REAL-TIME SIMULATION OF JEFF(B) AMPHIBIOUS ASSAULT LANDING CRAFT

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INTRODUCTION

Two prototype Amphibious Assault Landing Craft (AALC) designated JEFF(A) and JEFF(B) are being developed by Aerojet General Corporation, Tacoma, Washington and Bell Aerospace Company, New Orleans, Louisiana, respectively (figure 1). The craft are designed to ride on air contained by the flexible skirt systems and pressurized to slightly higher than the ambient pressure by the fan systems.

The missions of the craft are to ferry troops and supplies from supply ships to a landing beach and return. The ships are usually cruising off-shore to avoid attack by the shore batteries and surface-to-surface missiles. In performing the missions, the crafts must enter or back out from the well of the supply ships or come alongside the ships for reloading or unloading. The craft must be able to ride on the waves at sea state 2, travel across deep water, shallow water and surf zone, land on a sloping beach, and drive inland. The craft are designed to be able to negotiate approximately 12% slope at 120,000 lbs. normal payload.

This report presents the feasibility study of developing a real-time AALC simulator for JEFF(B) craft covering the over water operation and planning the over land operation.

METHOD OF APPROACH

The JEFF(B) craft has been selected for this study. The reason for selecting the JEFF(B) over the JEFF(A) was that the JEFF(B) had more data available at the time the project was being initiated.

The perturbation method has been extensively used for vehicle simulation. However, the fidelity of using the method to duplicate the AALC behavior is dependent upon the validated data obtained from the scaled model tests. As was pointed out by Doctors and Sharma (Reference 1), the perturbation method using resistance from constant speed towing tank results is not sufficient to predict the maneuvers, particularly involving large acceleration near hump speed. For AALC operation, large variation of acceleration and control forces are anticipated. Furthermore, a small change of the state of the craft may result in highly nonlinear forces and large coupling effects between degrees of freedom. Therefore, applying the perturbation method to simulate an AALC is questionable.

The modeling technique used in the present simulation is quite different from the conventional perturbation method. The mathematical model is based on the nonamnesic and nonlinear concepts. As the test results will show, the success of this model is mostly due to the simulation of the vehicle generated wave (VGW) and air cushion systems. The model was developed by the C.S. Draper Laboratory (References 2 and 3).

MATHEMATICAL MODEL

The mathematical model has six degrees of freedom and consists of five major sections; namely, the equations of motion, effector, engine, air cushion system, vehicle generated wave, and ocean wave systems (figure 2). The terrain model portion will be added later.

Equations of motion

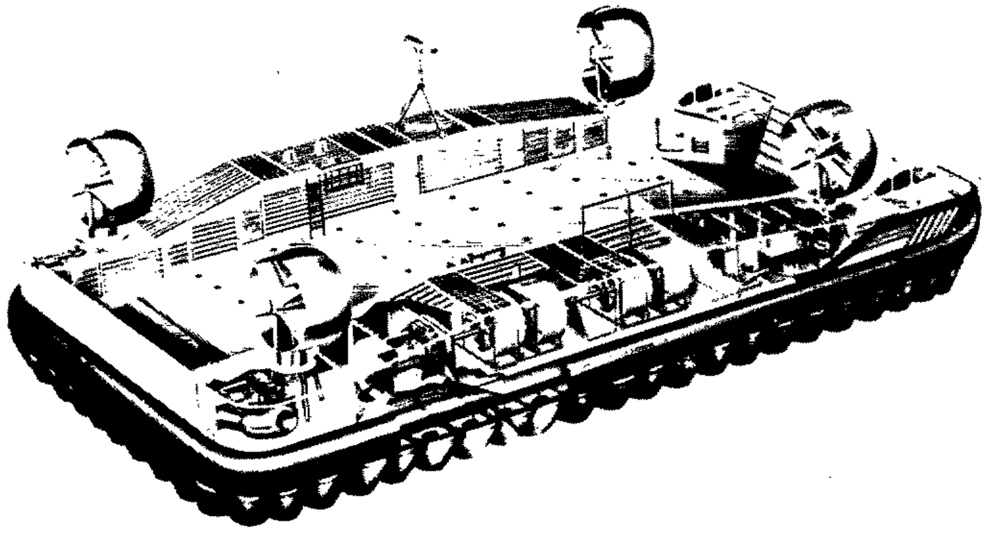
To provide proper motion and visual cues to an operator, the equations of motion are derived with respect to the operator station. The ETA equation is the control equation which is used to calculate the total wave heights for over water operation or the terrain heights for over land operation. However the terrain model is yet to be incorporated in the program. These ETA values are then used to calculate the cushion forces and moments acting upon the craft. Using the ETA equation, there is no need to employ two separate models for amphibious operation. Thus, considerable savings on the development cost of the mathematical model and real-time program have been realized.

Effector and Engine

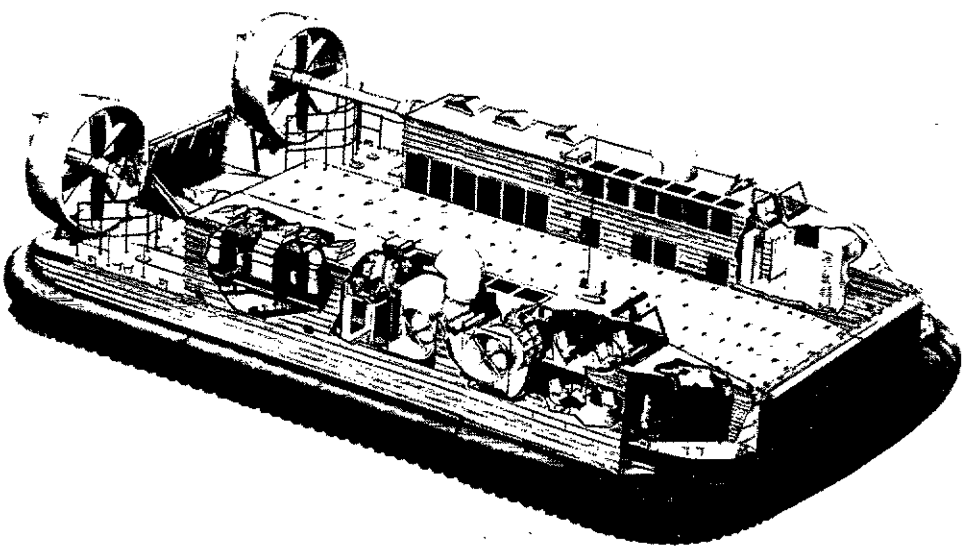
The technique used to model the effector and engine is a conventional one. The data provided by the Bell Aerospace Company for simulating these components are considered to be adequate.

Air Cushion System

The craft is supported by means of the air cushion pressure. Therefore, craft performance is intimately related to the accurate determination of cushion pressure. The cushion model is described by a set of six



JEFF A



JEFF B

Figure 1. Cutaway views and Characteristics of the JEFF Craft

TABLE 1. SELECTED PRINCIPAL CHARACTERISTICS OF THE JEFF CRAFT

	JEFF(A)	JEFF(B)
Overall length on cushion	96'	87'
Overall beam on cushion	48'	47'
Height	23'	23.6'
Design gross weight	340,000 lbs	325,000 lbs
Design payload (overload)	120,000 (150,000)	120,000 (150,000)
Engine	6 Avco Lycoming TF-40 Free Turbine Engine totaled 16,800 hps.	same
Propulsors	4 Reversible Pitch Shrouded Propellers	2 Shrouded Reversible Pitch Propellers 2 Bow Thrusters
Life Fan	8 Single Centrifugal Fans	4 Double Centrifugal Fans
Control system	Fly-by-wire 4 Rotatable Propulsors Yaw rate feedback Auto pilot	same 2 Rotatable Bow Thrusters 2 Aerodynamic Rudders 2 Shrouded Propellers
Skirt system	Looped Pericell 5' height	Bag Finger with Stability Trunks 5' height
Speed (Seastate 2 and 25 knts Headwind)	50 knts	50 knts
Range	200 n. miles	200 n. miles
Maximum slope	11.5%	13%

nonlinear continuity equations which are iteratively solved by a multidimensional Newton-Raphson procedure. Using the modeling technique, this AALC mathematical model does not have explicit damping terms except in yaw. The QPUMP terms in the continuity equations (figure 3) actually provide damping to the craft.

Vehicle Generated Wave and Ocean Wave

The concept of the VGW system is that wave configuration is a function of past velocity history and present state of the craft. Modeling the VGW is the most complex part of the whole simulation. The purpose is to obtain a VGW height under the designated hull point. This is done by integrating from the past T = -t to present T = 0 over 82 values of Kernal function (K).

$$\eta_{VGW} = \int_{-t}^{0} K\,dt$$

A total of 25 points are required. The preparation for the values of the Kernel function is a very tedious work. It took approximately three minutes to compute one Kernel value. A total number of 30 x 30 x 82 values were computed and tabulated in 82 tables which are stored in an equal time interval. The VGW profile under the hover condition is shown in figures 4 and 5.

The seawave simulation is a sinusoidal wave system. It takes in one dominant frequency at a time. It is desirable that it be replaced by a random wave system for more realistic simulation.

The off-shore wave system represents the waves propagating from deep water, through shallow water, and surf zone to a beach. The wave model is based on the small amplitude wave theory with the Stokes second order correction for the wave profile. The basic characteristics of the off-shore wave system are shown in figure 6.

Terrain Model

When the craft is detected to be on a beach or land, the terrain heights will be calculated instead of the wave heights. The designed terrain heights must be measured with respect to the main reference level as illustrated in figures 7, 8, and 9.

REAL-TIME PROGRAMMING

The real-time program is organized into five major modular sections (figure 10). These are:

- Program load and initiation
- Background
- Foreground
- Trap handling
- Common storage

To start an experimental run, the AALC program and VGW tables are loaded from separate magnetic tapes with all interrupts inhibited. The traps are initialized. If the program is successfully loaded, the program entry INITSTRT initializes the I/O and the timing and transfers to the background tasks. The VGW height profile calculation is performed in the background. The background tasks take up all computer time not spent in the foreground. The tasks of foreground operation are to provide the proper time interval for AALC mathematical model of the real-time operation. There are three program modes of operation, namely hold, reset, and operate modes. The operate mode is the real-time simulation of AALC model. The vehicle is maneuverable in this mode. The traps handle the abnormal or error conditions of the software and hardware. The common storage acts as a data pool for the program.

Program Description

The mathematical model is implemented on the Sigma 7 digital computer of Naval Training Equipment Center's (NAVTRAEQUIPCEN) TRADEC flight simulator. The program is written in assembly language and floating point arithmetic is used. The program consists of approximately 16,000, 32-bit words and is iterated at 20 cycles per second or 50 milliseconds per cycle. The computer 48 K memory is fully occupied by the instructions and mostly by the data of the VGW. For worst-case operation, 50, 34, and 16 percent of the 50 milliseconds are spent in running the main program, off-shore wave and VGW system, respectively.

EXPERIMENTAL SYSTEM SETUP

The system designated L (figure 11) is incorporated with a Computer Line Drawing Display Unit manufactured by Evans and Sutherland Computer Corporation, Salt Lake City, Utah. The system designated W (figure 12) is incorporated with a Wide-Angle Visual System. These visual systems are available in the NAVTRAEQUIPCEN laboratories. Because of the limited fundings, existing equipments have been utilized. The purpose is to demonstrate the feasibility of using these visual systems for the AALC experimental training device.

System L

The Computer Line Drawing Display unit interfaces with the Sigma 7 computer by a subroutine of approximately 500 instructions. Once the unit is started, it operates independently, fetches the data and drawing instructions from the computer memory, and continuously draws the well of the LHA mother ship.

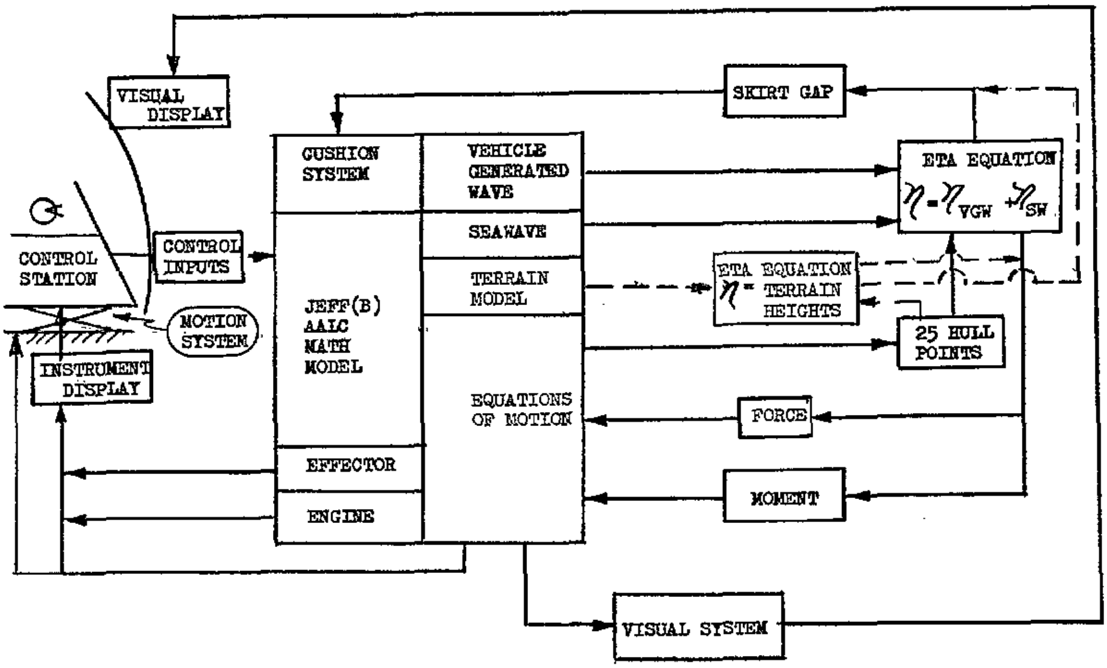


Figure 2. System Diagram for Amphibious Operation

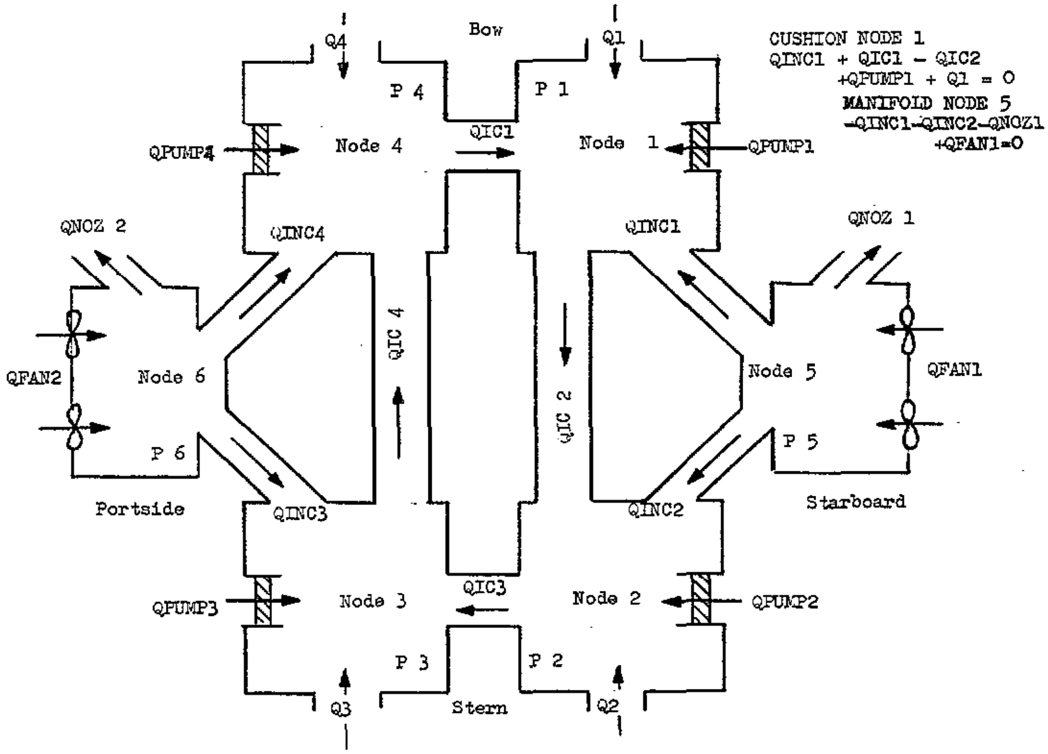


Figure 3. Cushion Pressure Schematic

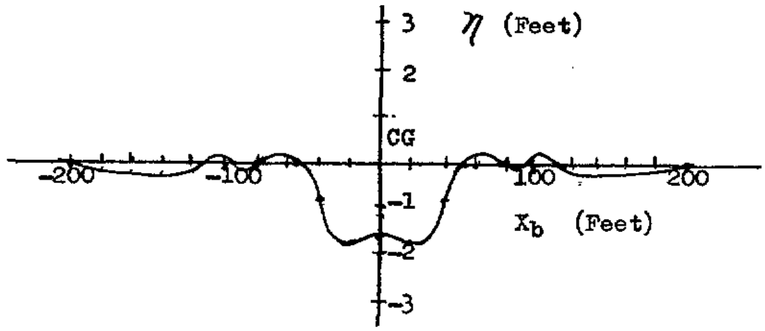


Figure 4. VGW Profile u = 0, Longitudinal

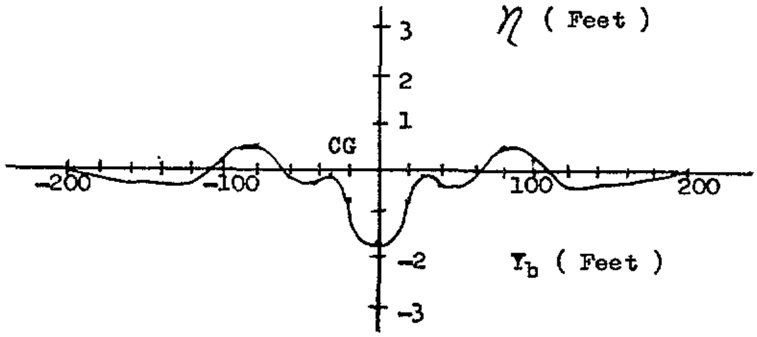


Figure 5. VGW Profile u = 0, Lateral

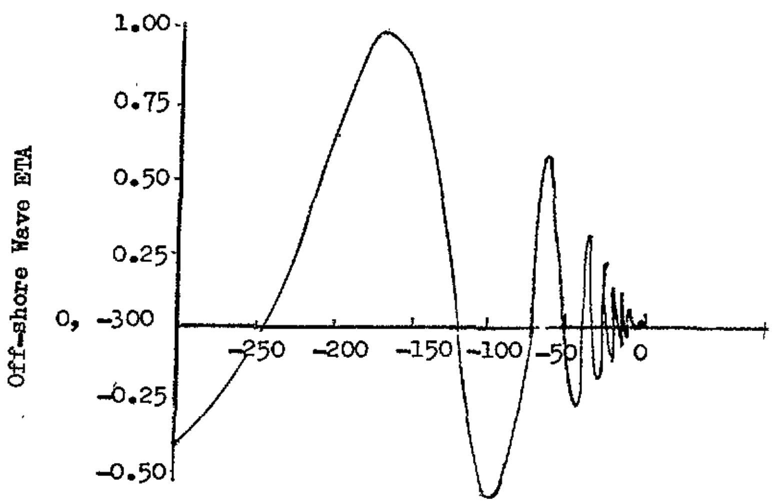


Figure 6. Off-shore Wave at Beach

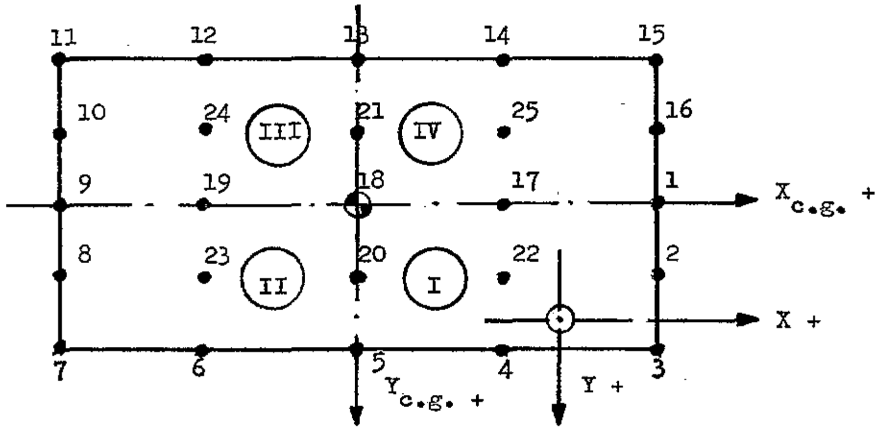


Figure 7. Location of 25 Hull Point

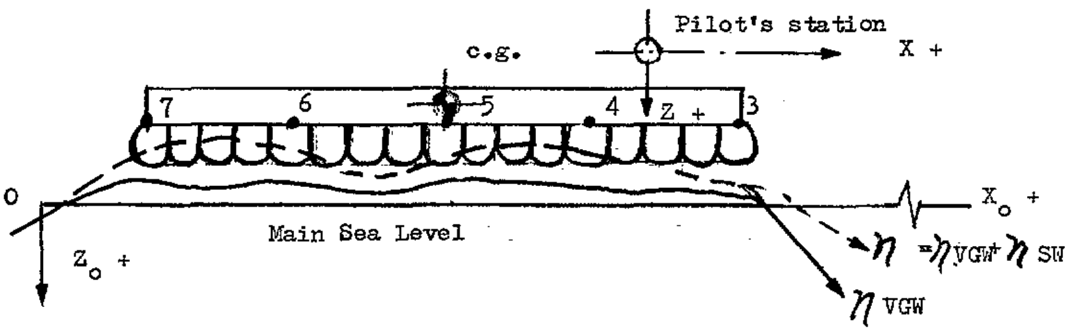


Figure 8. Wave Amplitude Schematic

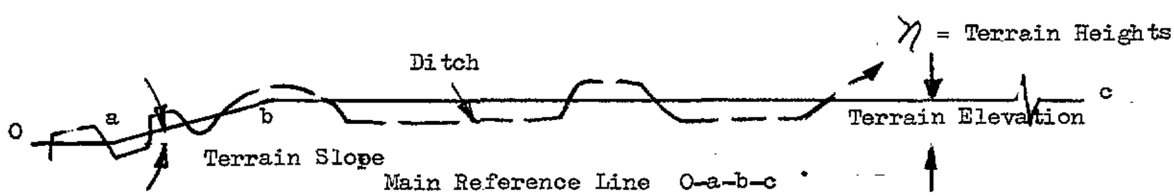


Figure 9. Terrain Height Schematic

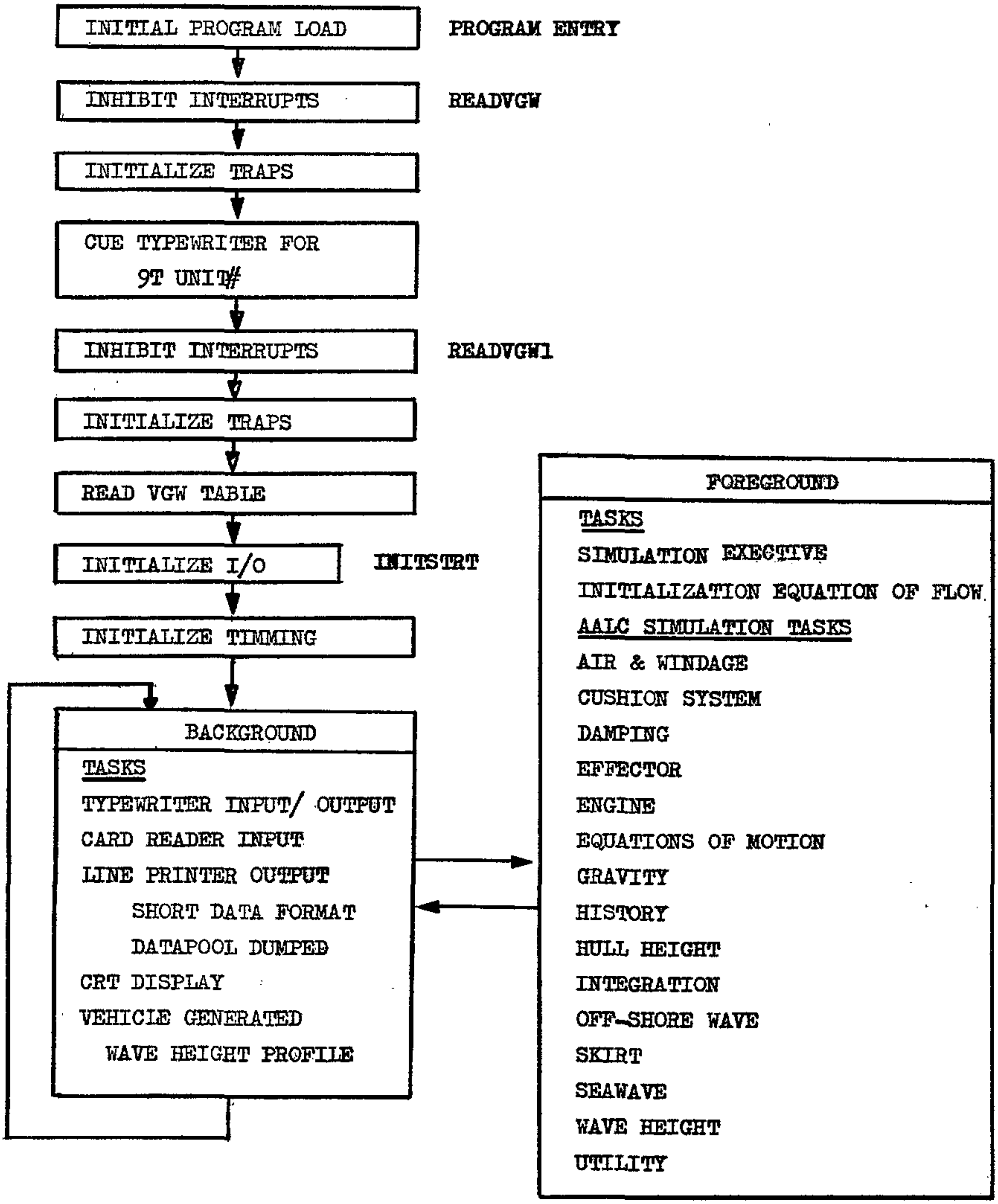


Figure 10. Basic Software Flow and Structure

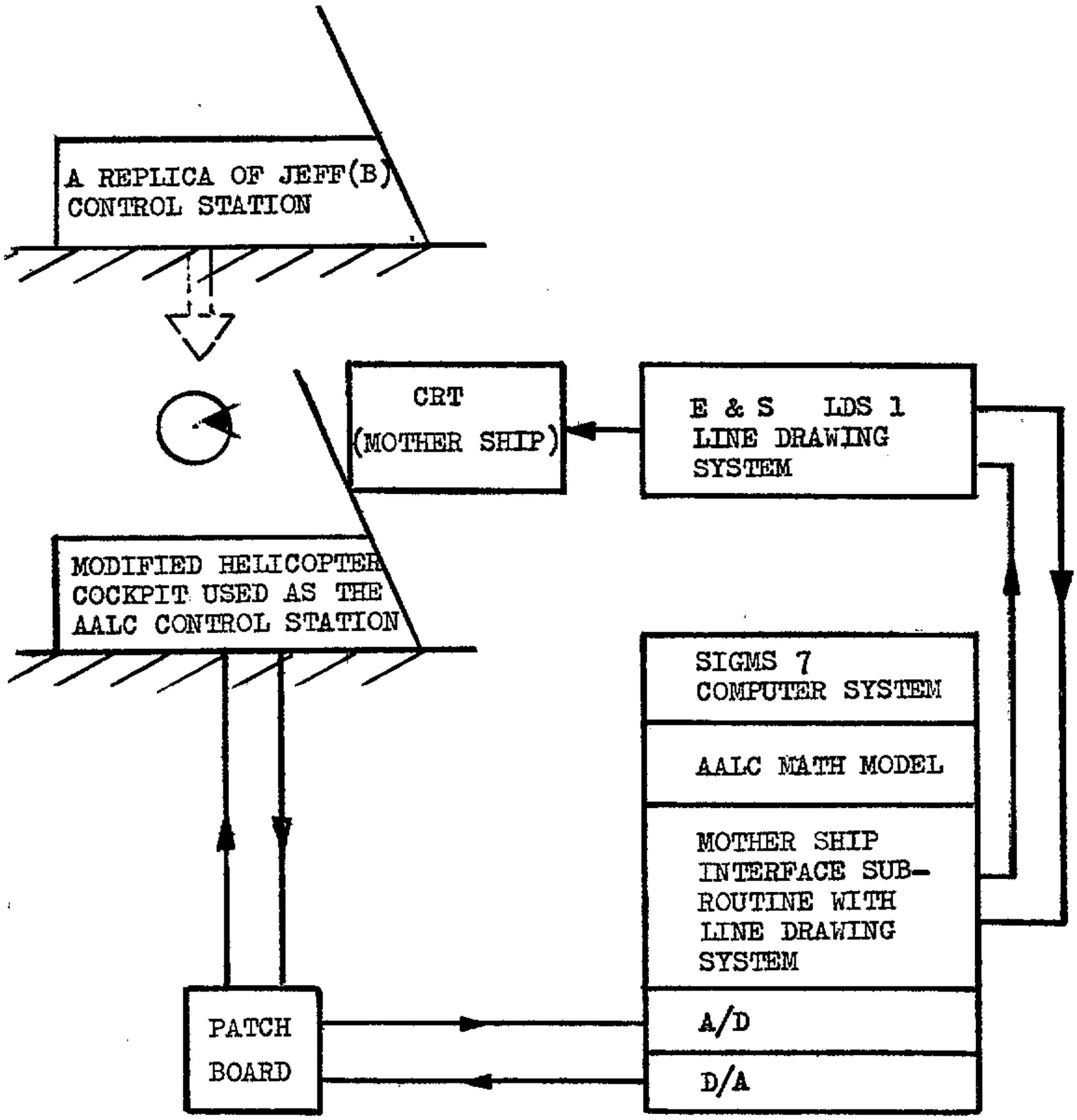


Figure 11. System with Line Drawing Display

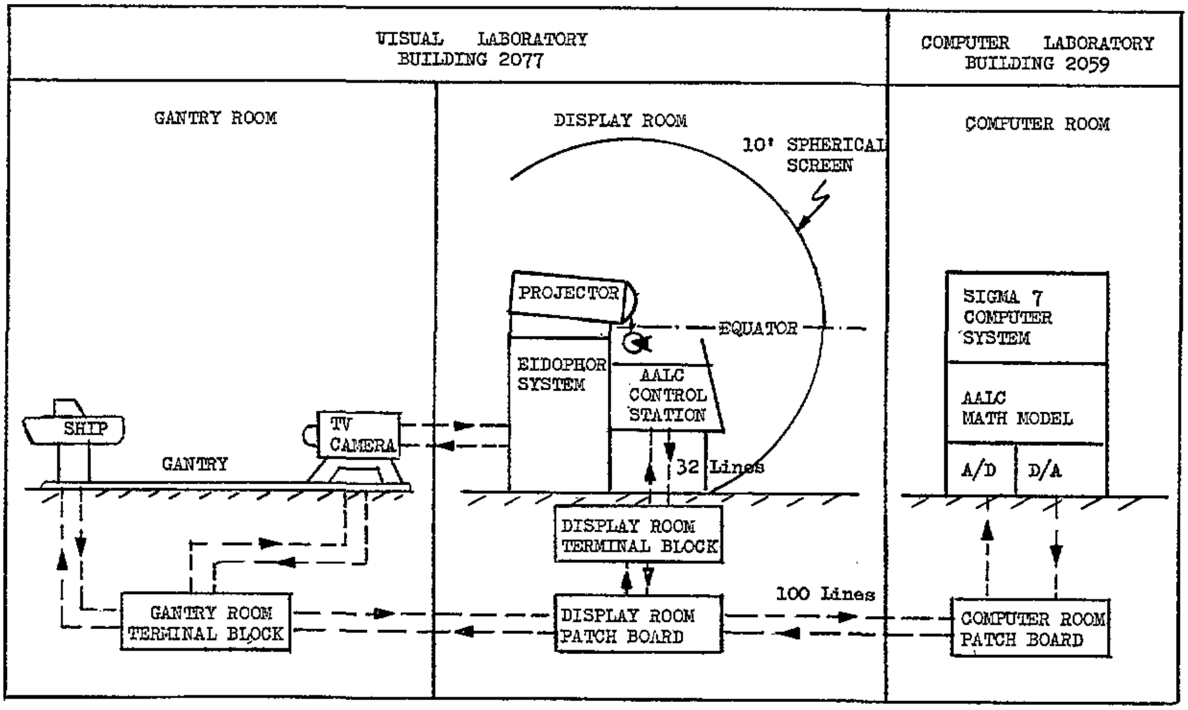


Figure 12. System with Wide Angle Visual Unit

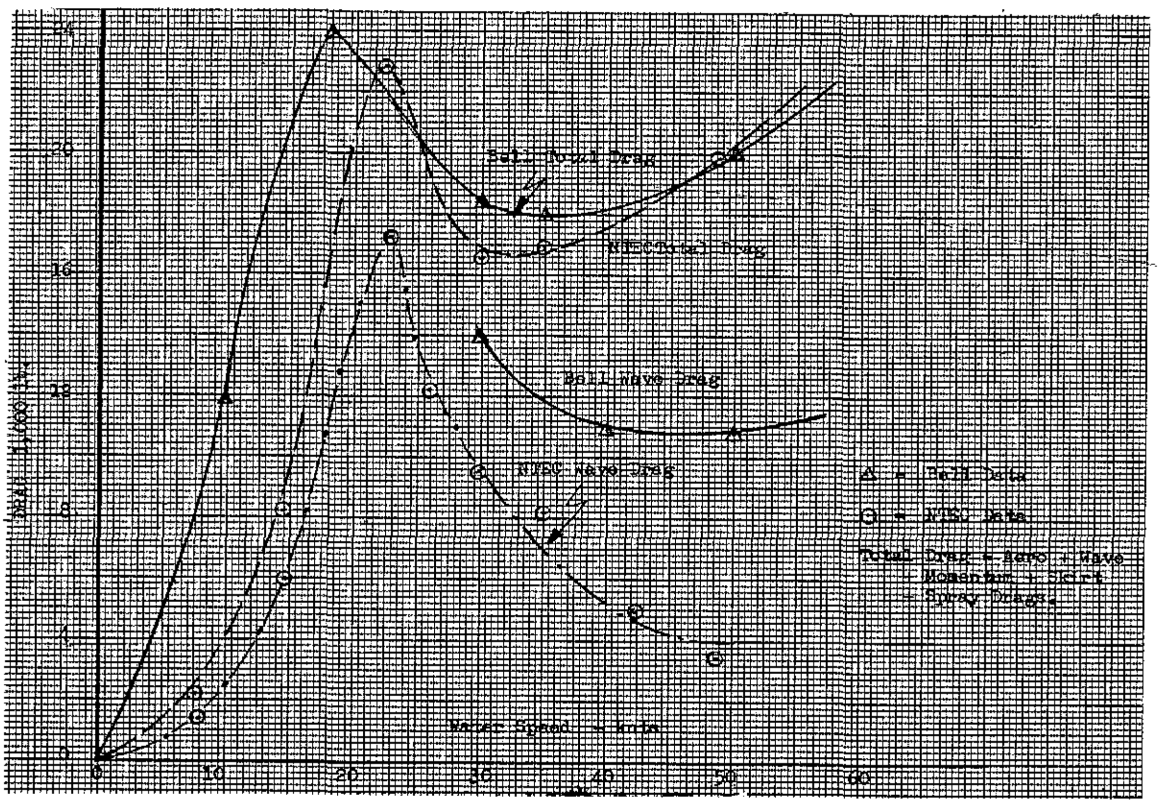


Figure 13. JEFF(B) Drag Characteristics

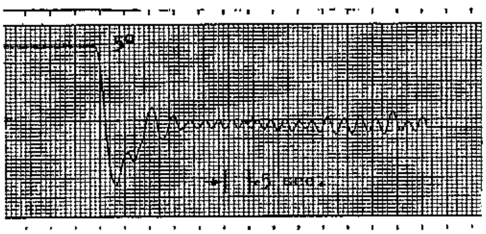


Figure 14.1. Pitch Frequency Response with VGW 5° Impulse, U = 0

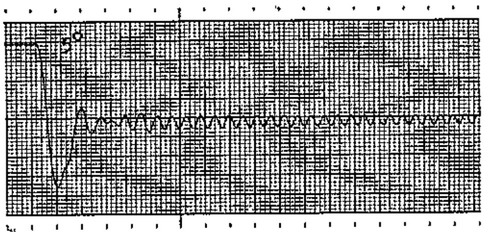


Figure 14.2. Pitch Frequency Response with VGW 5° Impulse, U - 50 knots

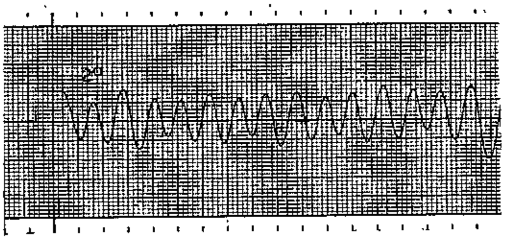


Figure 14.3. Roll Frequency Response with VGW 2° Impulse, U = 0

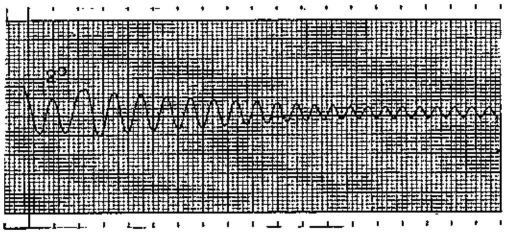


Figure 14.4. Roll Frequency Response with VGW 2° Impulse, U = 50 knots

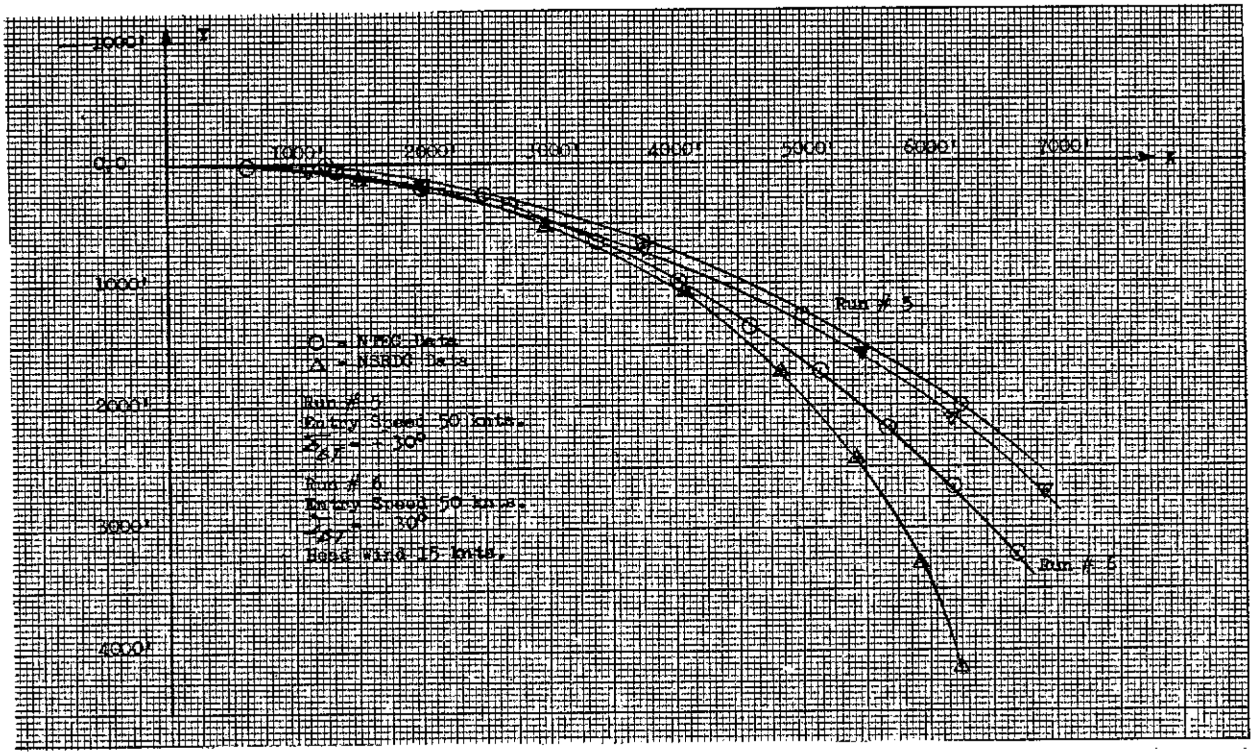


Figure 15. Turning Maneuver from a 15 Knot Headwind

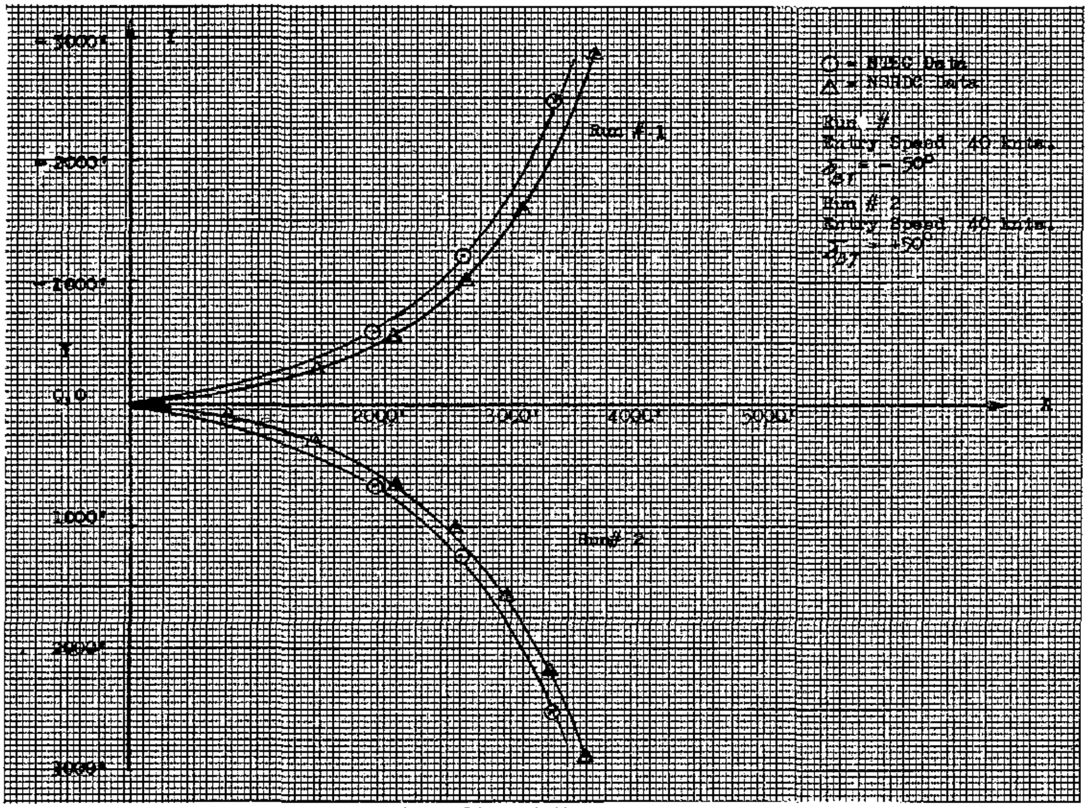


Figure 16. Steady State Turn

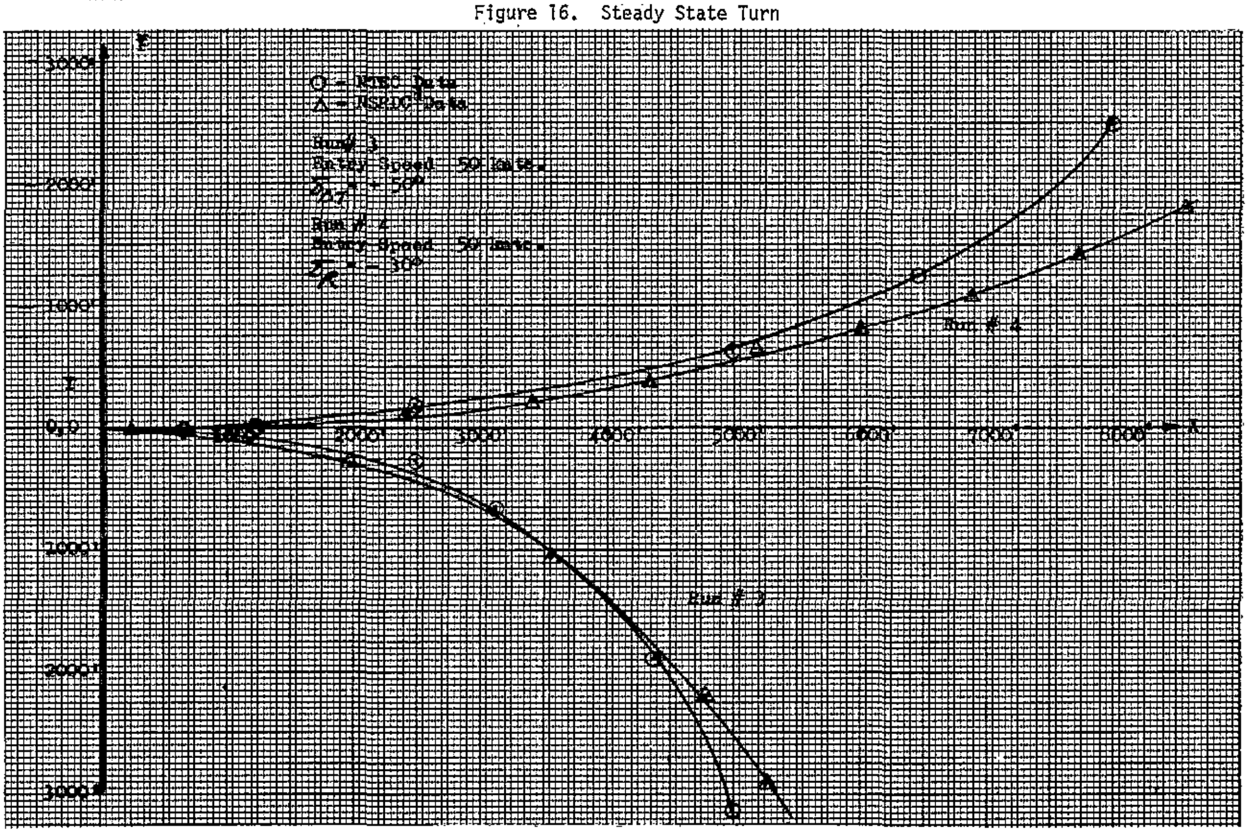


Figure 17. Steady State Turn

The AALC attitude instructions are stored in the computer memory by the program of AALC mathematical model and are updated every program cycle. The function of the display unit is to continuously draw the well of a LHA mother ship being viewed from an AALC operator's station during the docking maneuvers.

The system L integrating the modified and instrumented helicopter cockpit, digital program, and the Computer Line Drawing Display unit has been used to obtain performance data on the simulation and allow operators to perform docking maneuvers.

System W

The existing NAVTRAEQUIPCEN Wide-Angle Visual System is a single channel TV system with a field of view of 60° vertical and 160° horizontal using TV camera and an Eidophor light valve projector. The camera and projector are 1023-line units.

The system W integrating the replica of JEFF(B) control station, digital program, Wide-Angle Visual system, gantry system, 1/50 scaled LPD model, and 10-ft radius spheric dome is being used as an experimental training device. The camera picks up and processes the image of the physical model of LPD and puts out signals to the Eidophor unit. It processes signals and projects the image of the LPD model on a spheric screen supported by the structure of the spheric dome. The picture displayed on the screen with brightness of 5-foot lambert provides the visual scene to the operator. The movement of the gantry upon which the camera is seated is driven by the outputs of navigational positions and heading from the computer program which is governed by the operator's commands issued from the control station. It is instrumented the same as System L. Because of the limitation of the gaming area, the system is exclusively used for the docking maneuvers. No attempt has been made to collect performance data from the system.

Plan for Over Land Operation

The mathematical model has been developed for amphibious operation. The current model can operate on a flat ground. The plan is to add the terrain model to the program. The data base will be designed. No sophisticated equipments are required.

Test Result

Data dealing with the over water maneuvers were collected using System L. A total of five runs were conducted to verify the basic characteristics of the mathematical model. The VGW profile at hover condition, off-shore wave, hump speed and frequency response are presented in figures 4, 5, 6, 13, and 14, respectively. A total of eight runs were conducted at various entry speeds and control settings. The collected performance data were compared with the data provided by NSRDC from a nonreal-time JEFF(B) simulation program. The data are presented in figures 15, 16, and 17. The correlation between two sets of data were satisfactory. During August 1976, a total of 30 runs were conducted by Mr. James Fein of NSRDC to verify the performance of the craft over calm water and over wave. Most of the runs were conducted at the entry speed of 50 knots and at various control settings. Zero and high-speed (over hump speed) turnings were performed. The tests were conducted over wave at various wave heights (1' and 3') and periods (5, 6, 7, and 7.5 seconds). The performance data were rated satisfactory.

After completing the docking maneuvers in the System W on 28 February 1977, Lt. J.N. Mullican and Mr. R.E. Hughes of Amphibious Assault Landing Craft Experimental Trials have made comments on the operation of the experimental design. This points out a need for further refinement of the mathematical model.

Conclusion

System L has fulfilled its assigned objective. The existing Computer Line Drawing Display unit has been utilized to provide the interim solution to the docking maneuvers. The mathematical model was tentatively validated by comparing our collected performance data with the data provided by NSRDC's nonreal-time AALC program. The final validation of the mathematical model will be made when the full trial data or data from 1/6 radio controlled model comes available.

REFERENCES

1. Doctors, L.J. and Sharma, S.D., "The Wave Resistances of An Air-Cushion Vehicle in Acceleration," Michigan University, Ann Arbor, Dept. of Naval Architecture, January 1971.

2. Cummings, Damon, Kern, Edward, Shursky, Stanley and Young, Ronald, "Mathematical Model of an Air Cushion Vehicle," Technical Report NAVTRAEQUIPCEN 73-C-0138-1, May 1975.

3. Loud, J.E., "Simulation of an Air Cushion Vehicle," Technical Report NAVTRAEQUIPCEN 75-C-0057-2, March 1977.

ABOUT THE AUTHOR

MR. DAVID YIH is an Aerospace Consultant associated with the Experimental Computer Simulation Laboratory at Naval Training Equipment Center. From 1964 to 1968, he was a project engineer in charge of development of a high-enthalpy wind tunnel and fuel cell. Prior to that, he was a project engineer at Curtiss-Wright, VTOL Division in charge of development of flight test equipment for X19 VTOL aircraft from 1962 to 1964. From 1954 to 1962, he was a research associate at New York University in charge of development of air pollution and supersonic and shock wind tunnels. Mr. Yih received his B.E. degree in mechanical engineering from Hangchow University, Hangchow, China and the M.E. degrees in mechanical and aeronautical engineering from New York University. He also did graduate work in electronic engineering at Newark College of Engineering.