A FEASIBILITY MODEL OF AN UNDERWAY REPLENISHMENT TRAINER FOR OOD'S

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This paper details the development of an Underway Replenishment Trainer using a novel 70° x 180° FOV anamorphic lens pair in the visual display. Requirements for such a proposed trainer are described, together with the concept modeling, component selection, results and areas for improvement.

Currently, there are trainers for maneuvering tactics, emergency shiphandling and ship characteristic demonstration. These trainers concentrate on maneuvering rules, communications procedures, organization of Bridge and CIC (Combat Information Center), and Bridge to CIC coordination procedures, with no visual references. The ship characteristic demonstrator is used to acquaint the trainee with the various forces that affect the handling of a ship. None of the trainers, however, provide the visual cues as seen by the conning officer from the ship's bridge and which require the trainee to interact with speed, heading and relative position while conning a ship relative to another or to a mooring site.

The need for a complete trainer encompassing visual cues can best be seen by reviewing ship accident statistics collected by the Naval Safety Center at Norfolk, Virginia. Records for a portion of the period of 1969-1971[1] would reveal ship mishaps as follows:

Occuring In	No. of Accidents	% of Total
Underway Open Waters	16	13
Underway Restricted Waters	24	19
Mooring/Getting Underway	47	37
Moored/Hit by Another	28	22
Underway Replenishment	11	9
Total Number	126	100

Personnel error was identified as the cause of 104 of the 126 mishaps with 22 mishaps being due to material or equipment failure. The need for a multipurpose shiphandling trainer is generally acknowledged to permit junior officers to participate in conning of the ship. Including all underway situations reported in the two year period would result in a savings of three-quarters of a million dollars in ship damage cost. Through the use of a trainer of the type proposed, the understanding of the theoretical shiphandling problem would be presented dynamically as well as verbally in the classroom. Certainly this officer in training could be exposed to four rendezvous in one day on this trainer as opposed to possibly four per cruise when on board-ship.

Shiphandling trainers are also used by commercial fleet owners. Esso, Standard Oil Company has a two-week instruction course designed for experienced ship masters, chief officers and pilots.

Analysis of Proposed Trainer

If an UNREP (Underway Replenishment) operation were to be simulated, the problem would begin with two vessels at 1000 yards -- the approaching ship running parallel to the wake of the supply ship[2] with a speed of five knots greater than the fueling speed during approach. At 300 yards, the bearing of the supply ship's side should be 6 degrees from fueling course. The course would then be held until 90 feet hull to hull distance is achieved alongside. Replenishment could then commence.

Although a human factors training requirements analysis has not been performed for an OOD application, it is most likely that a requirement for an ultra wide angle FOV (field of view) visual display would be specified. Based on additional considerations, a 70° x 180° FOV was selected for this task.

If closed circuit television techniques are employed in the visual system, it has been determined by a previous study[3] that nine television lines are the minimum required for image height for recognition of the target vessel. At 3000 feet, the supply ship or oiler would subtend an angle of 2.2°, or only 246 television lines would be required for a 60° vertical FOV. Using a similiar criteria, horizontally, 1250 television lines would be required in the display. Assuming Kell factor of .8 for a 1023 line television system at a 30 Hz frame rate, 4:3 aspect ratio, a 40 MHz video bandwidth would provide the minimum required resolution.

Previous studies[4] have specified a method for selecting the model scale based on optical considerations—600:1 in this application is the calculated result. For motion to be imparted to the images, the equations of motion for an oiler (AO) and a long hull destroyer must be programmed. With a 1000 x 3000 ft. gaming area, arbitrarily selected for the problem,[5] and anamorphic pickup and projection lenses, it is necessary that no processing of the detected image be performed, once generated, since rigorous cancellation of geometric distortion occurs with matching lenses. Any position change of the image in the pickup field not reproduced in exactly the same position in the projection field negates the distortion cancellation. Motion to the images, therefore, must be by mechanical rather than electrical means. The equations of motion to the images developed by NSRDC,[6] and simplified by our Computer Laboratory, include together with normal, or emergency conditions such as misunderstood orders, incorrect engine room response to bridge orders, etc., the interaction effects[7] between close ships in deep water. When two vessels pass close on parallel courses, the pressure fields (repulsion on approach and pullaway) of the two hulls mix, requiring rudder correction. When directly abreast, a suction of the two vessels occurs causing attraction, and again rudder correction. These effects are included in the math model and are readily apparent when the two vessels remain abreast for a long period of time. The ship characteristics incorporated in the problem solution are:

Oiler speed 0 - 25 Knots
Oiler heading ± 90°
Own Ship Speed 5 knots back to 25 knots forward
Own Ship Rudder ± 33°
and background seascape lateral motion.

The calculation of vidicon characteristics, optical system resolution, diffraction limit of resolution, vidicon illumination, vidicon image sizes, depth of field and perspective distortion are also required to complete the analysis. These will not be discussed here.

Component Selection

Some examples in the selection of sub-assemblies to perform this task are given.

Optics.[8] *Since a lens pair had been* assigned for use in this proposed trainer, a review of their characteristics reveal:

FOV: 70° x 180°
Resolution @ f/8, on axis camera 200 l/mm
projector 28.5 l/mm
Camera Depth of Field, calculated 4" -∞ at 7% Focus change
Aperature, variable 5.6 - 22
MTF 20% at > 75 l/mm
Ratio of camera to projection lens 1:5.66

The development of this lens pair has previously been reported,[11] therefore, additional details will not be presented here.

Television Cameras - Off-the-shelf systems have been selected with one inch vidicons operating at,

Line Rate 1023
Vertical Sweep Rate 30
Interlaced 2:1
Video Bandwidth 40 MHz
S/N 37.5 db
Gray Scale Rendition 10 Shades

with standard automatic light range, shading correction, and resolution stability versus temperature and input voltage correction, etc., incorporated. Improved cameras, superior to those selected, are now available.

Video Processor - This system, designed *and fabricated in-house, utilizes IC circuitry* to combine a seascape background with the own ship's bow and the oiler imaged. Line by line inhibit and insert circuitry is used together with automatic electronic ranging of the two targets. Additional targets can be added with additional circuitry. Further effort could be expended to eliminate a delay in the mixing of the signals.

Projector - The projection system uses an Eidophor projector with the following characteristics:

Light Source, Xenon Lamp 1600 watts
Light Output, Open Gate 2025 lumens
Illumination Uniformity 68%
Contrast Ratio 166:1
Video Bandwidth 50 MHz

The system employs a hot cassette for ease of video driving, without the extreme lag and poor discharge of the oil film.

Image Motion - Designed and fabricated in-house, the gantry system, scaled 600:1, allows complete problem coverage in range and speed of the oiler and the own ship, as driven by a computer.

Instructor Station - Provides total control and operation of the system and allows introduction of errors into the problem. The trainee's commands to the computer are through a computer operator who represents the helmsman who relays the orders to the engine room via the Engine Order Telegraph. This time delay is also reproduced in the computer's equations of motion.

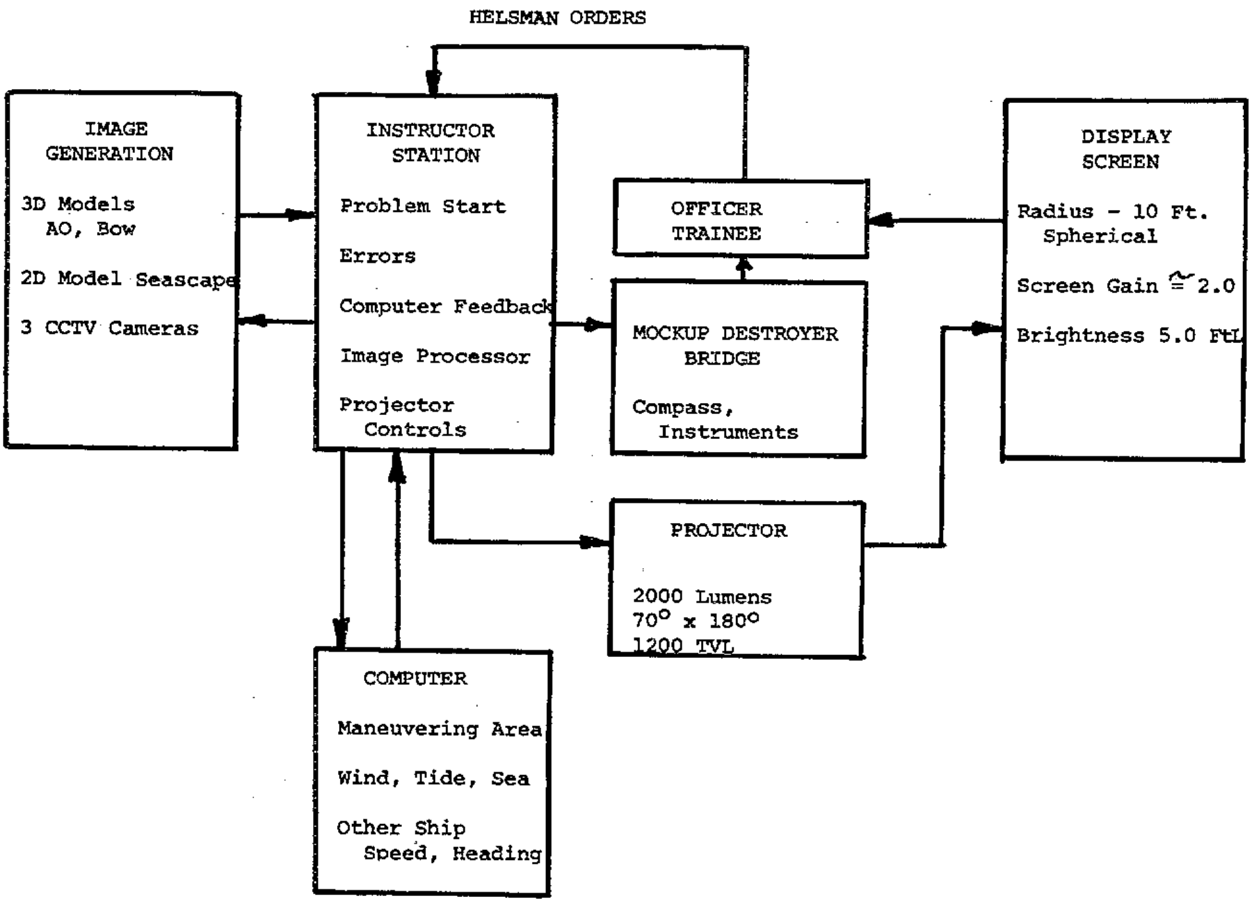

FIGURE 1. BLOCK DIAGRAM OF TRAINER

System Results - Assembly of the components resulted in the feasibility model of the trainer shown by the block diagram of Figure 1. The trainee reacts, through control of his own ship in the form of engine speed and rudder changes, to the visual environment presented on a 10 ft. radius spherical screen, generated by the Eidophor projector in an UNREP or shiphandling mission. A preliminary evaluation by two experienced Naval officers of the completed system indicates the trainer has merits in training and the visual system resembles a gray morning at sea. Specific changes were also suggested: The right FOV should be reoriented to allow visual lineup of the king posts on the supply ship; The jackstaff on the own ship should be removed, since this is not normally used during sea maneuvers; and that bearing and distance data be continuously available to the officer on the bridge.

Preliminary test results of the system shown in the figure are summarized as follows:

Visual System	$70^{\circ} \times 180^{\circ}$
Viewing Distance	10 ft.
Resolution	1200-1300 TV lines
Highlight Brightness	≈ 5 FTL
Gray Scale	5 shades with video insetting

From a summary of the visual results obtained, the problem areas in the system become readily apparent. How can the system more closely approach that of the real world? With approximately 18' of arc per line pair horizontally, there is room for improvement. Two changes can be suggested for immediate study or use.

1. Replace the one-inch diameter vidicon cameras with 2-inch diameter cameras. Several have been reported in the literature, as either in development or available. The characteristics of a typical one is as follows:[9]

MTF 50% at 1000 TVL, 10% at 2000 TVL

Line Rate	1365
Vertical Rate	30 Hz
Interlace	2:1
Video BW	60 MHz min

2. Improve the resolution of the Eidophor system. A preliminary investigation[10] indicates that research in the area of Electron Beam Size might provide useful results. Certainly a system matching a camera's 10% MTF at 2000 TVL would be most desirable and useful in the proposed trainer just discussed.

CONCLUSIONS

A feasibility model of an OOD-UNREP trainer has been designed, fabricated and evaluated on a subjective basis. Trial runs by two Naval officers indicate merits for the system in training transfer. Certainly, further qualitative evaluations, of an officer's response to the control of his own ship, in shiphandling, underway replenishment, emergency procedures, and other situations, based upon his evaluation of a visual presentation, should be performed.

Credits should be given to the Naval Training Equipment Center's Computer Laboratory, Laboratory Services Division, and Electronics and Acoustics Laboratory for their assitance in this task.

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