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NAVAL POSTGRADUATE SCHOOL

Monterey, California

DEVELOPMENT OF A REAL-TIME HYBRID COMPUTER SIMULATION FOR THE 3K-SES, 5 DOF, DATA-BASED PROGRAM PART I-FAMILIARIZATION AND PLANNING

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Three degree of freedom approximate models have been developed for the XR-3 and the 3K-SES. Implementation in the IBM 360/67 and comparisons of turning characteristics with the 6 DOF program for the XR-3 and the 5 DOF program for the 3K-SES show good correlation. Hybrid implementation of the 3 DOF model of the XR-3 also shows good correlation. Hybrid implementation of the 3 DOF model for the 3K-SES is in progress, and extension to 5 DOF is being planned.

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SUMMARY

The first step in the development of a hybrid computer simulation of the data-based, 5 DOF, 3K-SES program that will operate in real-time has been completed. A 3 DOF (Flat) turn model for an approximate and simplified XR-3 craft was used to provide the equations of motion in order to become familiar with 1) the turning characteristics of the CABSES, 2) the requirements of the (NPS) NAV PG School hybrid computer with regard to signal conversion, timing, accuracy and loop delay due to both signal conversion and (right-hand-side) computation and 3) the approximate size of program that can be computed on the existing hardware of the NPS facility.

In parallel with this investigation, the 5 DOF data-based digital program for the 3K-SES has been converted from CDC to IBM FORTRAN and is now operational and will serve as the standard for evaluation of the final hybrid simulation for the 3K-SES.

Results of the hybrid computer simulation of the 3 DOF turn model of the XR-3 indicate that the installation of the 5 DOF program of the 3K-SES should proceed (in the next phase) as a straight forward application of the right-hand-side computations within the digital computer and additional degrees of freedom on the analog computer. The successful operation of the hybrid computer simulation will

depend upon ability of the 10 year-old hardware--in particular the digital computer--to compute the many computational operations required for the right-hand-side of the equations of motion in the time frame necessary to approximate real-time manual control.

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INTRODUCTION

Reference 1 presents the Rohr Marine, Inc. analysis of the stability and maneuverability of the 3K-SES under direct manual control. The recommendations contained in Reference 1 included a suggestion to continue the investigation of manual control using a more realistic model of the response of the human operator to emergency conditions.

If a real time simulation can be developed it can provide a means of inserting an actual human operator in the loop, as well as any selected model of the operator. A hybrid realization of such a real time simulator appears to be feasible and would provide a convenient hands-on facility for a variety of human operator studies, plus many other studies in control and guidance.

This report presents the results of the first phase of a feasibility study, in which it is planned to develop a real time simulation using the NPS Hybrid Computer which consists of a CI-5000 analog unit and an XDS-9300 digital unit. The initial studies reported here are concerned with development of 3 DOF models for the XR-3 and the 3K, as a preliminary to the development of a 5 DOF Hybrid model.

II. FAMILIARIZATION AND PLANNING

IIA. THE 3 DEGREE OF FREEDOM MODEL

1. INTRODUCTION

The development of any computer model requires familiarity with both the system equations and the computer to be used. In addition, one needs quantitative data to insert the model into the computer, and one also needs typical performance data such as experimental test results in order to validate and verify the model. To develop a hybrid model of the 3K-SES, we chose to start by modelling the XR-3, because we have the required quantitative data, we have a good 6 DOF digital program, and we have good experimental data, plus availablility of the XR-3 craft for test as needed. We also decided to start with a 3 DOF model, for several reasons:

a) It is the simplest model which will permit turning tests that are verifiable.

b) The complexity of the initial model will thus be minimal, but we can readily add two more degrees of freedom with confidence in the resulting 5 DOF model, because the similarity of the differential equations will permit ready application of the techniques we develop in perfecting the 3 DOF model.

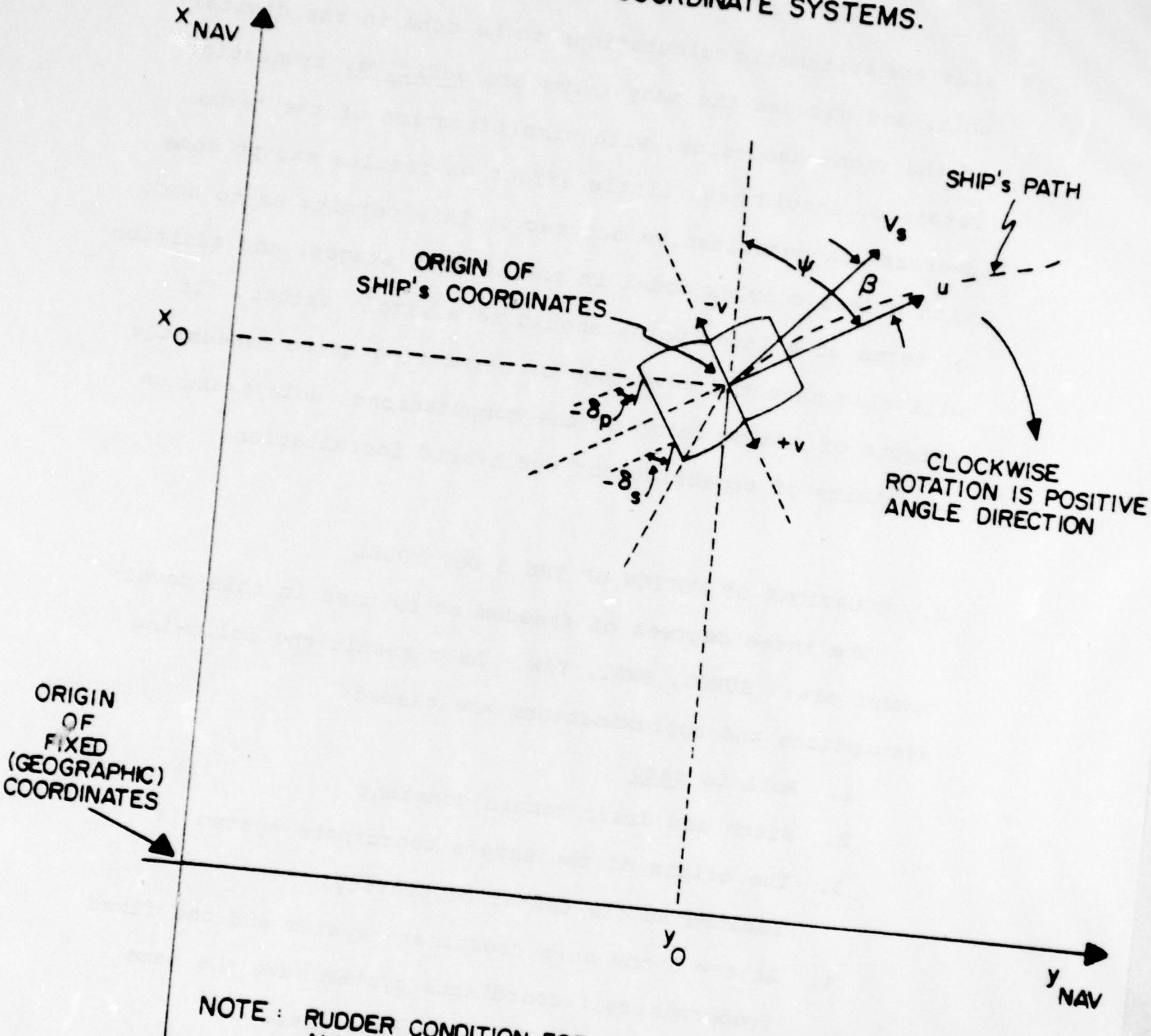
In addition to this decision to start with a 3 DOF model, we chose to simplify the model by simplifying the right-hand-side of the equations. Since the terms on the right-hand-side are arithmetic calculations to be done in the digital unit, and because the many terms are additive, truncation of the right-hand-side, with simplification of the terms retained, should have little effect on results except some decrease in quantitative accuracy. This permits us to work with a less complex model in the initial stages, and addition of terms at a later point should be a simple matter. It will also have the advantage of permitting us to assess the effects of adding terms on the computational delays and on the limits of capability of our hybrid installation.

2. EQUATIONS OF MOTION OF THE 3 DOF MODEL

The three degrees of freedom to be used in this development are: SURGE, SWAY, YAW. As a result the following assumptions and approximations are needed:

1. Roll is zero
2. Pitch and draft remain constant
3. The origin of the ship's coordinate system is located at the center of gravity.
4. At t = 0 the ship coordinate system and the fixed (geographical) coordinate system have the same origin and the same coordinate axes.
5. At t = 0 the ship is heading in the positive X_{nav} direction.

Figure 1. DEFINITION OF COORDINATE SYSTEMS.



NOTE: RUDDER CONDITION FOR RIGHT TURN IS SHOWN. ALL RUNS START AT GEOGRAPHIC ORIGIN, i.e., SHIP's COORDINATE ORIGIN IS LOCATED AT GEOGRAPHIC COORDINATE ORIGIN AT $\tau = 0.0$.

The equations of motion can then be approximated by:

<u>SURGE</u> $m(\dot{u} - vr) = X$ (1)

<u>SWAY</u> $m(\dot{v} + ur) = Y$ (2)

<u>YAW</u> $I_z \dot{r} = N$ (3)

<u>Navigation</u>

$\dot{x}_o = u \cos \Psi - v \sin \Psi$ (4)

$\dot{y}_o = u \sin \Psi + v \cos \Psi$ (5)

$v_s = \sqrt{u^2 + v^2}$ (6)

$\beta = \tan^{-1} (\frac{-v}{u})$ (7)

In the above equations:

m = mass of the rigid ship

I_z = moment of inertia about the z-axis

$u = v_s \cos \beta$ = velocity in the x-direction (SURGE)

$v = V_s \sin \beta$ = velocity in the y-direction (SWAY)

$r = \dot{\Psi}$ = angular velocity about the z-axis

Ψ = heading (yaw) angle (see Fig. 1)

β = drift angle (see Fig. 1)

δ = rudder angle, $+\delta$ produces a left turn (see Fig. 1)

Also:

$x_o = \int \dot{x}_o dt$ $u = \int \dot{u} dt$ $r = \int \dot{r} dt$

$y_o = \int \dot{y}_o dt$ $v = \int \dot{v} dt$ $\Psi = \int \dot{\Psi} dt$

The right-hand-sides (RHS) of the equations of motion have been designated X, Y, N. These symbols represent summations of forces (X,Y) and moments (N), and each summation may consist of many terms. For the initial simplified model we have discarded all terms in the summations except the few that are obviously major contributions. The terms retained are considered sufficient to produce a working simulation which should provide qualitative agreement with reference data. At a later point the model may be refined by adding terms and adjusting terms and adjusting coefficients.

After reduction of the right-hand-sides, these force summations become:

$$X = GT \cos \delta - C_{DX} u^2 \tag{8}$$

$$Y = GT \sin \delta - C_{Dy} v|v| \tag{9}$$

$$N = -(GT \sin \delta) l_o + C_{Dy} \, v|v| l_\omega \tag{10}$$

where: (see Fig. 2 also)

GT is the gross thrust in pounds

$\delta = \delta_s = \delta_p$ = angle of all thrust vectors

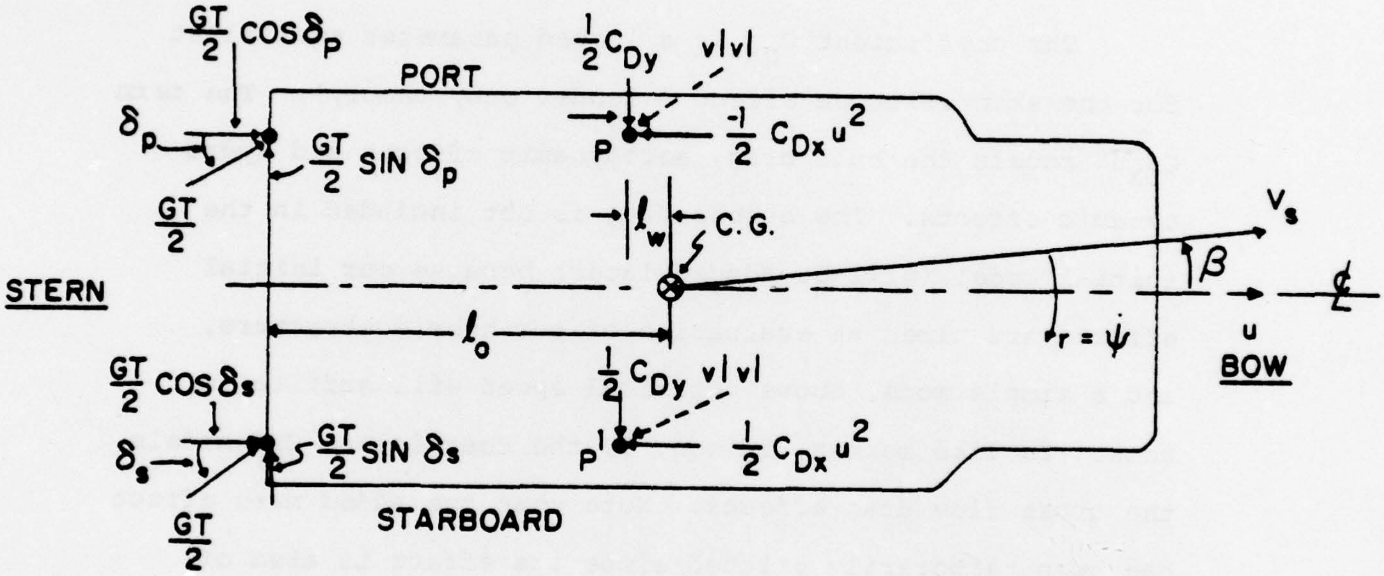
C_{DX} = coefficient of drag in the direction of surge

C_{Dy} = coefficient of drag in the direction sway

l_o (see Fig. 2)= thrust lever arm

l_ω (see Fig. 2)= sway-drag lever arm

In further explanation of equations 8, 9, 10, note that we have chosen to model the drag forces as lumped parameters acting at two points P and P´ (see Fig. 2).



NOTE: $\delta_s = \delta_p = \delta$

$P - P^1$ ARE EQUIVALENT FORCE CENTROIDS

Figure 2. FORCES ACTING FOR A RIGHT TURN.

The length 1_o is the distance from the stern to the center of gravity, and 1_ω is the component distance (in the x-direction) from the center of gravity to the points P-P'. 1_o is a fixed parameter for our initial studies (it could be changed by ship loading) but 1_ω is an adjustable distance which we will use as a parameter to make the model fit test data.

The coefficient C_{DX} is a lumped parameter equivalent for the skin friction effect (slender body theory). The term $C_{DX}u^2$ models the hull drag, aerodynamic effects and hydrodynamic effects. The bubble drag is not included in the initial model (will be addded later) because our initial efforts are aimed at evaluation of our hybrid structure, and a simple model above critical speed will suffice for this. In like manner, in eqn. 9, the coefficient C_{Dy} models the cross flow drag effects. Note that the added mass effect has been temporarily omitted since its effect is also of second order.

Substituting equations 8, 9, 10 into equations 1, 2, 3 provides the basic equations of motion for the 3 degree of freedom model:

$$\dot{u} = \frac{1}{m}\left(GT\cos\delta - C_{DX}u^2\right) + vr \qquad (11)$$

$$\dot{v} = \frac{1}{m}\left(GT\sin\delta - C_{Dy}v|v|\right) - ur \qquad (12)$$

$$\dot{r} = \frac{1}{I_z}\left(-(GT\sin\delta)1_o + (C_{Dy}v|v|)1_\omega\right) \qquad (13)$$

Equations 11, 12, 13 are applicable to any SES craft. Selection of parameter values to be used in the equations would depend on the particular craft, but the procedures used to identify the lumped parameter values are independent of the craft type.

3. IDENTIFICATION OF CRAFT PARAMETERS

In order to evaluate the parameters needed for the equations, the craft must be available for measurement and test (or suitable data must be available). The parameters m, I_z, l_o are constants which must be known, and GT, δ, u, v, r can be measured in steady state (if needed). Then C_{DX}, l_ω, C_{Dy} can be calculated as is shown below:

A. Surge Drag Coefficient, C_{DX}

The craft is run on a straight course with GT = constant and given rudder conditon δ. When steady state is reached u is measured. Then

$$\dot{u} = 0 = \frac{1}{m}\left(GT \cos \delta - C_{DX} u_{ss}^2\right) \tag{14}$$

from which

$$C_{DX} = GT \cos \delta / u_{ss}^2 \tag{15}$$

where

GT = gross thrust in pounds

u_{ss} = steady state speed in feet/sec

δ = rudder angle

B. Sway Drag Moment Arm, l_ω

Let GT = constant and $\delta = \delta_1$, a fixed angle. When the craft reaches steady state in the turn the sway equation becomes

$$\dot{v} = 0 = \frac{1}{m}\left(GT \sin \delta - C_{Dy} v|v|\right) - ur \tag{16}$$

from which

$$C_{Dy} v^2 = GT \sin \delta - m\,u\,r \qquad (17)$$

The steady state yaw moment equation becomes

$$\dot{r} = 0 = \frac{1}{I_z}\left[-(GT \sin \delta)\, l_o + (C_{Dy} v|v|)\, l_\omega\right] \qquad (18)$$

from which

$$C_{Dy} v^2 = (GT \sin \delta)({}^{l_o}/_{l_\omega}) \qquad (19)$$

Combining equations 17 and 19:

$$r = \frac{GT \sin \delta (1 - {}^{l_o}/_{l_\omega})}{mu} \qquad (20)$$

or if we wish

$$l_\omega = l_o \; \frac{GT \sin \delta}{GT \sin \delta - m\,u\,r} \qquad (21)$$

From Fig. 2 and eqn. 20 it is clear that the turning rate, r, is a function of the distance l_ω, with all other parameter values fixed. Since it is customary to command a turning rate, if we choose r we can then evaluate l_ω. For the XR-3, using steady state data obtained with our 6 DOF simulation,

$$r = -0.0266(1 - {}^{12}/_{l_\omega}) \text{ radians/sec} \qquad (22)$$

A plot of this relationsip is shown on Fig. 3.

C. Sway Drag Coefficient, C_{Dy}

Again assuming steady state conditions with fixed thrust and fixed rudder, the sway equation, eqn. 17, provides:

$$C_{Dy} = \frac{-m\,u\,r + GT \sin \delta}{v^2} \qquad (23)$$

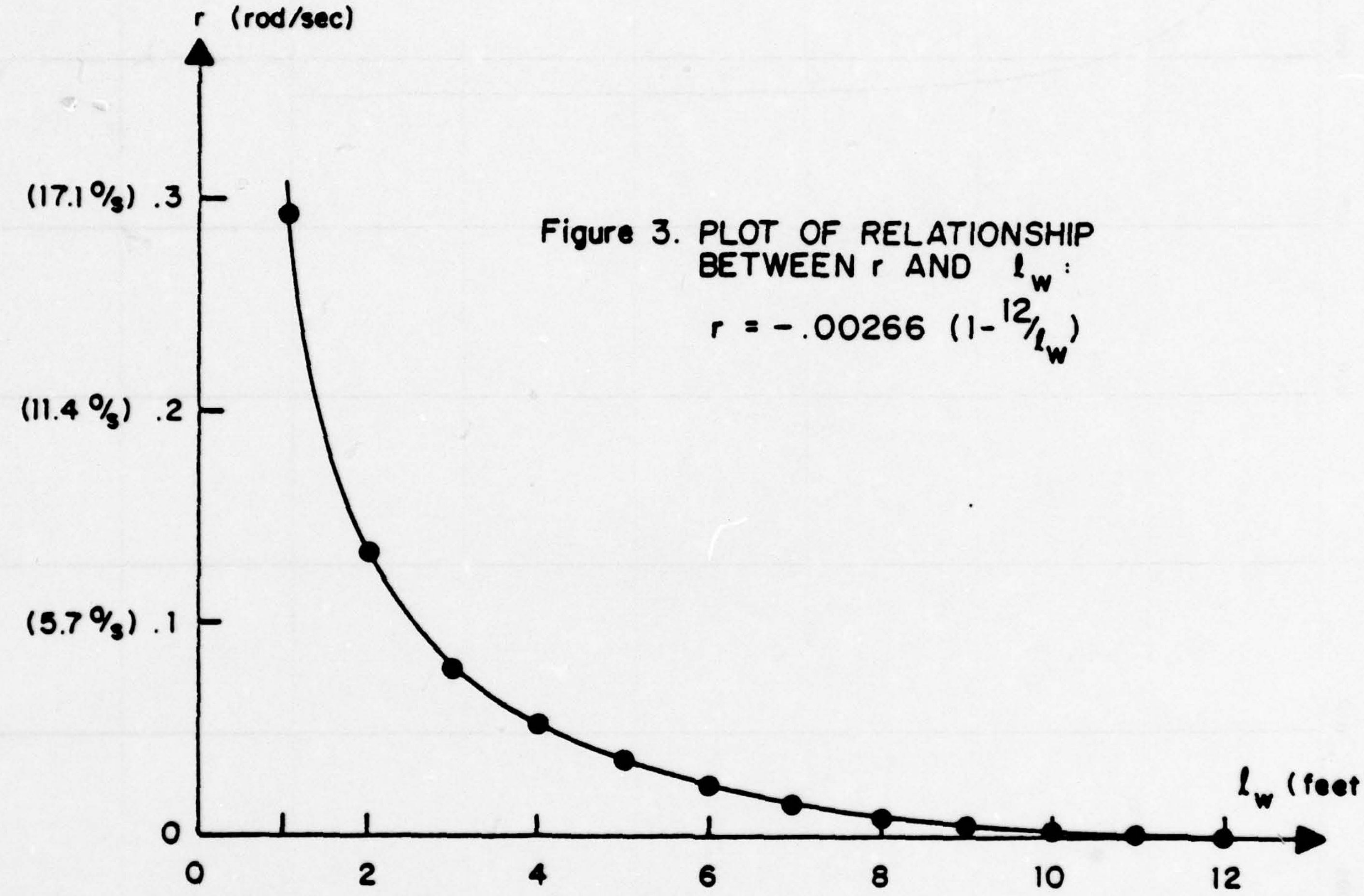


Figure 3. PLOT OF RELATIONSHIP BETWEEN r AND ℓ_w:

$$r = -.00266\ (1-{}^{12}/_{\ell_w})$$

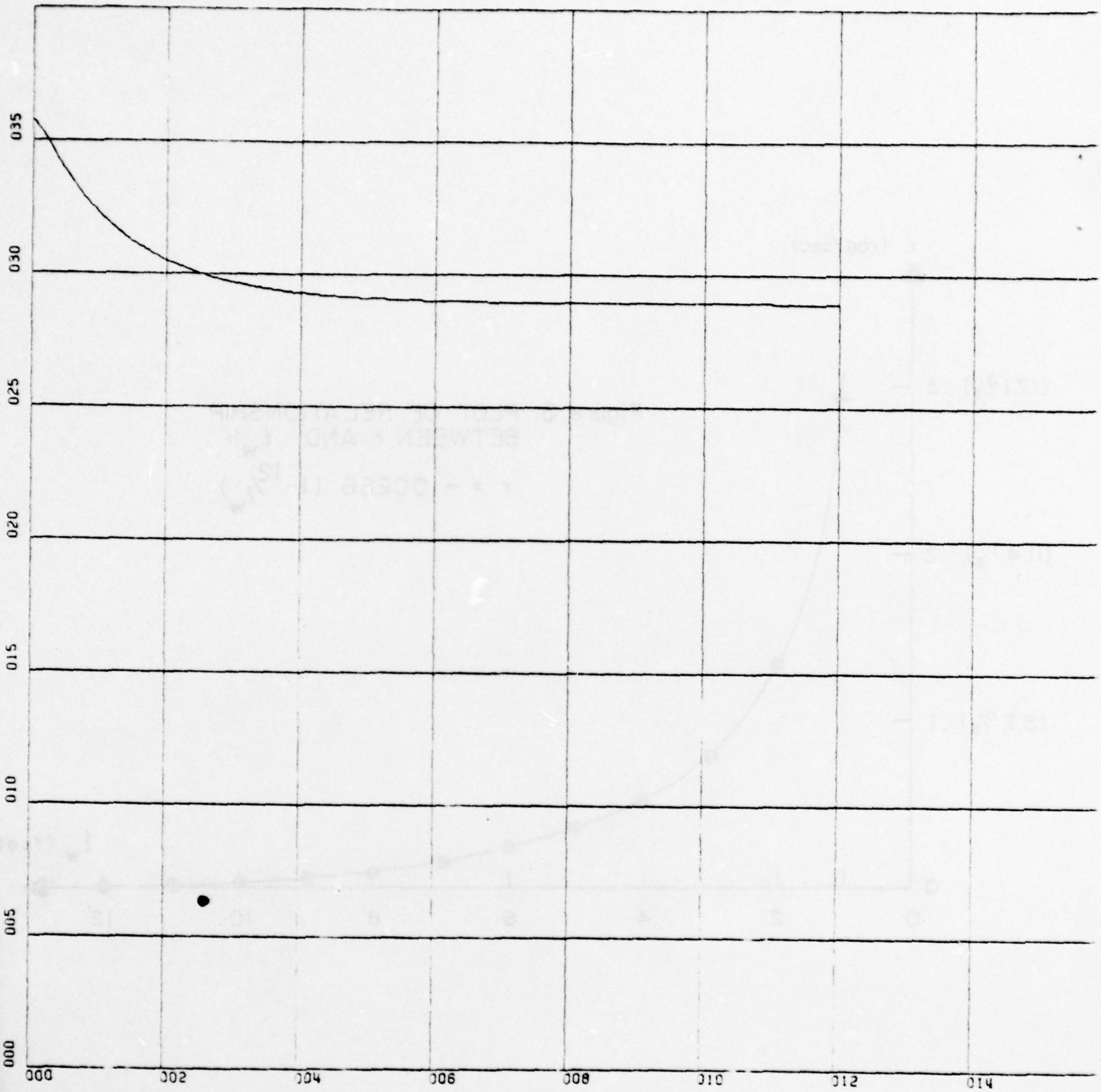


Figure 4-A. FLAT TURN DYNAMICS OF THE XR-3, PLOT OF VELOCITY vs. TIME.
r = .33 RAD/SEC (ℓ_w = 1 ft)

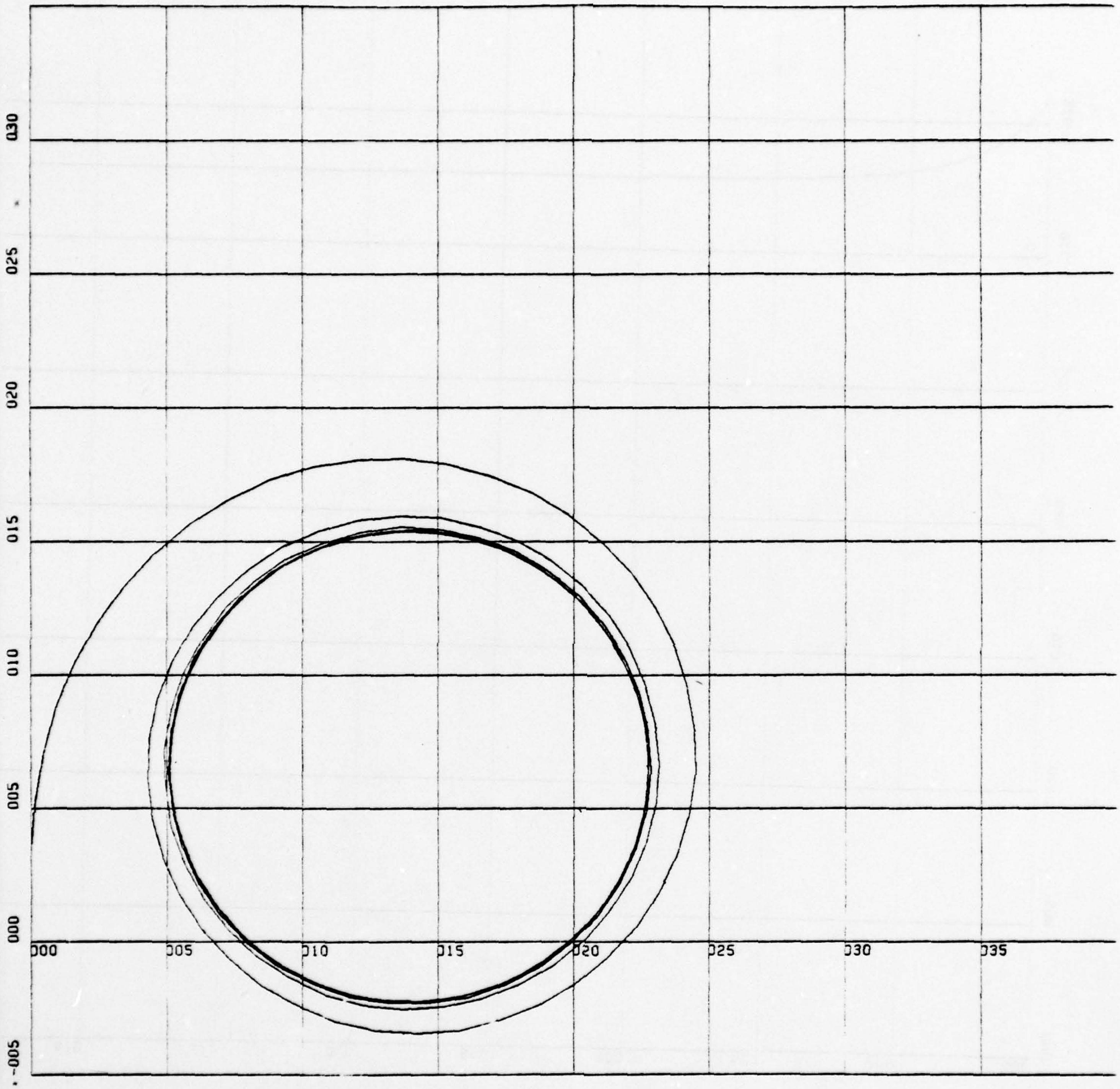


Figure 4-B FLAT TURN DYNAMICS OF THE XR-3, PLOT OF X vs. Y.
r = .33 RAD/SEC (ℓ_W = 1 ft)

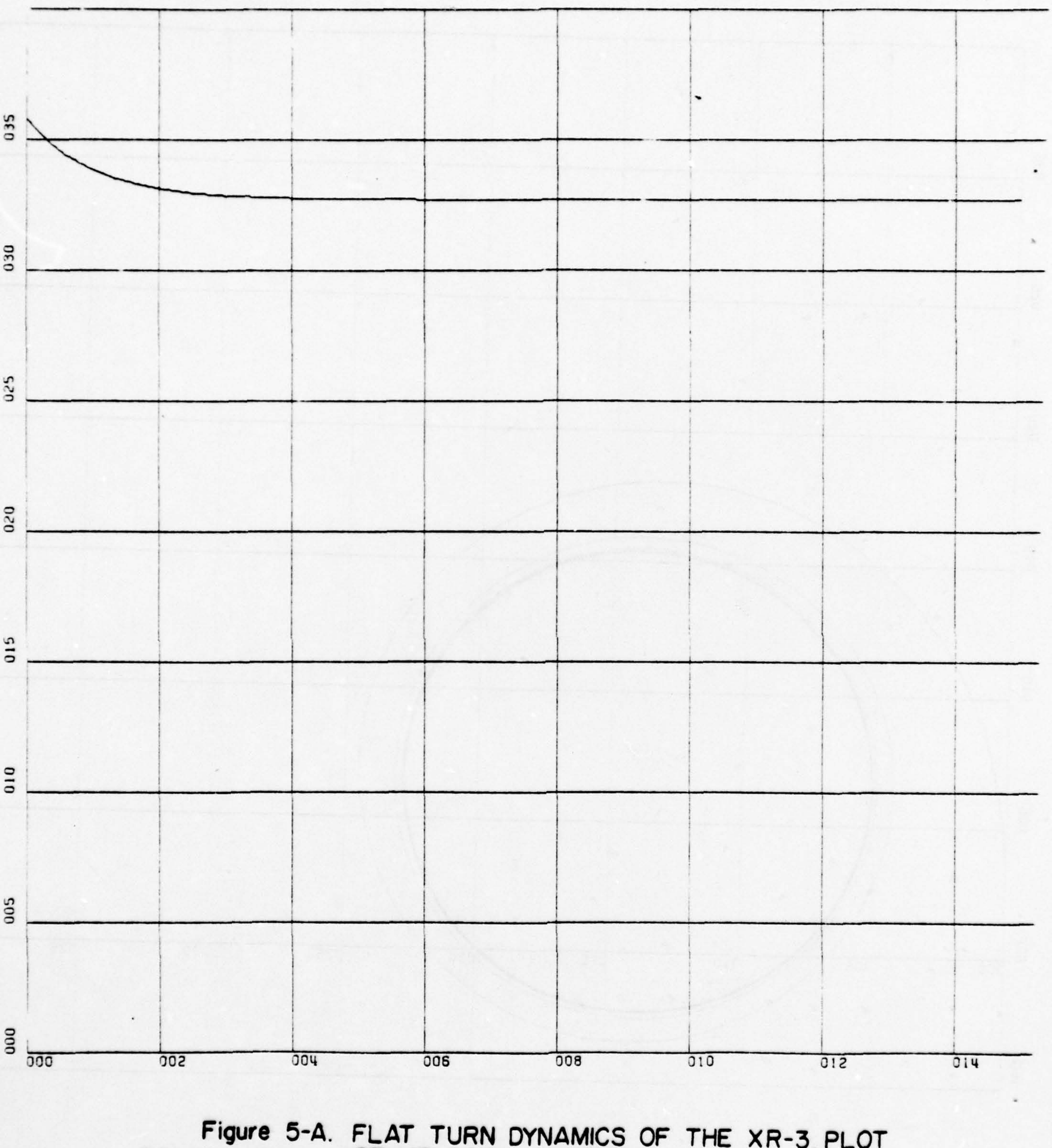


Figure 5-A. FLAT TURN DYNAMICS OF THE XR-3, PLOT OF VELOCITY vs. TIME.
$r = 0.1$ RAD/SEC ($\ell_w = 2.5$ ft)

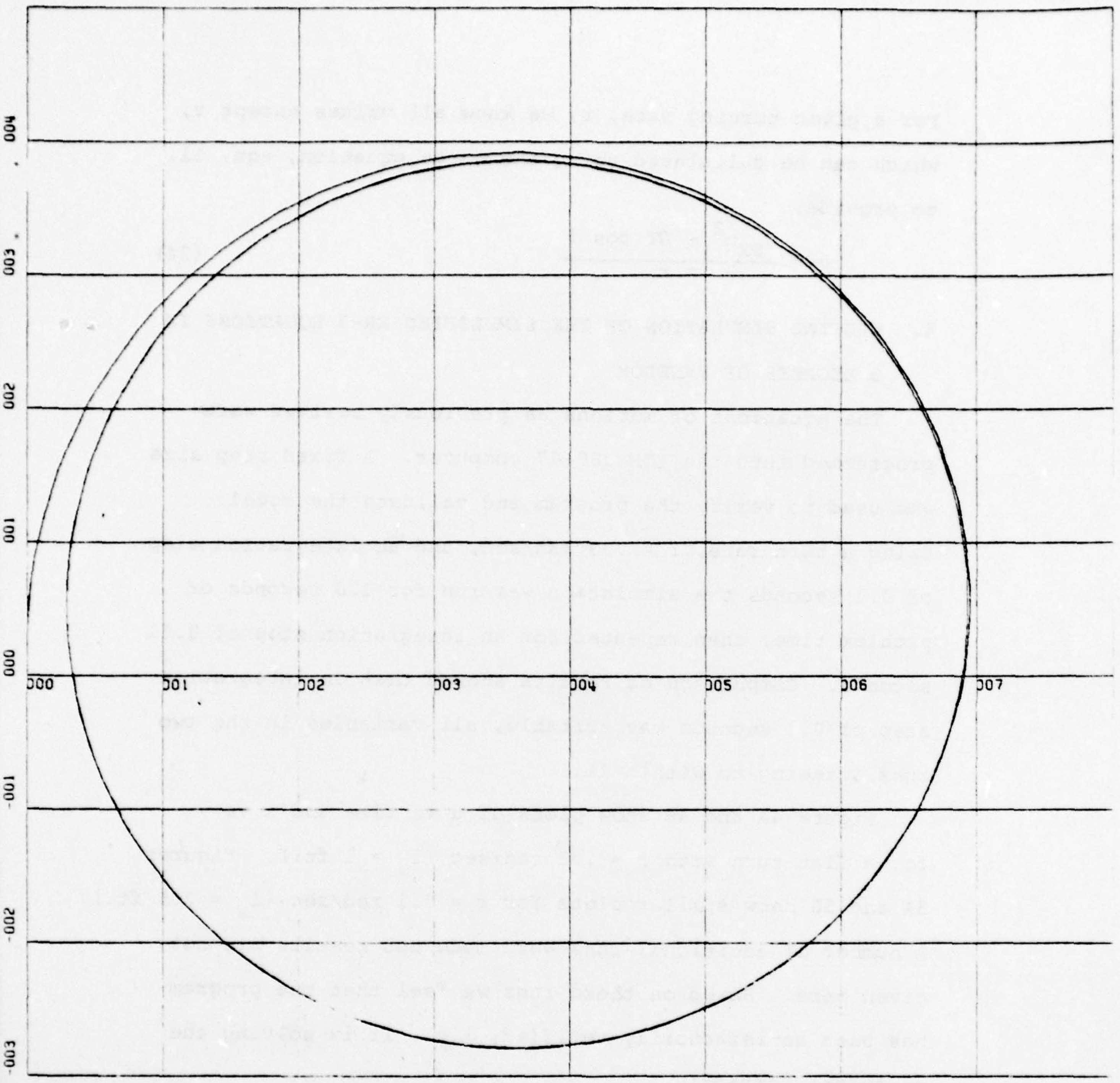


Figure 5-B FLAT TURN DYNAMICS OF THE XR-3, PLOT OF X vs. Y.
$r = 0.1$ RAD/SEC ($\ell_w = 2.5$ ft)

For a given turning rate, r, we know all values except v, which can be calculated using the surge equation, eqn. 11, to provide:

$$v = \frac{C_{DX}u^2 - GT \cos \delta}{m\ r} \tag{24}$$

4. DIGITAL SIMULATION OF THE SIMPLIFIED XR-3 EQUATIONS IN 3 DEGREES OF FREEDOM

The equations of motions as previously derived were programmed into the IBM 360/67 computer. A fixed step size was used to verify the program and validate the model. Using a turn rate, r = .33 rad/sec, and an integration step of 0.1 seconds the simulation was run for 120 seconds of problem time, then repeated for an integration step of 0.01 seconds. Comparison of results showed that an integration step of 0.1 seconds was suitable, all variables in the two runs agreeing to within 1%.

Figure 4A and 4B show plots of u vs time and x vs y for a flat turn with r = .33 rad/sec (l_ω = 1 ft.). Figures 5A and 5B show similar plots for r = 0.1 rad/sec (l_ω = 2.5 ft.). A number of additional runs were made but results are not given here. Based on these runs we feel that the program has been satisfactorily verified, i.e., it is solving the equations correctly.

The following observations seem appropriate:

1. Eqn. 22 and Fig. 3 are at least qualitatively correct.
2. The effect of added mass is neglegible.

3. We have gained confidence that, given the measured perfomance of any SES in an approximate flat turn, and given values for the parameters GT, δ, u, r, m and l_o, we can determine a value of l_ω which provides a simulation matching the measured performance reasonably closely.

4. If the simulation is performed with an initial step in the thrust angle, δ, approximate values for the system time constants can be evaluated from the resulting data. For the XR-3 operating in a flat turn the time constants are:

Variable	Time Constant
u	11.0 sec
v	0.8 sec
r	1.2 sec
β	0.9 sec

To validate the 3 DOF model, additional runs were made using the digital 6 DOF Oceanics program as modified by our NPS group for the XR-3. Also the 3 DOF model was run with 3K-SES data, and the 5 DOF model of the 3K-SES was run. For the XR-3 tests a step of rudder of 0.5 radians was suddenly applied with craft speed at 20 knots. For the 3K-SES tests and 11^o rudder was applied by ramping up for 1.0 second and holding at the 11^o value. Craft speed was 60 knots. Comarison of the 3 DOF, 6 DOF and 3 DOF Hybrid runs for the XR-3 is shown on Fig. 6. Correlation is not as bad as appears by inspection. Turning diameter and time for a 360^o turn are almost indentical. We presently attribute the differences to the fact that the 3 DOF model does not include

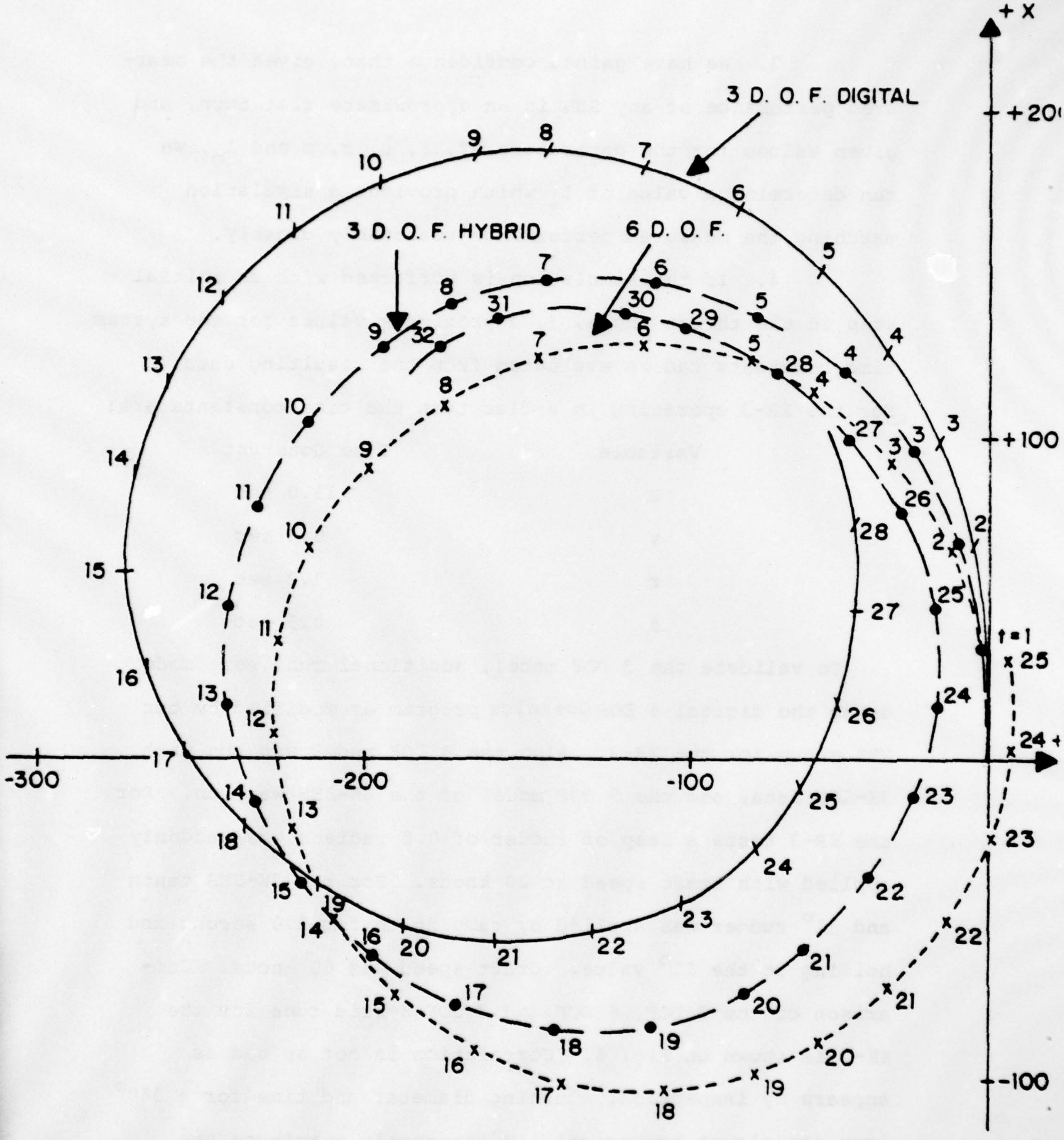


Figure 6. TURNING CHARACTERISTICS OF THE XR-3 RESPONSE TO LEFT RUDDER, 0.5 RADIAN STEP, 20 KNOTS.

a term for bubble drag.

Figure 7 compares the 3 DOF run with the 5 DOF run for the 3K-SES. The results are almost identical, despite simplifications in the 3 DOF. This gives confidence that our modelling technique will work well when we hybridize.

5. HYBRID SIMULATION OF THE 3 DEGREE OF FREEDOM MODEL OF THE XR-3

In developing a hybrid model various arrangements and structures (programming) are possible. The philosophy chosen for our initial hybrid model is shown in the block-flow diagram of Fig. 8. Details of the programming are given in Appendix A for the simplified XR-3 model.

The simplified XR-3 model was installed in the hybrid system and tested. Comparison of results with those obtained by digital simulation showed almost identical performance, differences being less than 2%.

In developing the hybrid simulation a major concern has been the amount of time delay introduced into the loop by the A/D and D/A conversions and by the time required to perform the digital computations. We have monitored these delays in the 3 DOF model with results as follows:

1. The fundamental loop delay using D/A for $\dot{u}$, $\dot{v}$, $\dot{r}$, x, y and A/D for u, v, r was 33 ms.
2. A lower language subroutine exists, called ADDA, which can be used to replace the Fortran subroutines for A/D and D/A. This can reduce the delay by 25%.

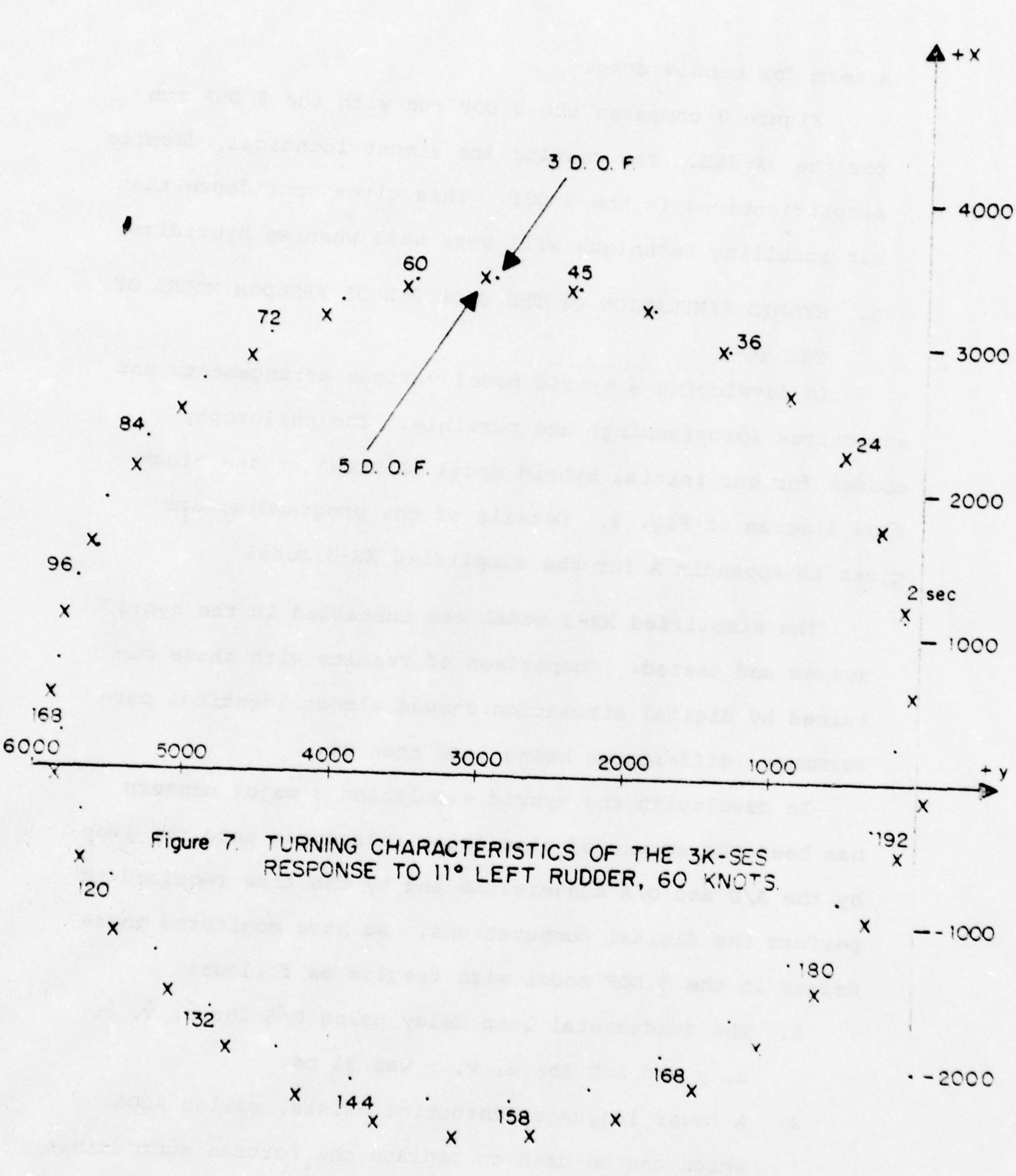


Figure 7. TURNING CHARACTERISTICS OF THE 3K-SES RESPONSE TO 11° LEFT RUDDER, 60 KNOTS.

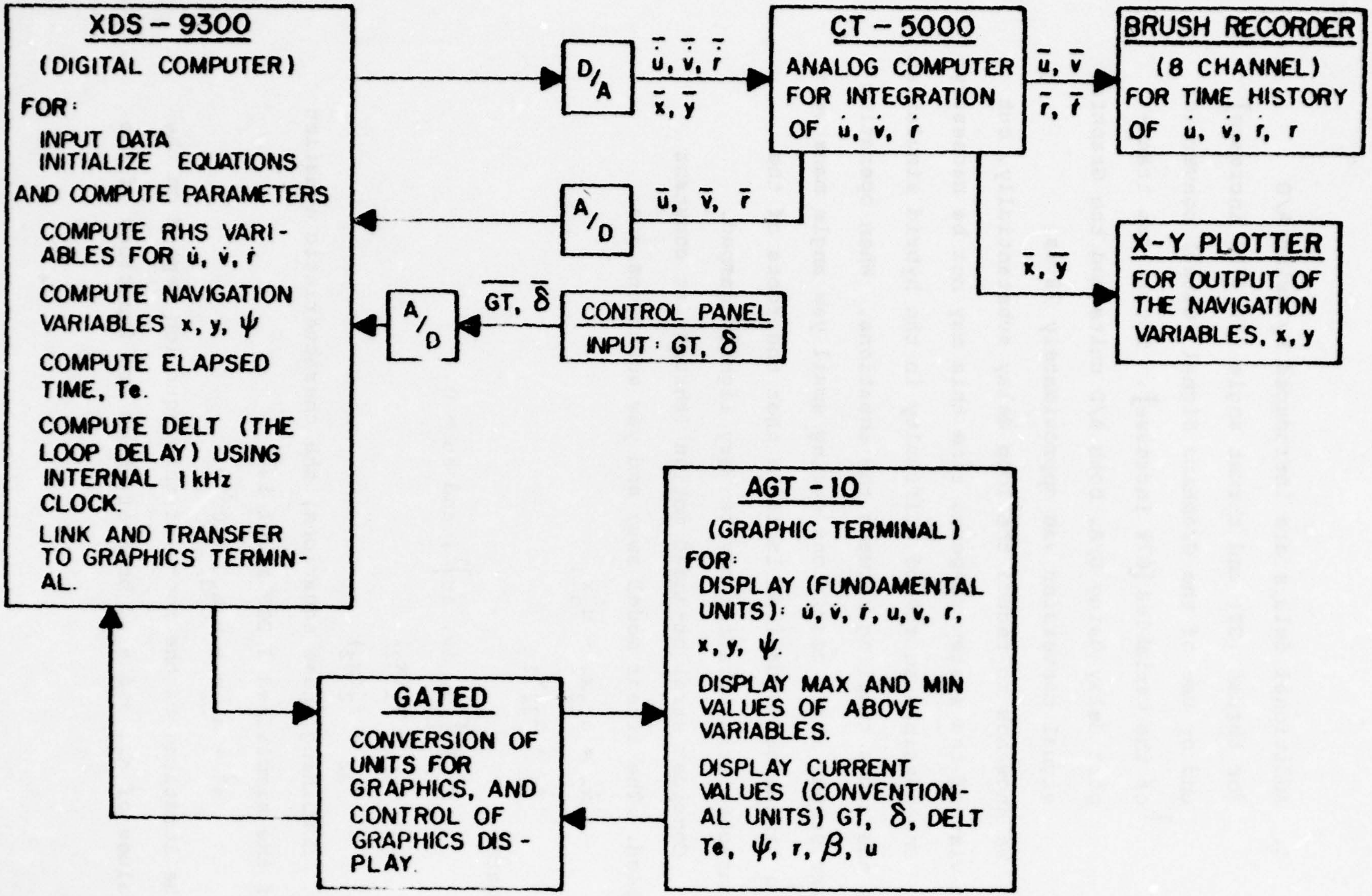


Figure 8. STRUCTURE FOR HYBRID SIMULATION OF 3 D.O.F. (FLAT) TURN EQUATIONS.

3. Additional delays are introduced by using A/D for thrust (GT) and thrust angle (δ) [76% increase] and by use of the Graphics Signal (Gated) conversion of the variables [67% increase]. Total loop transport delay using D/A, both A/D units and the Graphics signal conversion was approximately 78 ms.

We know how to reduce the loop delay substantially, but in view of the system response time this may not be necessary.

One possible source of difficulty in the hybrid simulation is the cross coupling between the equations. When operating near steady state conditions during small yaw angle maneuvers the linearized equations indicate that the roots of the characteristic equation may be very lightly damped.

Consider straight-ahead motion (thrust) at constant speed. The linear model sway and yaw equations are:

$$\dot{x}_2 = a_{22}x_2 - u_o x_3$$

$$\dot{x}_3 = a_{32}x_2$$

where

$$\underline{x} \triangleq \left[\Delta u,\ \Delta v,\ \Delta r\right]^T, \text{ and } \Delta u = 0$$

$$a_{22} = f_1(x_2)$$

$$a_{32} = f_2(x_2)$$

Combining these equations, the characteristic equation of the simplified 3 DOF model is

$$s^2 + a_{22}s + u_o a_{32} = 0$$

The locations of the roots of this equation depend on the values of a_{22} and a_{32}, both of which are functions of the sway velocity. For small values of sway velocity the roots are complex conjugates and approach the origin of the s-plane as the sway velocity approaches zero. For larger values of sway velocity such as those encountered in a turn maneuver the roots are real and negative, providing a well damped response for yaw and sway motions. This appears to be similar to the Dutch Roll effect in aircraft.

For straight ahead runs using the digital program for the 3 DOF model and setting the initial value of v to zero, no sway-yaw motions are observed. However, if we set a small initial condition on v a transient oscillation is observed in both sway and yaw as shown on Fig. 9. This verifies the existence of the phenomenon, and we expect to encounter it in the hybrid since the equations are the same. However, in the hybrid there is a possibility that the roots may move into the right half s-plane due to either:

1. DC unbalance in the analog computer integrators, or,
2. Excessive loop delay from A/D, D/A and digital computations.

The first of these possible causes can be avoided by careful balancing of the operational amplifiers before running. The effect of the loop delays can be controlled somewhat by minimizing the number of terms requiring digital computation.

6. STATUS OF THE 3 DOF MODEL STUDIES

These appear to be both complete and successful. Both

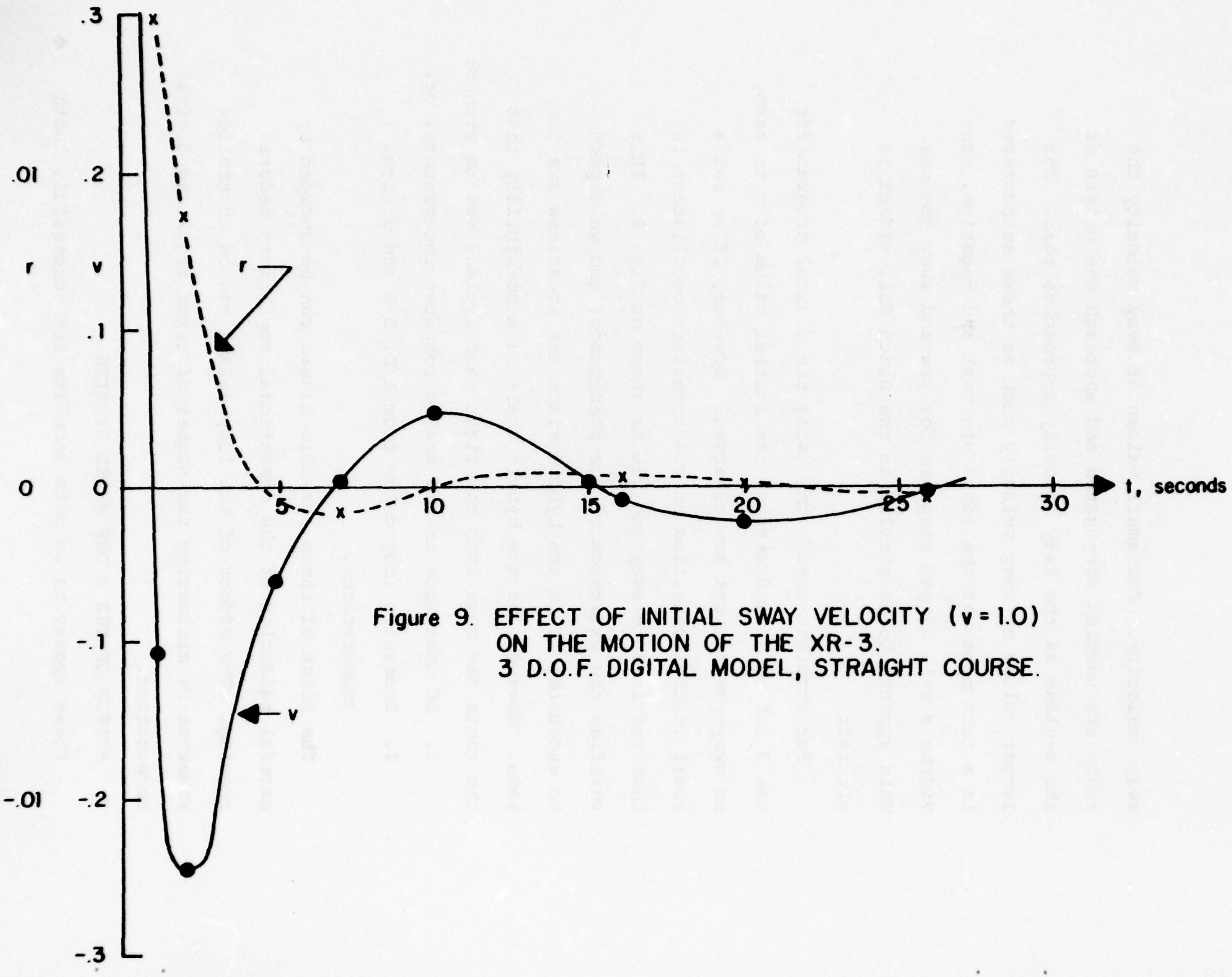


Figure 9. EFFECT OF INITIAL SWAY VELOCITY (v = 1.0) ON THE MOTION OF THE XR-3. 3 D.O.F. DIGITAL MODEL, STRAIGHT COURSE.

qualitative and quantitative agreement have been achieved with the 5 DOF digital simulation as a reference. Future studies will be aimed primarily at the 5 DOF model of the 3K-SES except when we wish to correlate computer data with specially designed experiments.

IIB. THE 5 DEGREE OF FREEDOM MODEL

1. INTRODUCTION

Having developed a simplified 3 DOF model of the XR-3, we now proceed to use the knowledge thus obtained and apply it to the 3K-SES. We do not plan to develop a 5 DOF hybrid model of the XR-3. Our procedure is to install the NSRDC 5 DOF program for the 3K-SES in our IBM 360/67 computer, generate reference curves with it, obtain any numbers we need for our 5 DOF hybrid simulation, then verify and validate the hybrid model of the 3K-SES.

2. THE DIGITAL SIMULATION OF THE 3K-SES IN 5 DEGREES OF FREEDOM

This program was obtained from NSRDC. It has been written for a CDC machine and had to be converted to the IBM version of Fortran for our computer. This has been completed, the program is operational and as far as we know has no obvious "bugs". We are familiarizing ourselves with the program, and exercising it to obtain data we will need in developing the 5 DOF hybrid model, and for validating it.

Details of the conversion-problems encountered, their solutions, etc. are discussed in Appendix B.

3. HYBRID SIMULATION OF THE 3K-SES

This is under development at the present time. Hopefully we need only insert a new set of constants in the equations of the hybrid XR-3 model, but undoubtedly other adjustments and modifications will be needed, particularily in the trade-off of digital vs analog computation in order to perform a real-time simulation.

4. STATUS

Progress has been satisfactory. It is too early to predict future developments.

III. SUMMARY AND CONCLUSIONS

[illegible]

The NPS Hybrid Computer consisting of the XDS-9300 digital and the CI 5000 analog computers has been programmed to simulate the 3 DOF Flat Turn maneuvering dynamics of the CAB type Surface Effect Ship.

The XR-3 has been programmed with simplified modelling of the drag forces and thrust-input force on the hybrid computer for simple flat turn maneuvers. An evaluation of the hybrid simulation was carried out by comparison of the time histories of the velocities and the navigation variables against those values obtained from the 3 DOF digital simulation for the same maneuvers. In addition, the XR-3 hybrid 3 DOF results were compared to the 6 DOF loads and motion output.

The result of this comparison was that the hybrid computer simulation produced a time response to a step rudder input that produced a navigational turning plot that was in-between the all digital 3 DOF and all digital 6 DOF trajectories.

Additionally the 3 DOF simplified RHS (right-hand-side) digital program was operated for the same turning conditions that was used for the 5 DOF, DBSIM5D Program and the comparison indicates close agreement in the navigational trajectories for an 11 degree vectored thrust angle full-turn maneuver.

This feasibility study has shown that the hybrid computer implementation for the 5 DOF 3K-SES in real-time is possible with the available equipment at the NPS Computer Laboratory. Real-time computation is of course only approximated when using the hybrid computer. The loop transport delay inherent in this simulation is due to the signal conversion (A to D and D to A) and the necessary digital computation for the acceleration forces and moments. The magnitude of this delay time has a fixed minimum value as a result of signal conversion and a maximum value due to righ-hand-side calculation required for the acceleration added to the fixed time due to the signal conversion. Real-time computation accuracy is determined principally by the magnitude of this maximum value for the loop delay.

The 3K-SES was approximated with the simplified 3 DOF Flat Turn equations and the results were compared. It was shown that the full maneuvering trajectories for an 11 degree thrust angle compared very closely with the 5 DOF, DBSIM5D Program results. These results indicate that only a few terms on the RHS may be all that are required to simulate the 3K-SES for the type of maneuvering control studies to be conducted in the future on the hybrid computer.

The conclusion of this feasibility study is that successful implementation of a hybrid computer, real-time simulation of the DBSIM5D Program has a very high probability. The degree of complexity necessary for the RHS computation will be the limiting factor on the loop delay that controls the real-time accuracy.

IV. LIST OF REFERENCES

1. E.H. Price, R.C. Stoner, V.L. Wener, Stability and Maneuverability Report, CDRL No. E03L, Document No. TTP0013A, Rohr Marine, Inc., Chula Vista, CA., 31 August 1978

APPENDIX A. HYBRID COMPUTER PROGRAM FOR THE 3 DOF (FLAT) TURN EQUATIONS

A general schematic diagram of the hybrid structure used is shown in Fig. A-1. The listing of the digital program for the XDS-9300 computer is also included in this appendix, and the analog computer connections are shown on Fig. A-2.

As may be seen from the listing of the digital program, the right-hand-sides (RHS) of the acceleration equations for the 3 DOF are computed on the XDS-9300, which also does the magnitude scaling for the analog computer (CI-500) voltages. In addition the XDS-9300 provides the required control logic, timing and temporary storage of computed variables.

The graphics terminal (AGT-10) provides real time display of the desired output and control variables, as well as their maximum and minimum values. Piloting of the craft is carried out at the graphics terminal. Additional permanent record outputs of navigation x and y are obtained with an XY-pen recorder, and plots of other system variables are obtained on an 8 channel Brush recorder.

A sample of the x-y output for the 3 DOF simplified XR-3 craft is shown on Fig. A-3. The plot starts with a right turn (δ = -0.5 radians) at t = 0, using a terminated ramp input. The rudder was held at δ = -0.5 for two turns, then reversed to δ = +0.5 for a half turn, followed by

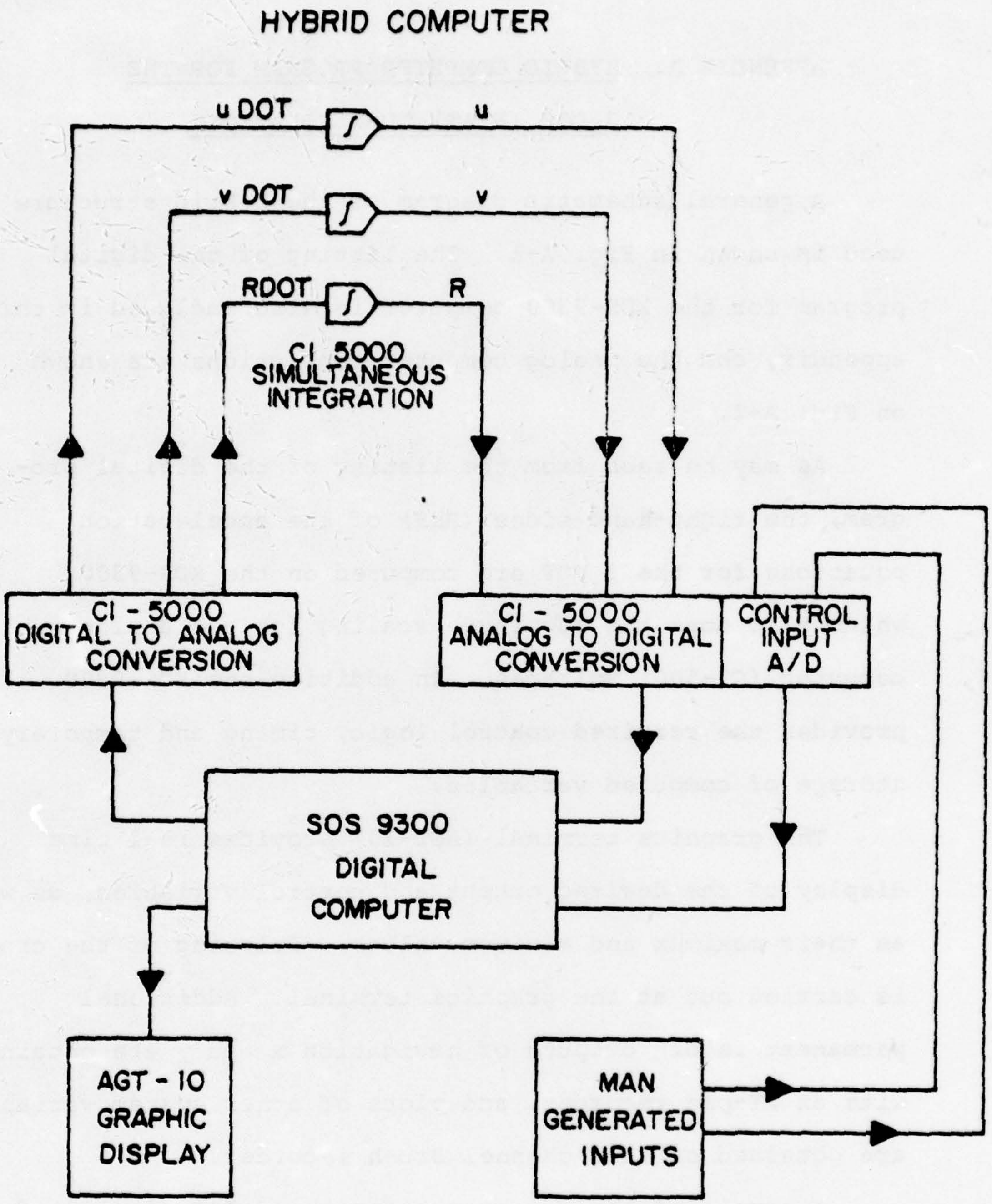


Figure A-1. BLOCK DIAGRAM OF THE HYBRID STRUCTURE.

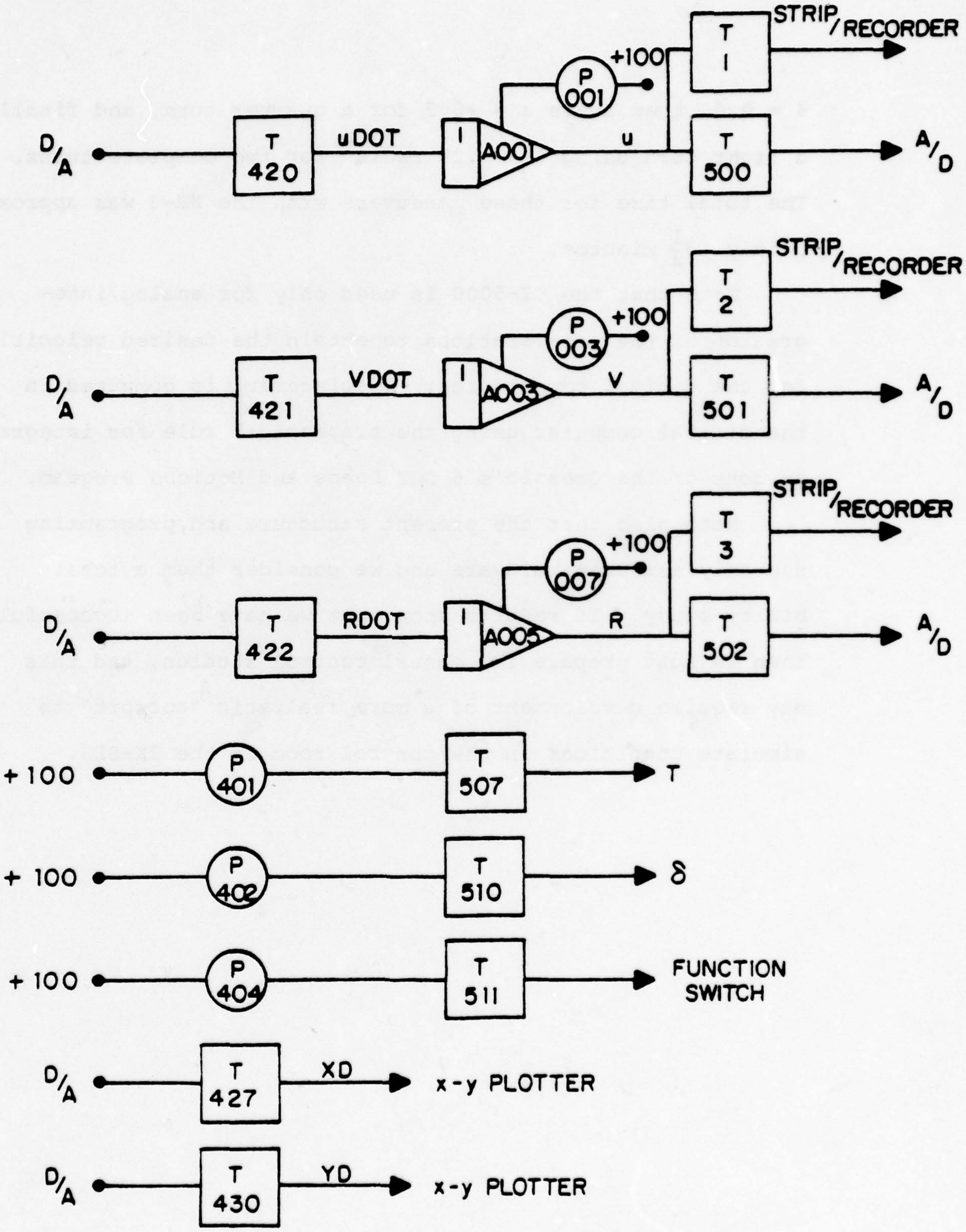


Figure A-2. DIAGRAM OF THE ANALOG COMPUTER CONNECTIONS.

$\delta = 0.0$, then again $\delta = +0.5$ for a quarter turn, and finally a right turn using $\delta = -.29$ radian for two complete turns. The total time for these maneuvers with the XR-3 was approximately $3\frac{1}{2}$ minutes.

Note that the CI-5000 is used only for analog integration of the accelerations to obtain the desired velocities for the digital computation. Displacement is computed in the digital computer using the trapezoidal rule for integration as done on the Oceanic's 6 DOF Loads and Motions Program.

Note also that the present structure and programming use only existing hardware and we consider them a feasibility study. If results show that we have been successful, then we must prepare for manual control studies, and this may require development of a more realistic "cockpit" to simulate conditions in the control room of the 3K-SES.

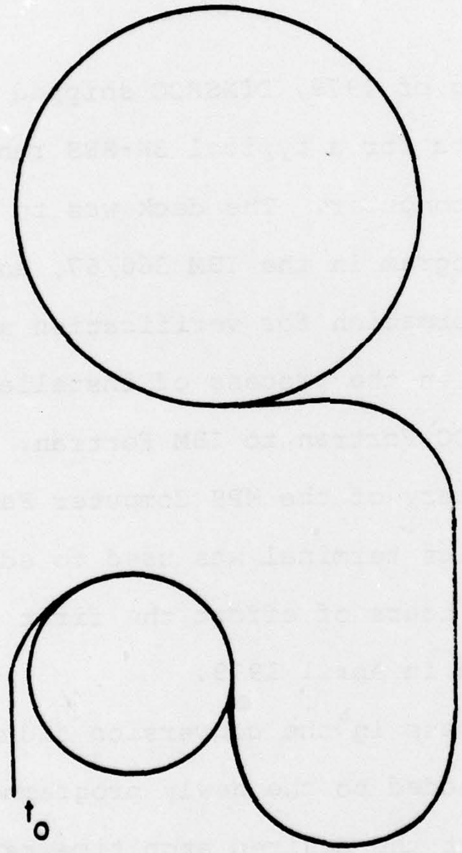


Figure A-3. SAMPLE OF THE HYBRID OUTPUT x-y PLOT FOR THE 3 D.O.F. XR-3

APPENDIX B. INSTALLATION OF THE 3K-SES, 5 DOF PROGRAM IN THE IBM 360/67 COMPUTER

In the fall of 1978 the 3K-SES, 5 DOF data based program called DBSIM5D was delivered to the Naval Postgraduate School, at which time a commitment was made by the NPS group to attempt a hybrid computer simulation based on this program.

In the spring of 1979, DTNSRDC shipped the card deck and the output data for a typical 3K-SES run, obtained by DTNSRDC on a CDC computer. The deck was to be used in installing the program in the IBM 360/67, and the output data provided information for verification and validation. The major problem in the process of installation was the conversion from CDC Fortran to IBM Fortran. With the help of Mr. Roger Hilleary of the NPS Computer Facility, the interactive graphics terminal was used to edit the program. After some 50 man hours of effort the first successful batch run was made in April 1979.

Complete success in the conversion did not occur until a correction was added to the newly programmed TIMER, to allow for a stop at the desired stop time rather than a premature stop time due to the timer program.

To validate the IBM version of the program we duplicated the sample run for the 3K-SES. This run, as provided by DTNSRDC, was for a left turn, using an 11 degree effector angle and a speed of 60 knots. The sample run terminated after 14.5 seconds of real (problem) time. The 11 degree effector angle was programmed as a ramp which terminated after 1 second, and remained constant at 11 degrees for an additional 50 seconds.

A comparison of the output of the IBM 360/67 version with the sample run data from the CDC computer showed that the recorded variables were in complete agreement within the accuracy differences of the two computer word length.

The problems of conversion were simple but time consuming and may be listed as follows:

1. 6 character variable name limit on the IBM computer as compared with a 7 character limit on the CDC.
2. Single statement limit on the IBM computer versus multiple statement on a single card for the CDC.
3. Identification of temporary files used for the output data.
4. Identification of the timing control and programming the IBM computer timer to provide the functions required for operation of the program.
5. Addition of the proper job control language (JCL) cards to compile, link and compute.

```
                                                                    DATE

FORTRAN LS,GO                                                          RT
      DIMENSION ITEXT(29),ILAP(24),POTS(24),PSTK(24),IMAGE(3000)
     C,IL(24),TITLE(24),AD(10),AA(12),ILA1(24),ILA2(24),ILA3(24),
     CILA4(24),ILA5(24),ILA6(24),ILA7(24),ILA8(24),IPLOT(10),IVIEWA(20),
     CIVIEWB(20)
      EQUIVALENCE (AD(1),A11),(AD(2),A21),(AD(3),A31),(AA(1),B11),
     C(AA(2),B21),(AA(3),B31),(AA(4),B41),(AA(5),B51),(AA(6),B55),
     C(AA(7),B61),(AA(8),B71),(AA(9),B81),(AA(10),B91),(AA(11),B101),
     C(AA(12),B111),(AD(4),A41),(AD(5),A51),(AD(6),A61),
     C(AD(7),A71),(AD(8),A81),(AD(9),A91),(AD(10),A101)
      CALL DAL(.0,.0,.0,.0,.0,.0,.0,.0,.0,.0,.0,.0)
      CALL SETPOT(4HP001,.0,4HP003,.0,4HP005,.0,4HP007,.0,4HP011,.0,
     C4HP015,.0)
      CALL RESET(1000)
      CALL COMPUTE
      CALL DGINIT(2,IVIEWA,20,IER)
      CALL DGINIT(2,IVIEWB,20,IER)
      CALL DGINIT(2,IPLOT,10,IER)
      CALL CTINIT(1,ITEXT,29,IER)
      ENCODE(96,1,TITLE0)
    1 FORMAT('              REAL TIME          ')
      CALL TEXTO(1,TITLE0,24,6,1,3,3,IER)
      ENCODE(96,2,TITLE1)
    2 FORMAT('     MOTION ANALYSIS PROGRAM     ')
      CALL TEXTO(1,TITLE1,24,9,1,3,3,IER)
      I=1000000
      CALL DELAY
      IVIEWB(1)=IHEAD(1,10)
      IVIEWB(2)=IPACK(0.0,1.0,0)
      IVIEWB(3)=IPACK(0.0,0.5,1)
      IVIEWB(4)=IPACK(-1.0,0.0,0)
      IVIEWB(5)=IPACK(-0.5,0.0,1)
      IVIEWB(6)=IPACK(0.5,0.0,0)
      IVIEWB(7)=IPACK(1.0,0.0,1)
      IVIEWB(8)=IPACK(0.75,1.0,0)
      IVIEWB(9)=IPACK(0.75,0.5,1)
      IVIEWB(10)=IPACK(0.5,0.75,0)
      IVIEWB(11)=IPACK(1.0,0.75,1)
      IVIEWB(12)=0
      CALL GRAPHO(2,IVIEWB,12,1,IER)
      IPR=0
      ICOA=0
      ICO=0
      NDA=12
      NAD=10
      IN=0
      X=-100.
      TIME=0.0
      AAAA=0.
      P=0.0
      G=0.0
      RHO=2.0
```

```
      G=32.2
      M=180.
      CDX=.3
      CDY=1555.0
      LW=1.0
      LØ=10.
      J=1
      IZ=8333.
      A22=1.0
      AU=.45
      AUDØT=.45
      AV=.020
      AVDØT=.020
      AR=0.0100
      ARDØT=0.0100
      AX0=25.
      AY0=25.
      AT=3.75
      AZ=.005
      IQG=0
      TX=0.0
      TY=-6000.
  650 CALL DTINIT(1,ITEXT,29,IER)
  501 FØRMAT('PRESENT',2F10.2,'          ',F4.2,'     ',F8.2,'              ',F6.3,
     C'          ',F6.3)
  525 FØRMAT('MAXIMUM',2F10.2,'          ',F4.2,'     ',F8.2,'              ',F6.3,
     C'          ',F6.3)
  526 FØRMAT('MINIMUM',2F10.2,'          ',F4.2,'     ',F8.2,'              ',F6.3,
     C'          ',F6.3)
  507 FØRMAT('PRESENT',F8.2,F10.3,'              ',F4.2,' ',F8.3,'                 ',
     CF5.3,'          ',F5.3)
  527 FØRMAT('MAXIMUM',F8.2,F10.3,'              ',F4.2,' ',F8.3,'                 ',
     CF5.3,'          ',F5.3)
  528 FØRMAT('MINIMUM',F8.2,F10.3,'              ',F4.2,' ',F8.3,'                 ',
     CF5.3,'          ',F5.3)
  511 FØRMAT('PRESENT',F7.3,F10.3,'    ',F10.2,'    ',F8.3,'          ',F6.3,'
     C    ',F6.3)
  529 FØRMAT('MAXIMUM',F7.3,F10.3,'    ',F10.2,'    ',F8.3,'          ',F6.3,'
     C    ',F6.3)
  530 FØRMAT('MINIMUM',F7.3,F10.3,'    ',F10.2,'    ',F8.3,'          ',F6.3,'
     C    ',F6.3)
  516 FØRMAT(F6.2,'    ',F4.2,'              ',F4.3,'    ',F6.2,'          ',F5.3,'
     C    ',F7.2,'/',F5.1,'  ',F5.2,'  ',F5.2,'  ',F5.2)
      ENCØDE(96,500,ILA1)
  500 FØRMAT('                                          PØSITIØN')
      CALL TEXTØ(1,ILA1,24,3,1,1,3,IER)
      IF(IER.NE.0)ØUTPUT(101) IER, '    PØSITIØN'
      ENCØDE(96,502,ILA2)
  502 FØRMAT('               X            Y            ZZ          PSI
     CPHI          THETA')
      CALL TEXTØ(1,ILA2,24,4,1,1,3,IER)
      ENCØDE(96,505,ILA3)
  505 FØRMAT('                                          VELØCITY')
```

```
      CALL TEXTO(1,ILA3,24,11,1,1,3,IER)
      IF(IER.NE.0)OUTPUT(101) IER, '   VELOCITY'
      ENCODE(96,517,ILA4)
  517 FORMAT('                  U            V             W           R
     CP             Q')
      CALL TEXTO(1,ILA4,24,12,1,1,3,IER)
      IF(IER.NE.0)OUTPUT(101) IER, '    LIST VAR VELOCITY'
      ENCODE(96,509,ILA5)
  509 FORMAT('                                          ACCELERATION')
      CALL TEXTO(1,ILA5,24,19,1,1,3,IER)
      IF(IER.NE.0)OUTPUT(101) IER, '   ACCEL TITLE'
      ENCODE(96,512,ILA6)
  512 FORMAT('                UDOT         VDOT          WDOT       RDOT        PD
     COT      QDOT')
      CALL TEXTO(1,ILA6,24,20,1,1,3,IER)
      IF(IER.NE.0)OUTPUT(101) IER, '     ACCEL VAR'
      ENCODE(96,514,ILA7)
  514 FORMAT(' CONTROL INPUTS           TIME                        NAV
     CIGATION DATA')
      CALL TEXTO(1,ILA7,24,27,1,1,3,IER)
      IF(IER.NE.0)OUTPUT(101) IER, '   CONTROL HEADING'
      ENCODE(96,515,ILA8)
  515 FORMAT('THRUST   RUDDER      DELT   ELAPSED      PITCH   HEADING/R
     CATE   DRIFT   ROLL   SPEED')
      CALL TEXTO(1,ILA8,24,28,1,1,3,IER)
      IF(IER.NE.0)OUTPUT(101) IER, '    SUB LABEL CONTROL'
      CALL WRITECLOCK(0)
      CALL STARTCLOCK
  101 CONTINUE
      CALL ADDA(AD,NAD,AA,NDA)
      CALL READCLOCK(N)
      CALL WRITECLOCK(0)
      X1=PSI/6.283185
      IX=X1
      AIX=X1-IX
      IF(AIX.LT.0.0)GO TO 10
      HEAD=AIX*360.
      GO TO 11
   10 AIX1=1.+AIX
      HEAD=AIX1*360.
   11 CONTINUE
      ARATE=(360.*R)/6.283185
      AROLL=(360.*PHI)/6.283185
      APITCH=(360.*THETA)/6.283185
      SPEED=U*.597213
      IF(H1.GT.XO)GO TO 700
      H1=XO
  700 IF(H2.GT.YO)GO TO 701
      H2=YO
  701 IF(H3.GT.ZZ)GO TO 702
      H3=ZZ
  702 IF(H4.GT.PSI)GO TO 703
      H4=PSI
```

```
703 IF(H5.GT.PHI)GO TO 704
    H5=PHI
704 IF(H6.GT.THETA)GO TO 705
    H6=THETA
705 IF(H7.GT.U)GO TO 706
    H7=U
706 IF(H8.GT.V)GO TO 707
    H8=V
707 IF(H9.GT.W)GO TO 708
    H9=W
708 IF(H10.GT.R)GO TO 709
    H10=R
709 IF(H11.GT.P)GO TO 710
    H11=P
710 IF(H12.GT.Q)GO TO 711
    H12=Q
711 IF(H13.GT.UDOT)GO TO 712
    H13=UDOT
712 IF(H14.GT.VDOT)GO TO 713
    H14=VDOT
713 IF(H15.GT.WDOT)GO TO 714
    H15=WDOT
714 IF(H16.GT.RDOT)GO TO 715
    H16=RDOT
715 IF(H17.GT.PDOT)GO TO 716
    H17=PDOT
716 IF(H18.GT.QDOT)GO TO 718
    H18=QDOT
718 IF(H30.LT.X0)GO TO 719
    H30=X0
719 IF(H31.LT.Y0)GO TO 720
    H31=Y0
720 IF(H32.LT.ZZ)GO TO 721
    H32=ZZ
721 IF(H33.LT.PSI)GO TO 722
    H33=PSI
722 IF(H34.LT.PHI)GO TO 723
    H34=PHI
723 IF(H35.LT.THETA)GO TO 724
    H35=THETA
724 IF(H36.LT.U)GO TO 725
    H36=U
725 IF(H37.LT.V)GO TO 726
    H37=V
726 IF(H38.LT.W)GO TO 727
    H38=W
727 IF(H39.LT.R)GO TO 728
    H39=R
728 IF(H40.LT.P)GO TO 729
    H40=P
729 IF(H41.LT.Q)GO TO 730
    H41=Q
730 IF(H42.LT.UDOT)GO TO 731
```

```
      H42=UDØT
  731 IF(H43.LT.VDØT)GØ TØ 732
      H43=VDØT
  732 IF(H44.LT.WDØT)GØ TØ 733
      H44=WDØT
  733 IF(H45.LT.RDØT)GØ TØ 734
      H45=RDØT
  734 IF(H46.LT.PDØT)GØ TØ 735
      H46=PDØT
  735 IF(H47.LT.QDØT)GØ TØ 736
      H47=QDØT
  736 CØNTINUE
      DELT=(DELT+(N/60.))/2.
      TIME=TIME+DELT
  651 Z=-0.5+A91
      IF(Z.GT..5)GØ TØ 790
      IF(Z.LT.-.5)GØ TØ 791
      IF(Z.GT..005)GØ TØ 792
      IF(Z.LT.-.005)GØ TØ 792
      Z=0.0
      GØ TØ 792
  790 Z=.5
      GØ TØ 792
  791 Z=-.5
      GØ TØ 792
  792 CØNTINUE
      T=AT*A81*100.
      IF(T.GT.375.)GØ TØ 793
      IF(T.LT.0.0)GØ TØ 794
      GØ TØ 795
  793 T=375.
      GØ TØ 795
  794 T=0.0
      GØ TØ 795
  795 CØNTINUE
  998 CØNTINUE
      PAAP=00.20*SIN(PSI)
      PHI=R
      THETA=UDØT
      W=PAAP
      P=PAAP
      Q=PAAP
      WDØT=PAAP
      PDØT=PAAP
      QDØT=PAAP
      U=A11*X*AU
      V=A21*X*AV
      R=A31*X*AR
      UDØT=((-1.)*(CDX/180.)*U*J)+((T/180.)*CØS(Z))+V*R
      VDØT=((T/M)*SIN(Z))-((CDY/M)*V*ABS(V))-J*R
      RDØT=((CDY/IZ)*LW*V*ABS(V))-((T/IZ)*LØ*SIN(Z))+(A22*J*V*(LW/IZ))
      BETA=ATAN(V/U)
      VS=((U*U)+(V*V))**.5
```

```
      PSI=PSI+DELT*R
      X0DOT=U*COS(PSI)-V*SIN(PSI)
      Y0DOT=U*SIN(PSI)+V*COS(PSI)
      X0=X0+DELT*X0DOT
      Y0=Y0+DELT*Y0DOT
      B11=UDOT/(AUDOT*100.)
      B21=VDOT/(AVDOT*100.)
      B31=RDOT/(ARDOT*100.)
      B71=X0/(AX0*100.)
      B81=Y0/(AY0*100.)
      IF(SENSE SWITCH 1)102,105
 102  CALL HOLD
      CALL STOPCLOCK
      WRITE(6,100)LR,JD,TTD,TD,TBEAR,HEAD,ATVECD,CCC,TVEC
 100  FORMAT(9F9.4)
      CALL STARTCLOCK
      CALL COMPUTE
 105  CONTINUE
      IF(A101.GT.-0.5)GO TO 101
      ICO=ICO+1
      IF(ICO.EQ.1)GO TO 653
      IF(ICO.EQ.8)GO TO 653
      IF(ICO.EQ.15)GO TO 653
      IF(ICO.EQ.22)GO TO 653
      IF(ICO.EQ.29)GO TO 653
      IF(ICO.EQ.36)GO TO 653
      GO TO 107
  653 ENCODE(96,501,ILAP)Y0,X0,ZZ,PSI,PHI,THETA
  600 CALL TEXTO(1,ILAP,24,6,1,1,3,IER)
      IF(IER.NE.0)OUTPUT(101) IER, '     PRESENT'
  107 IF(ICO.EQ.5)GO TO 108
      GO TO 109
  108 ENCODE(96,525,ILAP)H2,H1,H3,H4,H5,H6
      CALL TEXTO(1,ILAP,24,8,1,1,3,IER)
  109 IF(ICO.EQ.10)GO TO 110
      GO TO 111
  110 ENCODE(96,526,ILAP)H31,H30,H32,H33,H34,H35
      CALL TEXTO(1,ILAP,24,9,1,1,3,IER)
  111 IF(ICO.EQ.2)GO TO 601
      IF(ICO.EQ.9)GO TO 601
      IF(ICO.EQ.16)GO TO 601
      IF(ICO.EQ.23)GO TO 601
      IF(ICO.EQ.30)GO TO 601
      IF(ICO.EQ.37)GO TO 601
      GO TO 112
  601 ENCODE(96,507,ILAP)U,V,W,R,P,Q
      CALL TEXTO(1,ILAP,24,14,1,1,3,IER)
  112 IF(ICO.EQ.15)GO TO 113
      GO TO 114
  113 ENCODE(96,527,ILAP)H7,H8,H9,H10,H11,H12
      CALL TEXTO(1,ILAP,24,16,1,1,3,IER)
  114 IF(ICO.EQ.20)GO TO 115
      GO TO 116
```

```
 115 ENCØDE(96,528,ILAP)H36,H37,H38,H39,H40,H41
     CALL TEXTØ(1,ILAP,24,17,1,1,3,IER)
 116 IF(ICØ.EQ.3)GØ TØ 604
     IF(ICØ.EQ.10)GØ TØ 604
     IF(ICØ.EQ.17)GØ TØ 604
     IF(ICØ.EQ.24)GØ TØ 604
     IF(ICØ.EQ.31)GØ TØ 604
     IF(ICØ.EQ.38)GØ TØ 604
     GØ TØ 117
 604 ENCØDE(96,511,ILAP)UDØT,VDØT,WDØT,RDØT,PDØT,QDØT
     CALL TEXTØ(1,ILAP,24,22,1,1,3,IER)
 117 IF(ICØ.EQ.25)GØ TØ 118
     GØ TØ 119
 118 ENCØDE(96,529,ILAP)H13,H14,H15,H16,H17,H18
     CALL TEXTØ(1,ILAP,24,24,1,1,3,IER)
 119 IF(ICØ.EQ.30)GØ TØ 120
     GØ TØ 121
 120 ENCØDE(96,530,ILAP)H42,H43,H44,H45,H46,H47
     CALL TEXTØ(1,ILAP,24,25,1,1,3,IER)
 121 IF(ICØ.EQ.4)GØ TØ 602
     IF(ICØ.EQ.11)GØ TØ 602
     IF(ICØ.EQ.18)GØ TØ 602
     IF(ICØ.EQ.25)GØ TØ 602
     IF(ICØ.EQ.32)GØ TØ 602
     IF(ICØ.EQ.39)GØ TØ 602
     GØ TØ 923
 602 ENCØDE(96,516,ILAP)T,Z,DELT,TIME,APITCH,HEAD,ARATE,BETA,ARØLL,SPEE
    CD
     CALL TEXTØ(1,ILAP,24,30,1,1,3,IER)
 923 IF(A101.GT.-0.90)GØ TØ 924
     U=0.
     V=0.
     W=0.
     R=0.
     P=0.
     Q=0.
     X0=0.
     Y0=0.
     ZZ=0.
     PSI=0.
     PHI=0.
     THETA=0.
     UDØT=0.
     VDØT=0.
     WDØT=0.
     RDØT=0.
     PDØT=0.
     QDØT=0.
     TIME=0.
     H1=0.
     H2=0.
     H3=0.
     H4=0.
```

```
      H5=0.
      H6=0.
      H7=0.
      H8=0.
      H9=0.
      H10=0.
      H11=0.
      H12=0.
      H13=0.
      H14=0.
      H15=0.
      H16=0.
      H17=0.
      H18=0.
      H30=0.
      H31=0.
      H32=0.
      H33=0.
      H34=0.
      H35=0.
      H36=0.
      H37=0.
      H38=0.
      H39=0.
      H40=0.
      H41=0.
      H42=0.
      H43=0.
      H44=0.
      H45=0.
      H46=0.
      H47=0.
  924 CØNTINUE
      IF(ICØ.EQ.5)GØ TØ 603
      IF(ICØ.EQ.12)GØ TØ 603
      IF(ICØ.EQ.19)GØ TØ 603
      IF(ICØ.EQ.26)GØ TØ 603
      IF(ICØ.EQ.33)GØ TØ 603
      IF(ICØ.EQ.40)GØ TØ 603
      GØ TØ 610
  603 CØNTINUE
  58  CØNTINUE
      X1X=.45*CØS(PHI)
      Y1Y=.45*SIN(PHI)
      X1XA=(2.5*R)+X1X
      X11=2.5*R
      Y1YA=THETA-Y1Y
      X1XB=(2.5*R)-X1X
      Y1YB=THETA+Y1Y
      X1XC=(2.5*R)+(0.1*SIN(PHI))
      Y1YC=THETA+(0.1*CØS(PHI))
      ICØA=ICØA+1+(1.*U)+(10.*(ICØA/514.))
      Y1YD=(ICØA/514.)*(-1.0)+(THETA)-0.1*
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      Y1YE=(ICØA/514.)*(-1.0)+(THETA)-0.14
      X1XD=(X1XB-0.05)-((ICØA/514.)*0.2)
      X1XE=X1XB-0.05
      X1XF=X1XA+0.05
      X1XG=(X1XA+0.05)+((ICØA/514.)*0.2)
      Y1YR=Y1YA-0.14
      Y1YL=Y1YB-0.14
      H=(0.2/CØS(PHI))
      H1=H*SIN(PHI)
      Y1YEE=Y1YE-(ICØA/2700.)
      REARA1=-0.5
      REARA2=-0.5+Y1Y
      REARB1=-0.5
      REARB2=-0.6++Y1Y
      REARC1=0.5
      REARC2=-0.5-Y1Y
      REARD1=0.5
      REARD2=-0.64-Y1Y
65    SESX=0.75+(YC/5000.)
      SESY=0.75+(XC/5000.)
      IF(Y1YE.GT.-0.6)GØ TØ 59
      ICØA=0
59    CØNTINUE
      IVIEWA(1)=IHEAD(0,10)
      IVIEWA(2)=IPACK(REARA1,REARA2,0)
      IVIEWA(3)=IPACK(X1XB,Y1YB,1)
      IVIEWA(4)=IPACK(X1XA,Y1YA,1)
      IVIEWA(5)=IPACK(REARC1,REARC2,1)
      IVIEWA(6)=IPACK(REARA1,REARA2,1)
      IVIEWA(7)=IPACK(REARB1,REARB2,1)
      IVIEWA(8)=IPACK(REARD1,REARD2,1)
      IVIEWA(9)=IPACK(REARC1,REARC2,1)
      IF(R.GT..02)GØ TØ 50
      IF(R.LT.-.02)GØ TØ 51
      IVIEWA(10)=IPACK(X1XD,Y1YEE,0)
      IVIEWA(11)=IPACK(X1XE,Y1YE,1)
      IVIEWA(12)=IPACK(X1XF,Y1YE,0)
      IVIEWA(13)=IPACK(X1XG,Y1YEE,1)
      IVIEWA(14)=IPACK(0.0,0.0,0)
      GØ TØ 55
50    IVIEWA(10)=IPACK(X1XA,Y1YA,0)
      IVIEWA(11)=IPACK(X1XA,Y1YR,1)
      IVIEWA(12)=IPACK(REARD1,REARD2,1)
      IVIEWA(13)=IPACK(X1XF,Y1YE,0)
      IVIEWA(14)=IPACK(X1XG,Y1YEE,1)
      GØ TØ 55
51    IVIEWA(10)=IPACK(X1XB,Y1YB,0)
      IVIEWA(11)=IPACK(X1XB,Y1YL,1)
      IVIEWA(12)=IPACK(REARB1,REARB2,1)
      IVIEWA(13)=IPACK(X1XE,Y1YE,0)
      IVIEWA(14)=IPACK(X1XD,Y1YEE,1)
      GØ TØ 55
55    CØNTINUE
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DATE

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      IVIEWA(15)=IPACK(SESX,SESY,0)
      IVIEWA(16)=IPACK(SESX,SESY,1)
      IVIEWA(17)=0
      CALL GRAPHØ(2,IVIEWA,17,2,IER)
  610 IF(ICØ.LE.40)GØ TØ 101
      ICØ=0
      GØ TØ 101
      END
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