staging, and the maneuvers of the evaluation are described.

3.1 Preparations for the Evaluation. Once it was decided to conduct an evaluation of the console using experienced operational personnel, an initial contact was made at the Naval Academy. The contact was a lieutenant commander who volunteered his services to help obtain the other subjects. A commander of considerable experience agreed to help organize and participate in the evaluation. In order to get a feel for what might happen during the actual running of subjects during the evaluation, the commander was asked to evaluate the console while the evaluation team observed, asked questions, and took notes.

After the commander's evaluation experience, definite plans were formulated for the evaluation to follow.

3.2 Agenda. First, five conning officer and three conning assistant subjects were to be run. One conning officer subject would be run each morning. The team would then meet and have a debriefing session where clarification of the comments received and actions noted would take place. Each afternoon, one of the conning assistants would be run. A similar debriefing session would follow.

Second, each evaluation session would begin with the subject filling out a background form.

Third, a conning officer subject would be taken onto the simulated bridge and given a short orientation to the console. An evaluation team member pointed to each display and control on the console and gave a brief description of its function. An attempt was made to keep the descriptions as bland as possible and without bias. Questions by the subject at this time were answered at a descriptive rather than an explanatory level.

Fourth, the commander, who acted as ship captain in relation to the subjects who acted as conning officers, then took over. A tape recorder was turned on, and the human engineering team began to take notes. The commander first briefed the subject on the purposes of the evaluation and placed particular emphasis on the fact that this console represented a distinction between ship command and ship control. The mission in this evaluation was to evaluate the console as a ship control (course and speed control) console with the realization that overall ship command would reside elsewhere for the purposes of this test. Initial comments by the subject were solicited, and then he was given instructions to assume the role of

a conning officer during three particular maneuvers: man-overboard, replenishment at sea, and maneuvering in restricted waters. As the subject simulated these maneuvers at the console in response to the "captain's" orders, he discovered and pointed out omissions, overinclusions, faulty layout, and desired substitutions both on the console and about the bridge. The usual time for one subject's total evaluation at the console was 1 hour, 45 minutes.

Fifth, the subject was given a debriefing form and was encouraged to fill it out completely.

Sixth, the conning assistants were also run one at a time and, in a set sequence, were given a background form, oriented to the helm and throttle position, and questioned as to their evaluative comments for, on the average, 1 hour. Finally, they were given a debriefing form to fill out. Remarks made by the subjects on the debriefing form which were not clear to the evaluation team were clarified through further discussion.

In Appendix A are the filled-out background forms for the conning officers and conning assistants and samples of the debriefing forms.

3.3 Description of the Subjects. Six U.S. Navy officers, presently stationed at the U.S. Naval Academy as instructors, served as conning officer subjects in this evaluation. Their average length of experience in actually conning ships was 5 years, 8 months, with a range from 20 months to 11 years. Their average total time in the Navy was 15+ years with a range from 11 to 27 years. All had had recent conning experience; all except one held the rank of lieutenant commander. The exception was a commander who served as captain of the simulated bridge during the evaluation.

Three boatswain's mates served as subjects in the evaluation. They were all presently assigned to the North Severn Naval Station. Their past experience in serving as helmsmen averaged 6 years, 8 months, with a range from 6 to 8 years. Their total time in the U.S. Navy averaged 15+ years, with a range from 10 to 18 years. Rates held were one each BM 1, BM 2, and BM 3.

Additional information, relevant to the past experience, training, and assignments of all subjects, is to be found on their background forms in Appendix A.

4.0 RESULTS

Both officers and enlisted personnel strongly endorsed the objective of centralizing and integrating controls and displays in the bridge. Automatic course and speed control was regarded as acceptable, but a human override capability was considered necessary at all times. The officers expressed reluctance to depend exclusively on processed information and preferred to retain freedom of movement rather than to be required to remain at their seats.

Because detailed results are closely tied to discussions of aspects of human factors, they are voluminous. Therefore, they have been gathered in Appendix B where the complete discussion can be perused in detail.

5.0 DISCUSSION

Each category of comment obtained during the evaluation has been discussed in Appendix B. Therefore, this discussion section will deal primarily with the more general issues which seem to be of importance in establishing a final design for the console and in winning acceptance for it.

Regardless of the number of partially critical comments received during the evaluation, one must say that the evaluation subjects were overwhelmingly in favor of such a console. Primarily, this acceptance was due to the fact that on this console the conning officer has available to him at one place the information and controls which he needs to perform his job efficiently. Most of the functions on the console are already available on present-day ships. But their displays and controls are scattered about and often presented, as one officer commented, "grimly."

Recommendations for changes have been examined in light of several criteria. First, if a comment was of such a nature as to go counter to well established principles of good human engineering and had no overwhelming logic to support it, it was discounted. Second, if a comment was considered to be based simply upon tradition and nothing else, it was discounted. Third, if a comment was made which appeared to be in conflict with the clear-cut progression of human-monitored, automated control as a goal, it was discounted. Fourth, if a comment was based on the assumption that the automated equipment would be unreliable, it was discounted as being inappropriate to this phase of the project. Fifth, if a comment was based on the assumption that there would be no human override of an automatic system, it was discounted. These exclusions were used to limit the subjects' comments that were evaluated. After this screening and after collating the remaining comments the recommendations in the next section of this report were arrived at.

Based upon the principles of good human engineering and an evaluation of the comments received from the subjects, MEL's human engineering team is prepared to make recommendations for establishing the final design of the console. This evaluation, and particularly this report, provides a rationale for the final design. The resulting console product has, therefore, been designed using the two major tools of the human engineer: his adherence to the established principles of good human engineering, and the assistance of operational personnel experienced in the particular area for which the equipment is being designed.

The design of the console is only part of the task. A second and perhaps equally important part is gaining its acceptance by the men who will operate it. The evaluation revealed certain biases which are reflected in the criteria of acceptance of the subjects' comments as listed above. Essentially, there are two prevalent attitudes which tend to resist acceptance of this and other automated consoles. These are the adherence to traditional, preautomation-era ways of doing things, and a distrust of automatic equipment based on the memory of early, unreliable equipment to which the subjects had previously been exposed. Tradition says that the conning assistant stands; distrust of automated equipment causes one to leave the conning officer's seat during docking; yet aircraft are safely landed on instruments everyday. The studies reported in references (1) and (4) of Appendix C indicate that appropriate automation will definitely improve mission effectiveness of antisubmarine warfare ships. As an ultimate result, then, the bias for tradition and an attitude of distrust of automatic equipment may slow down our progress in developing and utilizing shipboard automation, and thus render us less competitive in future military warfare.

6.0 SUMMARY OF OPERATOR RECOMMENDATIONS

In examining the operators' recommendations based on this console evaluation, it must be remembered that this mock-up was a preliminary design and, although these recommendations are detailed, they do not dictate the design. Final system design should be based on both operator comments and on additional human factors data, which can only be obtained through additional experimental work outlined in Section 7.0 of this report.

6.1 Overall Impression of the Console.

- Dimming features should be included on all console light switches.
- Install "grab bars" under the console.
- Color or shape coding of the console should be considered.

6.2 Conning Officer's Position - Information Display and Control

- Relabel "auto maneuvering" as "course and speed keeping."
- Delete the transfer-return and accept-reject controls from the command function display.
- Add to the command function section of the panel an additional location of conn display and label it underwater battery.

- Substitute an analog readout for the digitally displayed rudder angle at the conning officer's position.

- Relocate the track display and the station keeping display by exchanging their positions, and move the status displays to the horizontal panel next to the now relocated station keeping display.

- Relabel "display by track no." as "interrogate" and have this button, in addition to its other functions, show CPA data for a target.

- Include an automatic status board on the bridge where continuously updated range, bearing, CPA data, etc, can be simultaneously displayed for all contacts around.

- A range and bearing display should be installed at the conning officer's side which will register such information from a knob-pointer input system located at the wing.

- Add a traditional clinometer to the bridge within easy sight of the conning officer.

- Alongside the clinometer, add a pitch indicator giving successive maximum values.

- Delete the percent water display from the ship status display.

- Design a new display permitting the presentation of more combat direction center (CDC) type weather information.

- Remove the dew point and sea state displays from the weather display.

- Install a separate fathometer display on the console with a constantly updated readout, reading in feet as well as fathoms, from keel to bottom, and indicating deepening or shallowing water.

- Restudy the navigation display's utility in light of navigating in and near port waters.

- Relocate the ordered course and speed and own ship course and speed displays adjacent to one another on the vertical panel at the conning officer's side of the console.

- Relocate the recommended course and speed display on the vertical panel as directly in front of the conning officer as possible.

- Install at the conning officer's position a readout in which course and speed are displayed and constantly updated by the computer when coming into port or during close-in maneuvers.

- Change time display to read "time of day."

- Incorporate the feature of permitting the displaying of superimposed raw radar data as well as synthetic data on the scope.

- Delete the capability of assigning target symbols and track numbers at the scope.

- Design the man-overboard (MOB) alarm so that upon depressing it a MOB symbol will appear on the scope and MOB range and bearing will be displayed in the station keeping display.

- Implement means by which categorical information can be displayed on the scope, such as "all closing targets."

- Display the direct location of the ball tab symbol at all times in terms of range and bearing.

- A higher resolution television screen, of at least a 1000-line raster, should be installed.

- Include a map projection technique on the scope display for navigational purposes.

- Provide television cameras on trainable mounts in conjunction with searchlights.

- Install a damage control switch which will televise on the console a view of the large status board at damage control central.

- Install a maneuvering board under the keyboard location or the horizontal panel or permanently mounted guides.

- Install a slide-out desk shelf between the two persons at the console for the communication status board, and provide a place for a grease pencil and rag holder.

6.3 Conning Assistant's Position - Information Display and Control.

- Add a helm position indicator at the conning assistant's and conning officer's positions.

- Add a spare gyrocompass to bridge equipment.

- Add a magnetic compass directly in front of the conning assistant on the horizontal panel.

- Redesign the compass so that its direction of rotation will correspond with that of the helm.

- Add standard order labels and detents to throttle control.

- Redesign the throttle quadrant for a sliding, horizontal, ahead-back action.

- Repeat revolution per minute fine adjust scale on the right side of the control.

- Position throttle for easy access by another operator.

- Add an ordered course and speed display directly in front of the conning assistant, near his actual course and speed displays.

- Delete the cross connection and acceleration adjust controls from the propulsion controls group.

- Add steering power failure and loss of throttle control lights at the conning assistant's position.

- Add alarm buttons to indicate to after steering and engine room that steering power or throttle control failure has occurred. Design so that the alarm will sound and the breakdown lights will be turned on after a 10-second delay.

- Add a ship lights silhouette display.

- Ensure that the automatic fog horn is randomly programmed.

- Install a jack box on each communication panel for headset use.

- Install a push-to-talk switch on top of the left helm wheel prong and eliminate the present push-to-talk switch at the conning assistant's position.

- Install voice tubes to the wings and CDC for emergency use only.

- Install a ship-to-ship phone at the conning assistant's position.

- Separate and code the ship-to-ship and the sound powered phones, distinguishable under darkened conditions.

6.4 Bridge Configuration.

- Position pelorus for direct line of sight through doorway to helm.
- Install overhead support, steady bars, and deck treads for standing in rough weather.
- Install foot rails at captain's chair positions in bridge.

6.5 Wing Controls and Displays.

- Install rudder angle repeater, standard speed order indicator, relative wind direction indicator, and a range and bearing knob-pointer input system at both wing positions.

7.0 RECOMMENDATIONS

As part of ship control portion of the ICS program, MEL has carried out the previously described limited, pilot-type human factors evaluation of a console having a degree of automation described by the "4+" designation (of reference 4 of Appendix C). The console was evaluated only with regard to the adequacy of layout, omission, overinclusions, and desired substitutions of controls and displays using qualified naval personnel as subject matter specialists in ships' conning procedures, as well as actual subjects in the evaluation. The console operators' recommendations have been taken into account in revisions of the console and in preparing console specifications, reference (b). While not all of the changes have been incorporated, those judged to have a significant effect on the operability have been included.

The following serious problems with this "4+" console remain to be solved in the near future to ensure the overall success of the ICS program:

- Conduct a human factors comparative study of the "4+" system versus present-day control system: showing time to accomplish tasks, failure rates, link analysis, information flow, etc. This would be a more detailed type of operational sequence and personnel effectiveness analysis of the type commonly used by human factors specialists and would not supplant cost-effectiveness studies carried out in the basic systems analysis.

- Conduct at-sea conning experiments. Many automated ships and sophisticated bridges exist, but there are no quantitative data available to demonstrate that a seated conning officer (supported by a seated helmsman) can effectively control the ship during vital manuevers. Appropriate experiments must be planned and conducted preferably using a destroyer. Concurrently, the same ship can be used to accomplish the human factors comparative study and also support the ambient lighting survey problem mentioned below.

- Conduct an ambient lighting survey of bridges of destroyers. The extreme range of bright glaring daylight to darkness of night is an unavoidable vision problem that is intimately connected with the final console design. Technological areas to be considered will involve the ranking of colored viewing filters, selection of optimum techniques for illumination of displays, tinted bridge windows, "bright" cathode ray tube (CRT) displays, preferential location of displays in bridge area, etc. Realistic experiments can be performed by weatherproofing and ventilating the present bridge mock-up and locating it out on the roof of an existing MEL building. An acceptable but more costly method would be to supply ample artificial daylight with provisions for decreasing the light level to that of night.

- Conduct experiments to determine the capability of human operators to judge speed and distance using advanced concepts of mono- and stereo-vision closed-circuit television systems. This work could be performed using the destroyer.

- Determine which information inputs are best displayed by mechanical or CRT displays and define the specific hardware.

- Define the need for concurrency of displayed information.

- Examine and define the need for redundancy of controls and displays including the feasibility of auxiliary or prime displays and suitability of bulkhead locations.

- Study the degree of compatibility of displays with the full range of ambient light conditions and the adverse effects on dark adaptation. The aforementioned problems are closely interrelated and vital to the overall success of the ICS program. A revision in funding of Task 10612 is necessary to solve these problems.

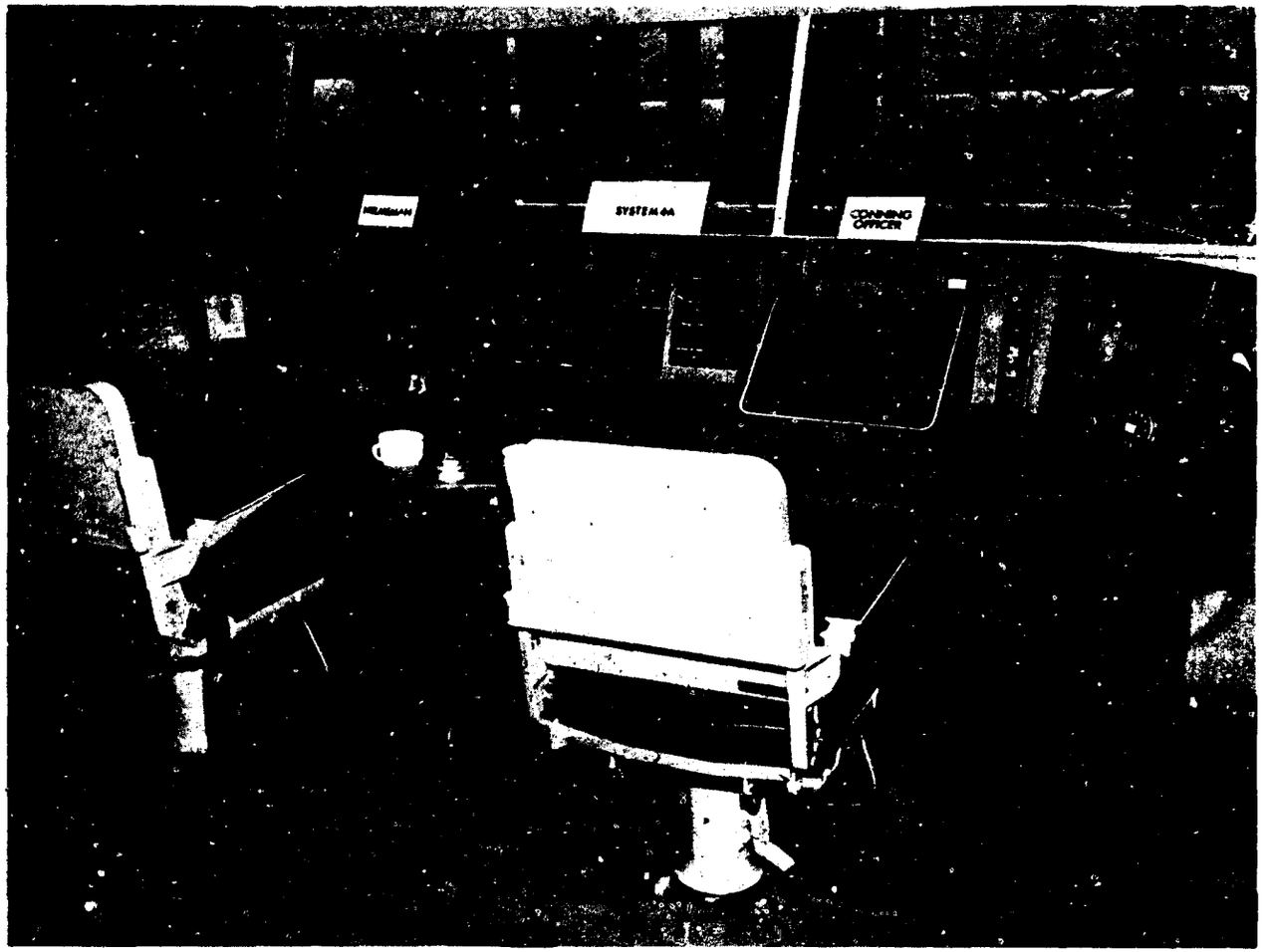

Figure 1 - Complete View of the Console

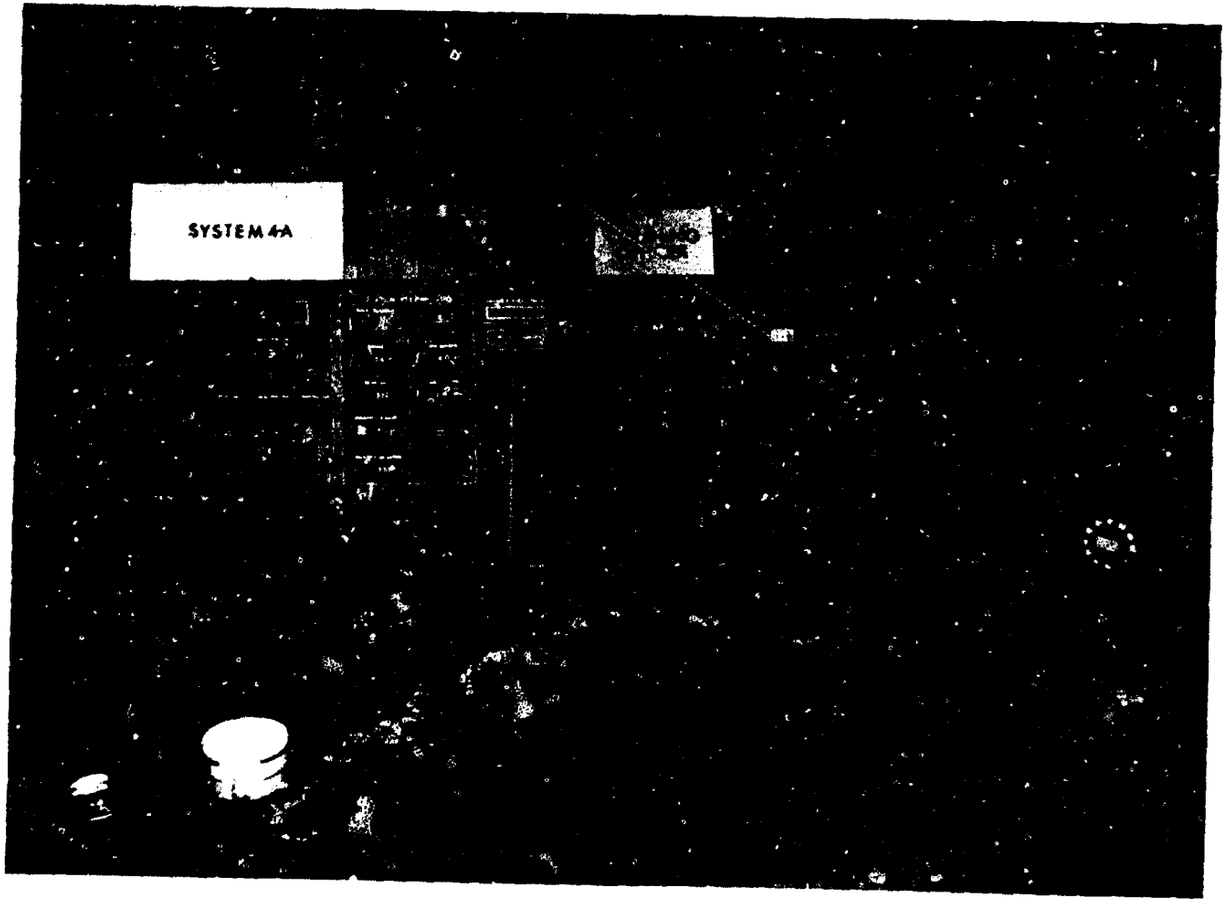

Figure 2 - Sectional View of the Console

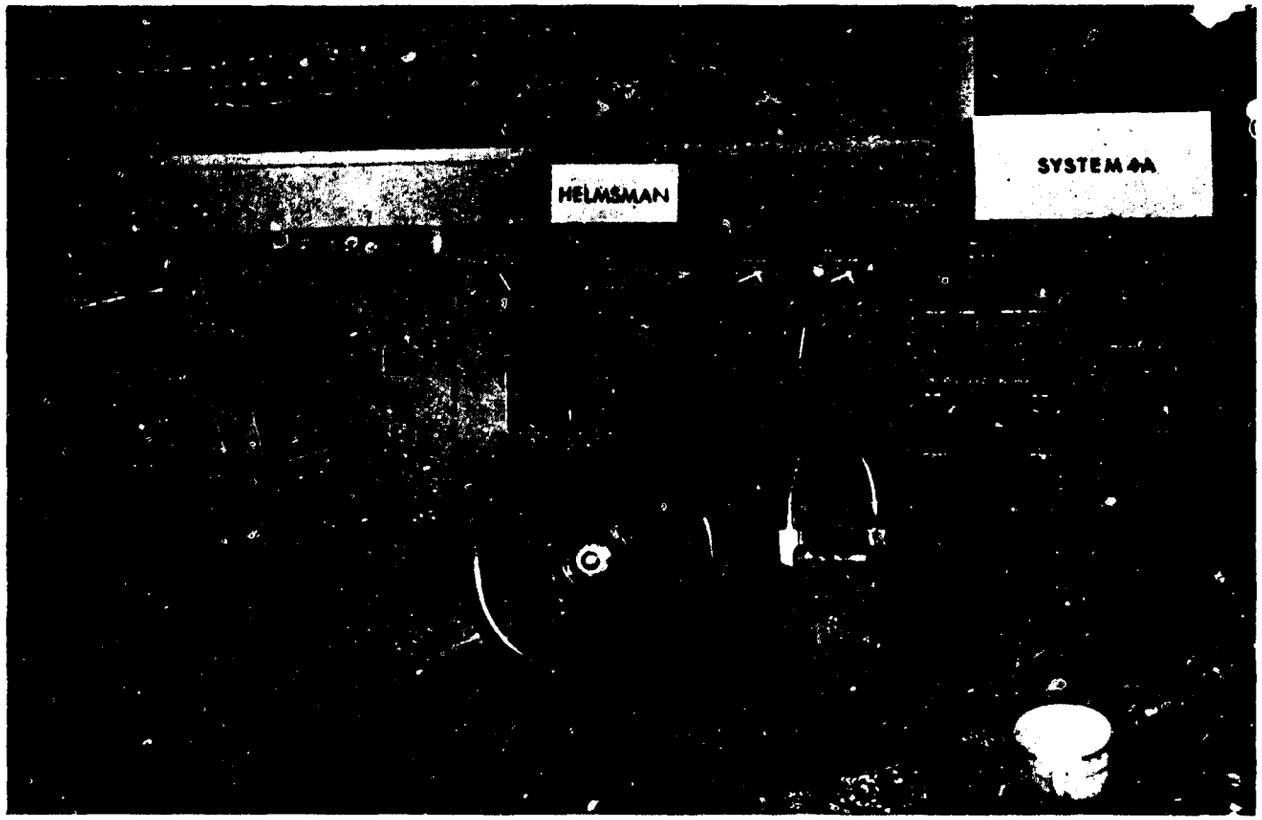

Figure 3 - Sectional View of the Console
Showing the Conning Assistant's (Helmsman) Side

Figure 4 - Console with Both Positions Occupied

Appendix A

Background and Evaluation Questionnaire

Appendix A contains the forms that were used in the evaluation. Copies of the background forms of the nine participants are followed by sample copies of the debriefing forms.

Background Information

Date 6/8/65

Questionnaire for Conning Officer

1. Name: A 2. Rank CDR USN

3. Present address: USNA 4. Phone:

5. Number of years in Navy: 16 Years (Commissioned)

6. Annapolis graduate: Yes X (Class of 1949); No

7. Training schools and/or courses attended with dates:

CIC Officer School, Glenview, Illinois	Jan-May 1952
Emerg. Shiphandling (3 times)	1949-58
USN PG School (M.S. Eng. Elect)	1955-58

8. Being brief, please list chronologically your tours of duty, giving where applicable:

(a) approximate dates by year
(b) type of ship, and
(c) the actual duties performed including title, if any

1949-50	CVA	Air Int. Off.
1951	AGC	OOD, CICWO
1952-54	DE	OOD, OPS, OFF., Air Controller
1954-55	COM 2nd Fleet Staff	CIC Off.
1955-58	USNPG School	Student (Electronics)
1958-60	CLC-1 (Cruiser)	CIC Off., OOD
1960-62	COMNORTEVDET	Radar Projects Off.
1962-64	DD	XO., NAV.
1964-65	USNA	Instructor (Electronics)

9. How much experience have you had in actually conning a ship:

72-100 (months).

Background Information Date 6/7/65

Questionnaire for Conning Officer

1. Name B 2. Rank LCDR

3. Present address: USNA 4. Phone:

5. Number of years in Navy: 27

6. Annapolis graduate: Yes (Class of); No X

7. Training schools and/or courses attended with dates:

RM, QM, Signalman Class A Norfolk 1939, Sonar School, Keywest, Fla., 1941
WOEES, NRL, 1946, USNPG School, Monterey, Calif. 1956-58,
7/60-6/63 Destroyer Development Group Two, Newport, R.I., Asst R&D Officer, Senior Project Officer, Communications Project Officer.
7/63-6/65 USNA Electronic Instructor.

8. Being brief, please list chronologically your tours of duty, giving where applicable:

(a) approximate dates by year
(b) type of ship, and
(c) the actual duties performed including title, if any

8/39-6/40	USS West Virginia	Radioman
7/40-10/43	USS Hilary P. Jones	Radioman
11/43-10/44	Staff Destroyer - Destroyer Escort Shakedown Group (USS Hamul (AD-20))	In Charge of Sonar Inspection & Repair, RMI & CRM
10/44-5/45	USS Stag (AW-1)	Chief Radioman & Warrant
7/45-12/45	INDMAN 8th ND	Asst EMO
1/46-12/46	Student Warrant Officers Electronics Engineering School NRL, Washington, D.C.	Warrant Radio Electrician & CWO
1/47-5/48	(Above School)	Instructor
6/48-6/49	USS Duluth (CL-87)	EMO
7/49-12/49	USS Saipan (CVL-48)	EMO
1/50-10/51	CIC Officers School Glenview, Ill.	Student
11/51-11/53	USS Midway (CVA-41)	Engineering Watch Officer
12/53-6/56	CIC Officers School NAS, Glenco, Ga.	Planning Officer During Construction, Plans and Installation of Equipment, etc
7/56-6/58	USN PG School Monterey, Calif.	Student
8/58-6/60	USS Northampton (CLC-1)	EMO, OOD
7/60-6/63	Destroyer Development Group Two Newport, R.I.	Asst R&D Officer, Senior Project Officer, Communications Projects Officer

7/63-6/65	U. S. Naval Academy	Electronics Instructor

9. How much experience have you had in actually conning a ship:

20 (months).

Background Information Date: 6/8/65

Questionnaire for Conning Officer

1. Name C 2. Rank LCDR USN

3. Present address USNA 4. Phone:

5. Number of years in Navy: 14 years commissioned (4 yrs. USNA)

6. Annapolis graduate: Yes X (Class of 51); No

7. Training schools and/or courses attended with dates:

CIC Watch Officer - Boston Jul-Aug 1951
USN P. G. School - Monterey Jul 1957-June 1960
PCO/XO ASW School - San Diego Feb 1962

8. Being brief, please list chronologically your tours of duty, giving where applicable:

(a) approximate dates by year
(b) type of ship, and
(c) the actual duties performed including title, if any

Sept 1951-March 1954	DD-643	FC Off. Nav. OPS Off. (OOD)
April 1954-Dec 1955	AGB-5	OPS-COMM NAV (OOD)
Dec 1955-June 1957	MSO-466	XO, NAV, OPS (OOD)
July 1957-June 1960	USNPG School	Student
July 1960-Dec 1961	Northampton Cruiser CLC-1	Electronic Material Officer OOD
Jan 1962-Feb 1964	DDR-870	XO, NAV CO (FRAM)

9. How much experience have you had in actually conning a ship:

60 (months).

Background Information Date: 6/14/65

Questionnaire for Conning Officer

1. Name: D 2. Rank LCDR USN

3. Present address: USNA 4. Phone:

5. Number of years in Navy: 14 years

6. Annapolis graduate: Yes (Class of); No X

7. Training schools and/or courses attended with dates:

CIC School	Glenview, Ill.	1954
USNPG School	Monterey, Calif.	1957

8. Being brief, please list chronologically your tours of duty, giving where applicable:

(a) approximate dates by year
(b) type of ship, and
(c) the actual duties performed including title, if any

1951-54	DD	OOD, Asst GUN, DCA	1957-60	USNPGS	Student
1954-55	CL	CIC OFF	1960-61	DD	XO
1955-57	MSC	C.O.	1961-63	APD	CO
			1963-65	USNA	Instructor

9. How much experience have you had in actually conning a ship:

*see below (months).

*50 Months actual mooring, Anc., getting underway.
80 Months conning at sea and in ports.

Background Information Date 6/10/65

Questionnaire for Conning Officer

1. Name E 2. Rank LCDR

3. Present address: USNA 4. Phone:

5. Number of years in Navy: 17 years

6. Annapolis graduate: Yes X (Class of 54); No

7. Training schools and/or courses attended with dates:

1955, '57, '61	Emerg Shiphandling	1963 '65	Geo. Wash. Univ.
1955	CIC Watch Officer, Air Control Off.		(MA Pers Admin.)
Various	Sonar and ASW Courses and trainers		
1958	Mine Warfare Staff Off		
1959 '61	USNPGS, Electronics BSEE		

8. Being brief, please list chronologically your tours of duty, giving where applicable:

(a) approximate dates by year
(b) type of ship, and
(c) the actual duties performed including title, if any

1948-50	Naval Air	Electronics Technician
1954-56	DD	CIC Officer
1956-58	DD	Division Staff OPS
1958-59	MSB, MSL	Squadron Staff OPS
1961-63	DER	XO

9. How much experience have you had in actually conning a ship:

42 (months).

Background Information

Date 6/15/65

Questionnaire for Conning Officer

1. Name: F 2. Rank LCDR

3. Present address: USNA 4. Phone: _____

5. Number of years in Navy: 11 years

6. Annapolis graduate: Yes X (Class of 54); No _____

7. Training schools and/or courses attended with dates:

ASW Officer, 8 wk, 1954-55
Deslant Gunnery, April-May 1955
Underwater Object Locator School, Key West, 1 month
PG School, Monterey, Calif., BS Eng. Electronics, 1959-61
18 hr, Graduate Work GWU in Electrical Engineering

8. Being brief, please list chronologically your tours of duty, giving where applicable:

(a) approximate dates by year
(b) type of ship, and
(c) the actual duties performed including title, if any

1954-56	DD, ASW Off.	Gunnery Officer, OOD
1957-58	Minesweeper	XO Navigator, OOD
1958-59	Staff Commander Middle East Force Aide	OpS Officer Flag Sec.
1959-61	PG School, Monterey	Student Electronics
1961-63	ATF, Pearl Harbor	Commanding Officer
1963-65	USNA	Instructor, Electrical Science

9. How much experience have you had in actually conning a ship:

72 (months).

Background Information Date: 6/10/65

Questionnaire for Conning Assistant

1. Name G 2. Rate: BMI

3. Organization: 4. Phone:

5. Number of years in Navy: 18

6. Training schools and/or courses attended with dates:

Harbor Defense School 10/30/55
To 12/22/55

7. Please list chronologically your tours of duty giving where applicable

(a) approximate dates by year
(b) type of ship and
(c) type wheel watches.

USS George Clymer APA-27	From	11/1/47	to	11/3/50	Helms and Lee Helms
USS Navarro APA-215	From	12/1/50	to	9/22/52	Helms and Lee Helms
Huntington DD-781		10/29/54	to	10/22/55	Helms
Meredith DD-890		6/20/57	to	9/27/59	BM of the watch
Eaton DD-510		11/11/59	to	12/6/60	BM of the watch
Beale DD-471		12/6/60	to	10/16/61	BM of the watch

8. How much experience have you had in actually serving as a helmsman:

72 (months).

9. Do you feel that the Helmsman can handle more functions than are presently included at his position on the console? Specify.

Yes, I think he could also handle ship's engine room - order telegraph, phone communications with engine room and steering aft.

Background Information Date: 6/8/65

Questionnaire for Conning Assistant

1. Name: H 2. Rate: BM 2

3. Organization: 4. Phone:

5. Number of years in Navy: 17 years, 6 months

6. Training schools and/or courses attended with dates:

3rd and 2nd class
1st and chief courses

7. Please list chronologically your tours of duty giving where applicable

(a) approximate dates by year
(b) type of ship and
(c) type of wheel watches.

USS Cabot CVL 28	Sept '48 to April '50
USS Coral Sea CVA-43	April '50 to May '53
USNS SCF Annapolis, Md.	June '53 to March '57
USS Watts DD-567	March '57 to Jan '62
USS Isbell DD-869	Jan '62 to Feb '63

8. How much experience have you had in actually serving as a helmsman:

8 years on and off (months).

training personnel on bridge watch.

9. Do you feel that the Helmsman can handle more functions than are presently included at his position on the console? Specify.

Depends on what the ship is doing at the time.

Background Information Date: 6/7/65

Questionnaire for Conning Assistant

1. Name: _____ 2. Rate: BM 3/c

3. Organization: _____ 4. Phone: _____

5. Number of years in Navy: 10

6. Training schools and/or courses attended with dates:

7. Please list chronologically your tours of duty giving where applicable

   (a) approximate dates by year
   (b) type of ship and
   (c) type wheel watches.

   DD
   Helmsmar and Lee Helm

8. How much experience have you had in actually serving as a helmsman:

   6 years (months).

9. Do you feel that the Helmsman can handle more functions than are presently included at his position on the console? Specify.

   No

Name:_____

Date:_____

Conning Officer

Debriefing Questionnaire

1. What categories or specific items of information, displays or control do you feel are needed but are missing from the console?

2. What displays and controls are presently on the console which might be deleted?

3. What suggestions can you make for improving the layout and grouping arrangements of the displays and controls on the console?

4. What physical characteristics of the console such as dimensions and appearance do you feel warrant changes?

   (a) What suggestions do you have for improving them?

5. Do you feel that the Conning Officer's position is too overloaded?

   (a) What suggestions would you make for improving the task load at the position?

6. Should coffee or smoking be permitted on the bridge? If not, why?

7. Should the Conning Assistant have a seat? If not, why?

8. Should the Conning Officer have a seat? If not, why?

9. What repeater instruments should be included on the wings?

10. Which, if not all, instruments may be digital?

11. Is a more elaborate damage control board needed on the bridge?

    (a) If so, where and how inclusive?

12. Should the Conning Assistant have access to a communication's panel? If not, why?

13. May the Conning Assistant's position at the console have more control than just speed and heading? If not, why?

14. How can ship's administrative detail be handled on the bridge without interfering with Conn activities?

15. General remarks:

Name:_____

Date:_____

Conning Assistant

Debriefing Questionnaire

1. What categories or specific items of information, displays or controls do you feel are needed but are missing from the Conning Assistant's position on the console?

2. What displays and controls are presently on the Conning Assistant's portion of the console which might be deleted?

3. What suggestions can you make for improving the layout and grouping arrangements of the displays and controls at the Conning Assistant's position?

4. What physical characteristics of the console such as dimensions and appearance do you feel warrant change?

   (a) What suggestions do you have for improving them?

5. Do you feel that the Conning Assistant's position is too overloaded? If so, why?

   (a) What suggestions would you make for improving the task load at the position?

Appendix B

Detailed Results

Because of the many items on which data were gathered, each will be followed by a brief discussion, with a summary discussion following.

Information gathered during the evaluation concerning the adequacy of the human engineering of the console is presented below. This information comprised data in the form of notes taken by the MEL evaluation team, information from the debriefing forms administered to the subjects, impressions and opinions of the commander who assumed the role of ship captain, and comments of knowledgeable naval personnel during maneuvers.

The order in which items are discussed is as follows:

1. Overall Impression of the Console.
2. Conning Officer's Position Information Display and Control.
3. Conning Assistant's Position Information Display and Control.
4. Seating of Conning Officer and Conning Assistant.
5. Coffee and Smoking.
6. Bridge Configuration.
7. Wing Controls and Displays.

1. OVERALL IMPRESSION OF THE CONSOLE

Before the orientation began, subjects were asked to give their general impressions of the console. Their comments follow.

Comments: At first glance, the console appeared quite complex to all subjects. They commented that it looked like a lot for a conning officer to handle. One suggested that it might be advisable to light up only those displays which the conning officer needed at a particular time. All agreed that there was a lot of information displayed on the console. One subject wanted to be assured that there would be a high correlation between what he would see with his naked eye of concern to the ship and what would be displayed on the console. Some general impressions were quite specific, such as thoughts concerning the advisability of including a dimming control for all console display lights. Some were quite broad, such as the underlying distrust of automatic equipment.

One suggestion was to color code the functional areas as an aid in training inexperienced operators.

"Grab bars" located under the console and on either side of the knees were suggested for balance and stability during rough seas.

Discussion: As the subjects explored the console and became more familiar with it, they began to feel less that it was too complicated and began to ask for the addition of more controls and displays.

The suggestion to light up only the displays needed at a given time was considered but rejected by the evaluation team. It was felt that since there is a constant necessity to monitor information other than that with which the conning officer is dealing at the moment, it would be inadvisable to limit the capability to do so.

It was agreed that dimming features should be included on all console light switches and that grab bars should be provided. Color or shape coding should be given consideration.

The earlier impression of awe at the complexity of the console and the many deviations from bridge tradition exemplified by the console gave way to strong feelings of approval for the concept by most of the subjects before the end of their experiences at the console. Although there were objections to specific features of the console, there was nearly complete unanimity concerning the console's overall usefulness. The most characteristic response was "I would like to try out this console in a real situation." This attitude prevailed throughout the subjects.

2. CONNING OFFICER'S POSITION INFORMATION DISPLAY AND CONTROL

a. Freedom of Movement.

Comments: The conning officer should be as free from controls demanding constant or periodic operation as possible.

Discussion: Since all the subjects felt that the conning officer should be able to leave the console should he desire to, this comment appears to be a good one.

b. General Location of Equipment.

Comments: It was suggested that only a minimum of controls and displays be placed in the visual range of the conning officer with most of them off to the side.

Control and execute buttons should be located near the keyboard on the horizontal panel. Displays should be located on the vertical panel. Most important buttons should be located for easy use by the right hand with "auxiliary" buttons located for use by the left hand.

One subject suggested that selected console display repeaters be installed on back of console (readable by someone standing between the console and the forward end of the bridge).

Discussion: One wonders about the advantage to be gained in placing a minimum of controls in front of the conning officer. It would appear that one would simply have moved the controls and displays to a less accessible and less readily visible location. However, it would be feasible to relocate the status and other displays of low-frequency use to a peripheral location.

The suggestion that displays be restricted to the vertical panel and controls to the horizontal conflicts sharply with the basic philosophy utilized by the human engineering team in designing the console. Approved human engineering practices and principles dictate that controls, whenever possible, should be located near the display they affect. This reduces the probability of operating a wrong control in response to displayed information. Wherever possible, this principle was adhered to in the design of the console, and there appears to be no good reason for abandoning it.

Locating repeater instruments on the back of the console appears to be asking for trouble. It would be an invitation for bridge personnel to monitor the displays by standing between the console and the forward windows, thus obstructing the console personnel from forward visibility over the bow.

c. Automatic Versus Manual Ship Control Modes.

Comments: There was a general hesitancy concerning the use of the automatic mode except for steaming in open sea. The automatic mode would be used for maneuvering, however, if there were a sure, fast, manual override system. Even if the automatic mode were not used, subjects desired to have the computer display a trial solution for a maneuver, with the option of using it left up to the conning officer's judgment. Because of the dangers foreseen in the automatic mode during close-in maneuvering, the manual mode would be used exclusively by most subjects.

Another subject stated that a backup manual system for all necessary components is a must in the event of component failure.

Comments concerning automatic station keeping were frequently voiced. Particularly, was it thought desirable to have computerized station keeping for steaming into waiting and lifeguard stations.

The differences between the maneuvering to station and auto maneuvering modes designations were not considered clear.

Discussion: There is much truth here particularly concerning the need for the availability of a manual backup at this time. However, the attitude which permeated the subjects' comments appear poor. Due to the complexity of future ship navigational systems, weapon systems, communication systems, and

others, the time is coming, if it is not already here, when some tasks are better performed by machines than by men. This reluctance to accept and to trust the new hampers increasing the efficiency of operation. The efficiency of automatically controlled functions is limited by its scope of cognizance of relevant variables and its reliability; both of these have improved at a fantastic rate during the past few years. It is feared that the judgment of the utility of automatic systems is too seriously impaired by the memory of earlier automatic systems of limited scope and low reliability. To assess their utility more objectively, it would appear desirable to use them, but also, to monitor them closely. Thus, progress will be served. No one suggests that an automatic maneuvering system can be left alone and unguarded.

The ability to display a trail solution already exists at the console. The conning officer types in the desired course, speed, and time at the keyboard, presses a "trial maneuvers" button, and relative motion lines appear for each moving object being tracked on the scope as well as for own ship.

As for automatic maneuvering to station and station keeping modes, whether waiting, lifeguard, or some other form, the capability is already present at the console.

As to the lack of apparent distinction of function in the labels "maneuvering to station and auto maneuvering," it is agreed that a change is needed. Auto maneuvering involves fixed course and speed. The computer must be told the course and speed one wishes to navigate. It would be better to change "auto maneuvering" to "course and speed keeping."

d. Transfer of Conn.

Comments: It was a general opinion that is is desirable, and at times mandatory, to transfer conn from the bridge to the combat direction center (CDC), formerly called combat information center, to the wings, and to underwater battery. However, only the ability to give conning orders should be transferred, not the physical ability to alter the course and speed of the ship, since the present method of giving course and speed orders from another location of conn to the bridge, via communications, has proved reliable, whereas the introduction of new equipment required for physical transfer of conn increases the chance of malfunction. The transfer-return controls should be eliminated.

The console contains an accept-reject control for transfer of conn. It is believed that this control is unnecessary.

Discussion: Agreed. An additional location of conn control should be added to the command function section of the console and that is underwater battery.

e. Analog Versus Digital.

Comments: In the opinions of the subjects, both analog and digital readouts have their places on the console. If there were any favoritism, it would be for the more traditional analog presentation. However, except for the use of an analog presentation of rudder angle for close maneuvering, there was no suggestion that digital not be used in all the readouts. As a matter of fact, the digital presentations of course and speed were overwhelmingly preferred. It would appear that most subjects would demand an analog presentation when rate of change of information is a determinant of their response to the display.

Discussion: Agreed. This would require a change in the design of the own ship display where rudder angle is presented digitally (or alphanumerically); viz, 10° right.

f. Rearrangement of Displays.

Comments: Most subjects felt that target information, rather than own ship information, should be displayed on the main part of the vertical console. Several comments concerned the location and juxtaposition of the status, CPA, station keeping, and track displays. It was suggested that the present location of the track display be exchanged with the station keeping display, and that the status displays be moved to the horizontal panel alongside the relocated station keeping display.

Some subjects suggested relocating the station keeping display off to one side of the console.

It was suggested that it would be most helpful to have an automatic status board for keeping information in digital form concerning range, bearing, CPA, time of CPA, etc, for all contacts around. The opinion was expressed that the status board, if provided, would be better left blank until needed, i.e., unlighted and no labels showing, or moved off to one side of the console. The reason given was that it might otherwise clutter the panel with too much information.

Discussion: The interchange is a good suggestion for it creates two more functional groups: (1) status and station keeping displays, and (2) track and CPA displays. This is in keeping with good human engineering principles.

It is doubtful if the station keeping display should be moved farther out of the picture than being placed on the horizontal.

The idea of an automatic status board is a good one. However, if certainly could not be part of the console. Rather, it should be located somewhere else on the bridge, preferably on the after bulkhead on the port side.

Even if the status board were part of the console, the method suggested of reducing potential overload may create more problems than it solves. The reduction of clutter on a console is good. In reducing clutter, however, one often finds he has reduced the amount of information he can monitor. In the case of the status displays, we have noted that they will exchange locations with the track display. It is believed that this will reduce clutter without reducing the amount of information available for monitoring at a given time. Although no aspect of the status displays appears until the appropriate button has been pressed, the fact that certain labeled buttons are within view of the conning officer serves to keep their potential for producing certain information in mind. The relocation suggested will solve the clutter problem by having meaningful displays grouped together, with the less important on the horizontal panel.

g. Track and CPA Displays.

Comments: It was suggested that the capability be built in for calling up the whole status of a track, continuously updated. By pressing a single button, such as "display track," information concerning the track in regard to range, bearing, height, depth, and CPA data would be simultaneously displayed. The subject felt he had to press several buttons to obtain this information on the present console design.

The automatic CPA violation alarm was approved by all.

The conning officer frequently needs a continually updated visual range and bearing from the wing, as during a man-overboard procedure. A display should be provided at the console in which the information is dialed by a knob-pointer system located at the wing.

Discussion: The console contains the capability now of displaying track data. The button one presses is labeled "display by track no." It is believed that a more meaningful label would be "interrogate." However, the console will not show the CPA range, bearing, and time for a track number so interrogated. This information should be made available.

A range and bearing display should be provided to display such information from the wings.

h. Ship Status Display.

Comments: The present pitch and roll buttons of the ship status display only produce information indicating average maximum pitch and roll. The subjects prefer to know maximum pitch and roll at any given time rather than average. It was suggested that the usual clinometer be substituted and installed within easy view of those seated at the console, but not necessarily on the console itself, and that a pitch indicator giving successive maximum values be provided.

There appears to be no reason for the percent water indicator on the console, since the power plants are gas rather than steam turbines.

Discussion: The human engineering team agrees with these comments.

i. Weather Display.

Comments: The weather information supplied on the console is inadequate for inclement days. Most subjects would want additional information which could be supplied by CDC. Some subjects expressed doubt that sea state and dew point are needed. There was some feeling that sea state is so subjective that the conning officer would probably simply look at the sea himself rather than press the button which would display sea state corrected every 30 minutes. The other weather displays on the panel were found quite satisfactory, and these are wind speed, wind direction, temperature, and pressure.

Discussion: A new display which would permit the presentation of more information should be considered. However, direct communication with CDC by the conning officer for a specific weather report for a specific purpose might be an easy solution.

The sea state and dew point displays should be eliminated.

j. Navigation Display.

Comments: The navigation control buttons provide access to information of use in navigating at sea, but some of this information is useless when one is navigating in port.

There should be a separate fathometer with a constantly updated readout. It should present depth in feet as well as fathoms, from keel to bottom, and give an indication of deepening or shallowing water. The present depth indicator on the navigation display was considered inadequate in light of these information demands.

Discussion: The navigation control buttons are labeled long, lat, set, drift, and depth. It is quite true that longitude and latitude displays are not necessary when in port. The kinds of information that are needed are so many yards to so and so, on track, off track, etc. However, in the destination display, both distance and time to destination are already available. The navigation information displayed at this location of the panel should be thought through again and appropriate design changes instituted, perhaps by integrating the navigation and destination displays into one common display. The use of radar information might be of value in feeding new displays with the kind of information desired.

A separate fathometer of the type described above should be installed.

k. Course and Speed Displays.

Comments: Many suggestions were made by the subjects concerning ordered course and speed and recommended course and speed displays. Their suggestions follow.

The ordered and own ship course and speed displays might better be located adjacent to one another because of the constant need to compare them.

Since the recommended course and speed is needed at all times, the display should be located on the vertical panel as directly in front of the conning officer as possible. It is presently located on the horizontal panel to the conning officer's left.

When under manual operation, the recommended course and speed should be constantly updated when coming into port or during close-in maneuvers and fed from the computer (where it exists for the automatic mode) into the appropriate display.

One subject coupled, in his thinking, the present time of day readout with the ordered course and speed display as though it was part of an interrelated display. He thought the distinction should be clarified.

Discussion: In the automatic great circle and maneuvering to station modes, the computer calculates course and speed necessary to reach the desired location upon receiving certain information from the conning officer. It would be a simple matter to display what this course and speed would be, for

example, 5 minutes from now, as a recommendation for use during manual control. This information should be made available at the console, but displayed in a separate readout, not in the recommended course and speed display, as this display is a direct source of information from other shipboard departments.

It is advisable to change the label "time" to "time of day" to avoid confusion.

The human engineering team agrees with the other suggestions.

l. Radar Display.

Comments: The controls on the vertical panel to the right of the scope should be placed on the scope's right-hand bezel.

It would be advantageous to have the display, when desired, of symbols superimposed on raw radar data to aid in the identification of any or all pips on the screen. This would supplement and help clarify the synthetic data which comes from CDC-evaluated data.

The ability to assign symbols of track numbers is not needed at the bridge. Indeed, this capability might be contraindicated for a ship control console. It would appear to be a CDC matter.

One subject wanted a MOB spot to appear on the scope, indicating the position with the designation MOB labeling it. In addition, he would like to have man-overboard information displayed on the station keeping display. Both would appear as the alarm sounded.

Another comment had to do with the need for displaying categorical information about a number of tracked ships simultaneously, such as all closing ships, all friendly, all enemy, etc.

There is not enough information displayed or controls available to provide efficient usage of the ball tab symbol (target specifier). A direct alphanumeric readout showing where the ball tab is at all times is needed. This information should consist of range and bearing. The additional control should be a "locate" button.

Discussion: The controls for the scope on the vertical panel can be moved to the bezel of the scope, but it is not believed that this will increase the efficiency of operation. Since it would require a specially designed scope bezel, it does not appear worth the effort.

The ability to combine raw radar and synthetic information is a good one, and should be provided.

While CDC has the capability of assigning target symbols, it is doubtful that CDC will retain target symbols to designate stationary objects, such as buoys, once they have been identified. To ensure that the conning officer has at his disposal the means of displaying such necessary information, the capability of assigning target symbols at the console should be retained.

The man-overboard displays and means for displaying categorical information simultaneously are worthwhile suggestions and should be implemented.

The addition of a range and bearing display to locate the position of the ball tab symbol will greatly enhance its utility.

m. Television Displays.

Comments: One of the subjects found that the television screen bothered him. He reported that it made him dizzy. He expressed the opinion that if the screen were smaller (the present one was a 17-inch), he would be able to adjust to it better since he would be able to see the entire picture at once. Other subjects reported no difficulty in viewing the screen. All reported that the radar picture would be easier to view for longer periods of time than the television.

All subjects reported that they would leave their seats when docking, making turns, or during a man-overboard emergency. They felt that at these times natural vision would be superior to television. They suggested that a 1000-line television raster would be required to achieve the necessary resolution for most purposes where television would be used. The major deficiency of the use of television was thought to be its inability to convey valid rate information to the observer when viewing at far range.

It was suggested that the television cameras should be secured on trainable mounts in conjunction with searchlights.

All subjects reported that they would like to have a map projected on the CRT display for use as a navigational aid. In this case, one's own ship would be at the center of the screen and the map would move under it.

Discussion: The reluctance to use the television in place of direct observation is understandable but in most cases unnecessary. The ability to use a television display as a source of direction and rate information is greater than one's confidence in its usefulness. There should be an effort made to utilize the television to the full extent of its capabilities. Future wartime situations and equipment designed to meet these situations, viz, nuclear attack and radiation, may make skill in using such equipment indispensable if one is to accomplish his mission in a sealed ship.

It is necessary to have as fine resolution as possible on the television. The suggestion of a 1000-line television raster is good.

The television cameras should be provided on trainable mounts in conjunction with searchlights.

The map projection is well within the state-of-the-art and should be included.

n. Damage Control Status Display.

Comments: The opinions ran all the way from no need for a damage control status display to a need for a more elaborate board giving more detailed damage information. Some felt that if more information were not given by the display, then it should be eliminated altogether. Those who said there was no need for the display believed that damage control is a command function, or perhaps administrative or secondary information. They felt that the conning officer needs only that damage control information which limits his control of the ship. He can get this from damage control central directly. Those in favor of the damage control status display felt that a more elaborate display was needed. For instance, is fire under control? What class fire? It was suggested that a television pickup of the main board at damage control central could put the information on the conning officer's screen.

Another comment had to do with the need for a damage control alarm loud enough to be heard by the conning officer even if he were on one of the wings of the bridge.

Discussion: The human engineering team believes that the conning officer must have his own access to damage control status information. It is true that not enough damage information is presently displayed on the console to provide him with the elements necessary for course, speed, and maneuvering decisions. It is doubtful that much more information than presently displayed can be permanently provided space on the console. Therefore, the team feels that the alarm and location display, such as now provided on the console, should be retained. However, as was suggested above, in addition, a closed-circuit television pickup from damage control central should be made available for the conning officer's television display at the console. He should be provided with a switch which would bring in the display on his screen but only on demand.

o. Alarms.

Comments: When the movement of maneuverability of the ship is affected in any way by, say, a steering power failure, engine control loss, man-overboard, or fire, alarms must be given instantly to alert the ship and to warn other ships.

The alarm locations on the conning officer's side of the console were approved by all subjects except one who would move the alarms to a sideline position.

The conning officer needs an alarm to indicate the reversal of an engine order by conning assistant.

Discussion: The alarms may be placed in less conspicuous places, but good human engineering dictates that alarm controls be grouped together and so located as to be within easy sight, reach, and understanding of persons who are less well trained than the usual operator of the console. In emergencies, any one of the bridge personnel may have to sound an alarm.

To provide an alarm to indicate that the conning assistant has reversed an engine order, the conning officer would have to set some control or knob with each command of throttle change that reversed direction of rotation of the screw. Since he can readily see the response of the conning assistant in terms of throttle movement, it does not seem necessary to add this alarm to the console.

p. Maneuvering and Other Boards.

Comments: There is a need for two boards to increase the efficiency of the conning officer. All subjects expressed a need for a maneuvering board. It would be used to check on CDC and as a back-up for the track display, particularly when in formation. The board would be the standard issue type which holds the standard printed maneuvering board filler. The board could be stored under the horizontal panel on permanently mounted guides.

A second board, a communication board, needed by the conning officer, is for recording communication status and general notes. The communication board would generally be used for recording ship names and call signs. Most subjects suggested a plastic board approximately 10 x 12 inches. It could be stored with the aforementioned maneuvering board. A holder for grease pencils and a wipe cloth for erasing could be mounted on the right side of the television display. One subject suggested attaching a pull-out shelf, plastic covered, at desk height between the two positions. The conning officer could swivel his chair to face the shelf and have a much larger writing surface available. This pull-out shelf could replace the communication status and general note board. The subject also suggested that the shelf could serve as a chart table for ocean navigation.

Discussion: Such boards are needed to supplement and provide a more permanent redundancy of information status storage easily accessible by the conning officer. The human engineering team favors the maneuvering board stored under the keyboard location of the console. It also favors the slide-out shelf between the two positions. However, it is doubtful that ocean navigation charts would fit on such a shelf. Indeed, if they did, they would be cumbersome to use on such a narrow shelf top.

A chart table is presently located on the bridge and has been placed in the after-port corner against the after bulkhead. This table is of sufficient size and adequately lighted for its intended purpose. However, it is with hesitation that the table is placed on this bridge, since the eventual automated bridge will do away with the need for the conning officer to leave his seat, regardless of the need for information. The console should supply him with the information needed for navigation, and this information should come from orders given by the captain as a result of recommendations from the navigator.

3. CONNING ASSISTANT'S POSITION INFORMATION DISPLAY AND CONTROL

a. Steering.

Comments: A helm position indicator should be added to permit the conning assistant to know when his helm is in the neutral position or at various standard positions from neutral. The conning officer needs the same display to monitor the correct response to his rudder order.

The quickened course display would be easy to use after one got used to it and would improve performance of the helmsman by minimizing over and under shoots. One subject felt that there was no use for the quickened display in that by the time a man is assigned as a helmsman he knows how to steer and will not miss his course. (This subject withdrew his remark when the operation of quickened display was more fully explained.)

Two gyrocompasses are needed on the bridge, one to be used as a backup.

No magnetic compass is located on the console. It was recommended repeatedly by the subjects that one be installed as a backup for the gyrocompass. It should be located near the gyrocompass and preferably on a true line directly in front of the helm and on the horizontal panel for accurate reading.

Discussion: The helm position indicator should be added to the conning assistant's displays and should be located on the top side of the wheel hub or be made part of the rudder angle indicator display. The same information should be provided at the conning officer's side.

The quickened display should not be changed, but it should be noted that observers must have its advantages explained to them.

An additional gyrocompass should be provided in the bridge.

A magnetic compass should be installed in the manner described above.

The direction of movement of the compass is not compatible with that of the helm, in that a clockwise rotation of the helm, for example, produces a counterclockwise rotation of the compass. Since this arrangement conflicts with a human engineering principle that the display rotate in the same direction as the control, the team recommends that the compass be redesigned, perhaps by providing a fixed dial and moving pointer display.

b. Throttle Control and Revolution per Minute Adjust.

Comments: The throttle control should be designed so that it has detents corresponding to engine-order telegraph-throttle control. The same labeling (standard orders) should be displayed. A sliding rather than a rounded quadrant was suggested.

The throttle should be positioned so that a lee helmsman can operate it under emergency and restricted steaming.

The revolution per minute fine adjust should be available for adjusting revolution per minute of each shaft separately.

The revolution per minute fine adjust scale should be duplicated on the right side of the control so that the conning officer and the lee helmsman might be able to see it better.

The general feeling was that the speed controls, except for above, are quite satisfactory. The opinion was expressed that the Navy should have had the revolution per minute fine adjust for a long time.

Discussion: The use of standard orders for labeling the throttle is good and should be instituted. Since a rounded quadrant surface may make it difficult to read the labels, a sliding quadrant is recommended as a substitute.

All of the subjects assumed that a lee helmsman would be operating the throttles during certain times. The human engineering team doubts that this will be needed with the increased efficiency afforded by the new console and particularly with its quickened course display. However, this is an empirical question which can best be answered by an experiment. Therefore, such an experiment in the interest of reducing the number of bridge personnel without sacrificing efficiency is recommended.

The throttle should be relocated so that it is easily accessible to another operator.

It is doubtful whether action should be taken on implementing the suggestion that the revolution per minute fine adjust be separately applied to each shaft. Seldom, if ever, will differential revolution per minute be called for on the two shafts. However, the scale could be duplicated on the right side with advantage.

c. Ordered Course and Speed Display.

Comments: Many subjects felt that the mass of information displayed in the vicinity of the ordered course and speed display might interfere with the conning assistant's performance. In particular, it was felt he might be bothered by the track information as it moved into the display. A beveled panel or a plastic shield was suggested as a remedy.

Discussion: Since there is need for the conning assistant to compare frequently his ordered and actual course and speed displays, an ordered course and speed display should be installed in the vicinity of his actual course and speed display to simplify comparison. This relocation should also eliminate the possible distraction associated with the present location of the display.

d. Propulsion Controls.

Comments: Adverse comments were directed toward the cross connection controls. The consensus was that they should not appear on the console.

One major objection to having the acceleration adjust control was that there would be a loss of control possible because of the various positions in which the control could be set. If it were not set where one thought it was, then the unknown acceleration in response could be dangerous in close maneuvering.

Discussion: Since there appears to be no real need for the above controls and because of their potential for creating a hazard, the team is of the opinion that they should be removed from the console.

e. Alarms and Emergency Controls.

Comment: A warning light is needed on the conning assistant's side of the console in conjunction with an audible alarm if steering power is lost. The conning assistant should also have an alarm which alerts after steering, turns on the breakdown lights on the mast, and blows the ship's whistle. The whistle should have a built-in 10-second delay to permit verbal orders before the noise of the whistle commences. All of this should be accomplished the conning assistant's pressing a single alarm button.

A similar light and button are needed for engine control in the event of loss of throttle control.

A rudder-order telegraph to after steering, perhaps located on the helm or rudder angle indicator, is needed in the event of steering-power failure. However, one subject commented that rudder orders to after steering can better be given by phone than by a rudder-order telegraph.

An engine-order telegraph is d in case of throttle malfunction.

Discussion: There appears to be no need to change the design of the console in relation to the alarms. Emergency indicators, signal buttons, rudder-order telegraph can easily be added to the present design. Backup controls, such as engine and rudder-order telegraphs, have not been provided on the console or elsewhere on the bridge. Further study is recommended to determine backup control needs of the system, including rudder- and engine-order telegraphs.

f. Ship Lights and Fog Horn.

Comments: The comment was made that the conning assistant should not be expected to perform chores such as turning on the lights or sounding the fog horn. Some felt he should have nothing at his console except heading and speed controls and indications.

A silhouette of a ship with pilot lights positioned could be used as a display showing which lights are on at any given time.

The automatic fog horn should be randomly programmed so as not to coincide with another ship's fog horn.

Discussion: There is ample room for such functions as ship lights to be placed at the conning assistant's position. The functions are of such a nature as to be task-paced rather than time-paced. It is believed that functions such as these should stay where they are on the console.

The silhouette light display is acceptable.

The automatic fog horn should be randomly programmed.

g. Communication Panel.

Comments: Most of the subjects, both conning officers and conning assistants, expressed the opinion that the conning assistant has little time for anything other than minding his course and speed at the console. Considerable exception was taken to the communication panel at the conning assistant's position. Most subjects felt that the conning assistant could not be expected to answer the phone while following helm orders. One conning officer expressed the opinion that, if the conning position were damaged or inoperative, he might have to take over the communication panel at the helm position. Thus, he considered this a backup communication system. Other subjects, particularly the conning assistants, felt that they should have direct communication with after steering and the engine room as it applies to their job only. Thus, the present communication panel on the console would be reduced in capability.

A jack box is needed on each communication panel for plugging in a headset.

There was a preference for a headset rather than a panel mike and loudspeaker for the conning assistant. It was thought there would be less interference with helm activities, less noise, it would be constantly ready, and the conning assistant would be quicker to answer. The present push-to-talk switch on the vertical panel should be eliminated and a switch on the top of the wheel prong substituted. Earphones should be restricted to the wearing of one on the ear away from the conning officer. This would enable the conning assistant to receive verbal commands directly without impeding his hearing.

Ship-to-ship phones should be added to the panel. There should be a separation between the sound powered phones and the ship-to-ship phones. Their handsets should be coded to avoid mistakes, particularly at night.

Designations other than JA, JJV, etc, are needed to avoid confusion on the sound powered phones, according to one subject.

There was some disagreement as to the advisability of cross-connecting intercoms and of cross-connecting sound powered phones. Conning assistants appeared to be in favor of the latter and conning officers the former.

Voice tubes from the helm to the wings and CDC were suggested.

Discussion: It is agreed that there will be times when the conning assistant will be so preoccupied as to preclude any other activity. However, there is much time at sea when ample time-sharing opportunity is available. The team believes that the communication panel should remain where it is and with its present capacity. In this manner the panel can serve as a backup for the conning officer's communication controls and as an auxiliary panel for other bridge personnel. The conning assistant will not be expected to use the communication panel at anytime unless so directed by the conning officer. The one exception to this will be in the event of steering power failure and loss of throttle control when communication to after steering and engine room is automatically authorized.

A jack box should be made available on each side of the console and headsets provided for the conning assistant.

The relocation of the push-to-talk button to the helm would enable the conning assistant to communicate more quickly and easily, and should therefore be carried out.

There is no provision for ship-to-ship phones on the conning assistant's side of the console. They should be installed near the sound powered phones and coded for day or night vision use so as to minimize confusion; this should be done on the conning officer's side also.

There does not seem to be sufficient reason to modify the sound powered phone labels. A ship information book exists for each ship in which the number of circuits, the control stations, and their location are specified for the entire system. This information is made available in routine training courses and is widely used by shipboard personnel. It is better to retain the present labels than to substitute less familiar symbols.

A cross-connection panel for the sound powered phone system, but not for the intercom system, is presently available in interior communication, where this service is provided upon request for the whole ship. Confusion as to the location of a cross connection might easily follow if this panel were duplicated elsewhere. The team does not recommend its installation at the console.

Voice tubes are so noisy as to make a quiet bridge an impossibility. Their use is discouraged. However, the installation of voice tubes from the helm to the wings and from the bridge to CDC for emergency use only is recommended.

4. SEATING OF CONNING OFFICER AND CONNING ASSISTANT

Comments: This feature seemed to unnerve the traditionalist subject. Some were against either the conning officer or the conning assistant being permitted to sit down. These subjects preferred a stand-up console. Most gave their reasons against sitting down as being due to a fear that the personnel would go to sleep, that the conning officer could move about more easily if he were on his feet, or that he does not want to be tied to a chair.

Those subjects in favor of sitting down point out that in rough weather the conning assistant can have better control of the helm; that the personnel in submarines and aircraft sit down, often in the case of aircraft for extremely long watches without going to sleep; that short, rotated watches would solve the problem; and that the conning officer's console was designed to give him the necessary information to do his job without running all over the bridge.

Discussion: The reluctance of the conning officer to sit down seems to stem from a basic lack of confidence in the informational facilities under his control at the console. There was little reluctance on the part of the conning assistants. Short, rotated wheel watches would solve the problem as they see it. The future ships of the automated age will without doubt place the bridge personnel firmly in their seats. Let us begin now. There is no human engineering reason why the personnel cannot be seated. At the present, if the Conning Officer wishes to go out to the wings, he is free to do so. It is a step backward if these personnel do not have seats at the console of this and future systems.

5. COFFEE AND SMOKING ON THE BRIDGE

Comments: The typical comment of the conning officers and conning assistants was that there should be no smoking but there should be permissible coffee drinking at the console. The major objection to smoking was the loss of dark adaptation due to the flare of a lighter when lighting up. However, when it was suggested that an electric cigarette lighter could be provided, nearly all objection subsided.

Discussion: The human engineering team believes that there should be neither smoking nor drinking of coffee at the console in that console equipment might easily become tarnished from coffee stains or cigarette ashes and perhaps eventually malfunction. However, the drinking of coffee in the bridge itself should cause little difficulty. It is probably a good rule that the "smoking lamp is out" on the bridge except for daylight hours.

The present coffee cup holders and ash trays should be removed from the console. The space would be better used for the pull-out shelf writing surface.

6. BRIDGE CONFIGURATION

Comments: The general layout of the bridge received favorable comments. However, there were a few points mentioned which should be considered. The doorways leading from the bridge to the wings should be positioned so that one has a direct, unobstructed line of sight from the pelorus to the helm. Thus, the doorway or, perhaps better, the pelorus, needs to be repositioned slightly.

Bars fastened to the overhead should be positioned so that one standing to the right of the conning officer, in front of the console, or to the left of the conning assistant can steady himself in rough seas.

Deck treads should be laid down for better traction in rough weather. Foot rails should be fastened to the bulkhead near the captain's bridge chairs located within the forward corners of the bridge.

Discussion: Agreed.

7. BRIDGE WING CONTROLS AND DISPLAYS

Comments: There will be times when the conning officer will take the conn to the wing. He will need certain information there and will have to be able to communicate with the helm. The consensus of the subjects was that he would need a rudder angle repeater, course indicator (pelorus), speed and revolution per minute indicators for both shafts, and a relative wind direction indicator. One subject thought that a standard order readout would give sufficient information about speed.

The conning officer would not need any physical controls but should be able to give meaningful orders from the wings to the helm. Most subjects felt that they would seldom use controls if they were located on the wing. Further, the subject would rather give verbal orders from the wings than use knob-pointer settings in giving orders to the helm.

During a man-overboard procedure, the conning officer needs a continual visual bearing and range from the lookout over the sound powered phone. It would be advantageous to have this information fed into an appropriate console display by means of a knob-pointer input system located on the wings.

Discussion: Keeping in mind that we have been directed to deal only with ship control and not ship command, the controls needed on the wings by the conning officer are few. As a matter of fact, since the emphasis is on supplying the conning officer with all he needs at the console, placing additional repeat informational outlets on the wings encourages him to abandon his console. The human engineering team feels that the instruments requested by the subjects are reasonable at this time, but that with later systems, the conning officer should be satisfied to stay at his console. Electronic aids, such as high resolution television and automatic positioning and safety devices, will make it unnecessary to leave the console and go to the wings. In fact, an even less efficient operation may result if the console with its automated functions is left behind.

Appendix C

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The adequacy of the human engineering for a ship control conning console static mock-up was evaluated by six naval officers and three enlisted personnel. The console was designed for two operators - conning officer and conning assistant. Each officer was instructed to simulate three maneuvers: man-overboard, replenishment at sea, and maneuvering in restricted water. He criticized the adequacy of the mock-up in light of the criteria established by the human engineering team by pointing out omissions, overinclusions, faulty layout, and desired substitutions. Two members of the team observed and took notes. The enlisted personnel were also questioned as to their evaluative comments at the conning assistant's position. Comments of both officers and enlisted men were analyzed and a list of recommendations was made. The subjects approved the ship control console concept and were in favor of its automatic features as long as a human override was available. Seating the conning officer and assigning both helm and throttle to the conning assistant alone were disapproved. The results of this experiment, combined with continuing system development efforts, will be used as a basis for refining the conning console design. A prototype operational configuration will be constructed and tested in a simulated environment.

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2. Ships - Control systems - Human engineering
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