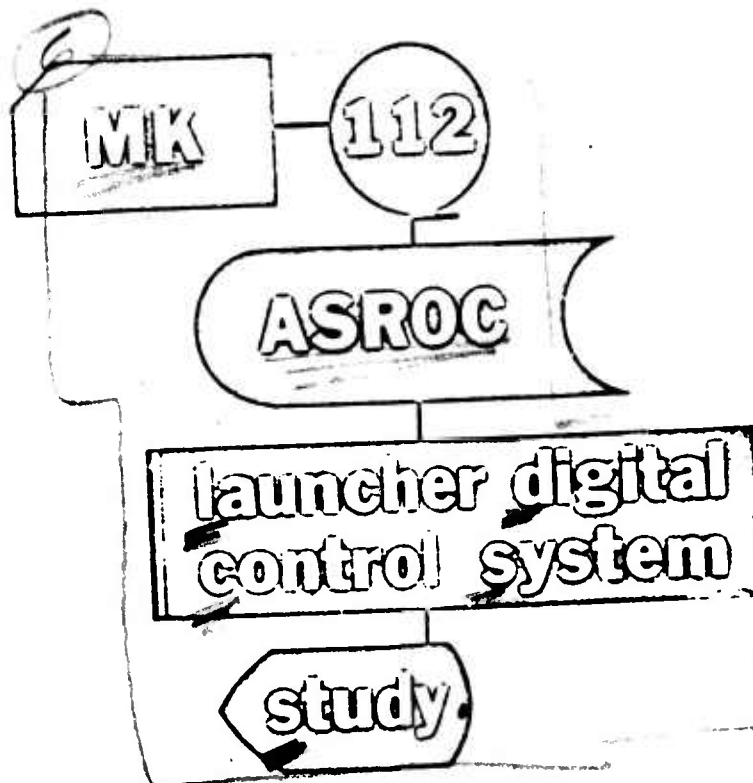


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10 D. L. Buck, D. W. Doherty, and R. W. Nowli
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PART 1

COMPUTER PROGRAM SPECIFICATIONS, GENERAL

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1.0 PURPOSE

This study of the MK 112 ASROC Launcher Digital Control System* developed at the Naval Electronics Laboratory Center (NELC) is intended for use by agencies and personnel concerned with the development of digital fire-control techniques. The program documented herein does not in any sense furnish an operational entity, but does demonstrate the feasibility of launcher control by digital techniques and forms a basis from which the launcher control portion of an operational program can be developed. The program is designed to exercise both train and elevation functions simultaneously.

2.0 SCOPE

This volume comprises a comprehensive description of the computer program designed, implemented, and tested by NELC. For convenience of use, all specifications pertinent to the program have been compiled within this volume.

Parts 1 to 6 contain all information pertinent to each of the respective program areas. As a prerequisite for fully understanding the material contained in this volume, the reader should be familiar with the UNIVAC Type 1218 (CP 789) Digital Computer and Trim II (field-data code) programming language. Reference to applicable documents concerning the computer and the Trim II language is made in Section 4.0, Part I.

2.1 Computer Program Performance Specifications

Part 2 describes the design of parameters for the computer program in terms of performance criteria and hardware constraints. It also contains a comprehensive description of the simulation techniques employed in creating an artificial launcher environment that parallels as closely as possible the operational environment.

*Prepared by the Naval Electronics Laboratory Center, Code S360, in support of the Antisubmarine Warfare Project Office (ASWPO 202). This task was directed under 634-02-42 S31-03 10572, NELC Task N201.

2.2 Computer Program Design Specifications

Part 3 defines the program design and contains a detailed description of the overall program and individual routines. Also included is a complete set of flow diagrams. Section 5, Part 3, includes a printed output listing of the complete program.

2.3 Computer Program Operator's Manual

Part 4 provides complete instructions for program operation. It presumes a basic knowledge of the Type 1218 Digital Computer and familiarity with its operating controls.

2.4 Computer Program Test Plan

Part 5 presents a plan for testing the computer program.

2.5 Computer Program Test Specification

Part 6 describes the detailed requirements and parameters of the program test as conducted at the Naval Nuclear Weapons Training Center Pacific (NWTCP) during the period 10 July 1968 to 28 August 1968. Also included in Part 6 is a comprehensive description of the hardware and equipment employed in the tests.

3.0 APPLICABILITY

This volume is applicable to organizations and personnel concerned with the development and implementation of computer programs for weapons controlled by digital techniques.

4.0 REFERENCE DOCUMENTS

The following documents contain reference material applicable to the content of this volume.

- a. NAVWEPS OD 14430, "Factory Acceptance Test Power Drive MK 61 and MK 62, Power Amplifier MK 153 "
- b. Naval Underwater Weapons Research and Engineering Station TM 379, *Operational Tests of the ASROC Launcher MK 112 with Simulated ASROC and ERA Missile Loads*, by W. B. Cullison, CONFIDENTIAL, November 1966
- c. Naval Electronics Laboratory Center Drawing RAAC 340.1-2230, *Encoder-Synchro Assembly*, March 1968
- d. Univac PX 2526, 4 vols., *Technical Manual For Type 1218 Digital Data Computer*, May 1964
- e. Naval Ordnance Systems Command WS-8506, *Requirements For Digital Computer Program Documentation*, 15 December 1966
- f. Bureau of Ordnance Drawing LD 541510, *ASROC Weapon System FCG Mk 111 Functional Schematics For DD 710 Class Ships*, 28 June 1961
- g. Univac PX 2910, Revision A, *Programmers Reference Manual for UNIVAC 1218 Computer*, December 1963
- h. Bureau of Ships NavShips 94093(A), v.2, *Technical Manual For Digital Data Converter CV-1123/USQ-20(V)*, Section 8, v.2, 14 June 1963
- i. Naval Electronics Laboratory Center, *Computer Program Performance Specifications For the MK 112 ASROC Launcher*, by D. L. Buck, 28 June 1968

j. Bureau of Weapons NavWeps OP 2385, v.2 (Revision 1, Change 2), *Launching Group MK 16 Mods 1, 2, 3 and 4, Train Power Drive MK 61 Mod 0 and 1, Elevation Power Drive MK 62 Mods 0 and 1, and Power Drive Amplifier MK 153 Mod 0 Amplifier Chassis; Description and Maintenance*, 14 May 1965

k. Navy Electronics Laboratory Report 1354, *Digital Control of the Guided Missile Launching System MK 13*, by J. B. Slaughter and D. W. Doherty, CONFIDENTIAL, 11 February 1966

l. Naval Underwater Weapons Research and Engineering Station TM 392, *Development of a Linear Math Model For the ASROC Launcher MK 112 Power Drives*, by E. W. Wilbur, April 1968

5.0 EXPLANATION OF TERMS

Paragraphs 5.1 through 5.9 define the terms and equipment names referred to in the specifications contained in this volume. Since the terms are not unique, the explanations given here will clarify their usage in this study.

5.1 Executive

The Executive is the overall control routine for the program. This routine, as a function of manual selection on the Command Selector Control Panel, initializes the program and calls each routine in its proper sequence.

5.2 Launcher Order

The Launcher Order is a driving function, as opposed to Launcher Position. The order implies physical movement of the launcher to a new position.

5.3 Launcher Position

The Launcher Position is the actual position as measured by a position feedback device.

5.4 Loop Error

The Loop Error is defined as the difference, in degrees, between the actual Launcher Position and the ordered position.

5.5 Program

The term "Program" refers to the entire group of routines that have been assembled to demonstrate the feasibility of digital launcher control.

5.6 Program Initialization

The Program Initialization is the procedure by which program operation is started, including table generation. Once initialized, the program will cycle in response to inputs from the Command Selector Control Panel.

5.7 Command Selector Control Panel

The Command Selector Control Panel is a special-purpose panel that provides a means of introducing simulated fire-control-system inputs to the program.

5.8 Routine

This item, "Routine," describes an entity that in a larger program might be termed a subprogram.

5.9 Symbology

Certain symbols are employed to identify various fire-control positions and functions. The following symbols will be used:

Bdg'	=	Launcher train position
Edg'	=	Launcher elevation position
$Bdg'l'$	=	Launcher train order
$Edg'l'$	=	Launcher elevation order
$DBdg'$	=	Launcher train rate (velocity)
$DEdg'$	=	Launcher elevation rate (velocity)
$DBdg'l'$	=	Launcher train rate order
$DEdg'l'$	=	Launcher elevation rate order
$Bdg'l' - Bdg'$	=	$e(Bdg') =$ Train error as a function of launcher position
$Edg'l' - Edg'$	=	$e(Edg') =$ Elevation error as a function of launcher position

Special symbols, of the following form, were created to meet the requirements for expressing digital functions:

$f(e(Bdg'))$	=	Control input to Zeltex train amplifier, consisting of a modified error signal summed with feedforward velocity signal.
$f(e(Edg'))$	=	Control input to the Zeltex elevation amplifier, consisting of a modified error signal summed with the feedforward velocity signal.

6.0 EXPLANATION OF VOLUME FORMAT

The program specifications described in Section 2.0, Part 1, are contained in this volume as Parts 2 through 6. Each specification is a complete entity and, in deviation from normal documentation practice, has been sectionalized independently so that it may, if desired, be removed from the volume for user convenience. Following Part 6 is an appendix that contains a suggested format for an operational digital launcher control program.

PART 2

COMPUTER PROGRAM PERFORMANCE SPECIFICATION

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1.0 SCOPE

1.1 Identification

Part 2 describes the performance requirements for the computer program used to test the feasibility of digital control of the ASROC Mk 112 Launcher.

1.2 Functional Summary

The computer program is used to provide inputs to the ASROC Mk 112 Launcher for testing its responses in two different configurations. In one configuration, the launcher position is inputted via keyset central (KCS) and in the other, the launcher position is inputted by shaft position encoders. This specification describes the program used for testing in terms of system functional requirements. It includes an analysis of the ASROC launcher power drives and presents the characteristics that the digital control must display. Section 7.0, Part 2, contains a supplementary description of the analog computer simulation of the train power drive.

2.0 APPLICABLE DOCUMENTS

2.1 System Performance Specifications

- a. NAVWEPS OD 14430, "Factory Acceptance Test Power Drive Mk 61 and Mk 62, Power Amplifier Mk 153 "
- b. Naval Underwater Weapons Research and Engineering Station TM 379, *Operational Tests of the ASROC Launcher MK 112 With Simulated ASROC and ERA Missile Loads*, by W. B. Cullison, CONFIDENTIAL, November 1966

c. Naval Underwater Weapons Research and Engineering Station TM 392, *Development of a Linear Math Model For the ASROC Launcher MK 112 Power Drives*, by E. W. Wilbur, April 1968

d. Bureau of Weapons NavWeps OP 2385, v.2, (Revision 1, Change 2), *Launching Group MK 16 Mods 1, 2, 3 and 4, Train Power Drive MK 61, Mods 0 and 1, Elevation Power Drive MK 62 Mods 0 and 1, and Power Drive Amplifier MK 153 Mod 0 Amplifier Chassis; Description and Maintenance*, 14 May 1965

e. Bureau of Ordnance Drawing LD 541510, *ASROC Weapon System FCG Mk 111 Functional Schematics For DD 710 Class Ships*, 28 June 1961

2.2 Inter-Subsystem Specifications

a. Naval Electronics Laboratory Center Drawing RAAC 340.1-2230, *Encoder-Synchro Assembly*, March 1968

b. Univac PX 2526, 4 vols., *Technical Manual For Type 1218 Digital Data Computer*, May 1964

c. Univac PX 2910, Revision A, *Programmers Reference Manual For UNIVAC 1218 Computer*, December 1963

d. Bureau of Ships NavShips 94093(A), v.2, *Technical Manual For Digital Data Converter CV-1123/USQ-20(V)*, Section 8, v.2, 14 June 1963

2.3 Miscellaneous Documents

a. Navy Electronics Laboratory Report 1354, *Digital Control of the Guided Missile Launching System Mk 13*, by J. B. Slaughter and D. W. Doherty, CONFIDENTIAL, 11 February 1966

3.0 REQUIREMENTS

3.1 Introduction

The MK 112 launcher power drives for train and elevation consist of two separate electrohydraulic systems. Since the train and elevation power drives are functionally identical, only the train power drive is discussed. The test program is, however, designed to exercise both the train and elevation power drives. The normal configuration of the train system is shown in the block diagram (fig. 2-1). The design of the digital control system is based on two considerations: (1) the dual-mode controller approach to error compensation, and (2) the system configuration shown in figure 2-2. The conventional, continuous compensation for the power drives is not used in the digital system and therefore will not be discussed. Figures 2-2 and 2-3 show the NELC digital system configuration. The dual-mode controller consists of a nonlinear error curve for large-signal compensation and a biquadratic lag controller for small-signal compensation. This compensation is performed by the digital computer. The selection of a controller is based on error magnitude. The error-shaping curve is used for error compensation for all error magnitudes greater than 1 degree. Error compensation is switched to the linear controller on a *decreasing* error signal when its magnitude becomes less than or equal to 1/2 degree. This small signal controller is switched, out of the loop and the error curve, back in on an *increasing* error signal when the error magnitude exceeds 1 degree. Thus this asymmetrical operation allows, after insertion into the loop at 1/2-degree error, the linear controller to remain in the loop until error magnitude is greater than 1 degree. Feedforward velocity is calculated and filtered by the computer and added to the output of the dual-mode controller. The resultant sum is then outputted as a dc voltage and summed with the stroke feedback voltage. This resultant signal is called velocity error.

The small-signal compensation is a low-pass filter with a steady-state gain of 20 and is designed from the linear model of the power-drive system. The large-signal, nonlinear error-shaping curve is used to drive the launcher into the linear, small-signal region with a predetermined error/velocity relationship. Its design is based on the nonlinear characteristics of the power drive. The electrohydraulic power drive (fig. 2-4) operates in the following manner: A dc signal from the control amplifier is applied to the torque motor windings. Linear motion less than or equal to ± 0.0075 inch is transmitted by the armature of the motor to position the paddle within the servo valve. The in-and-out position of the paddle directs the flow of hydraulic fluid to piston X, the first stage of a two-stage hydraulic amplifier. Piston X controls the flow and direction of fluid to the ends of control pistons Z and Y. The control piston in the second stage of the hydraulic

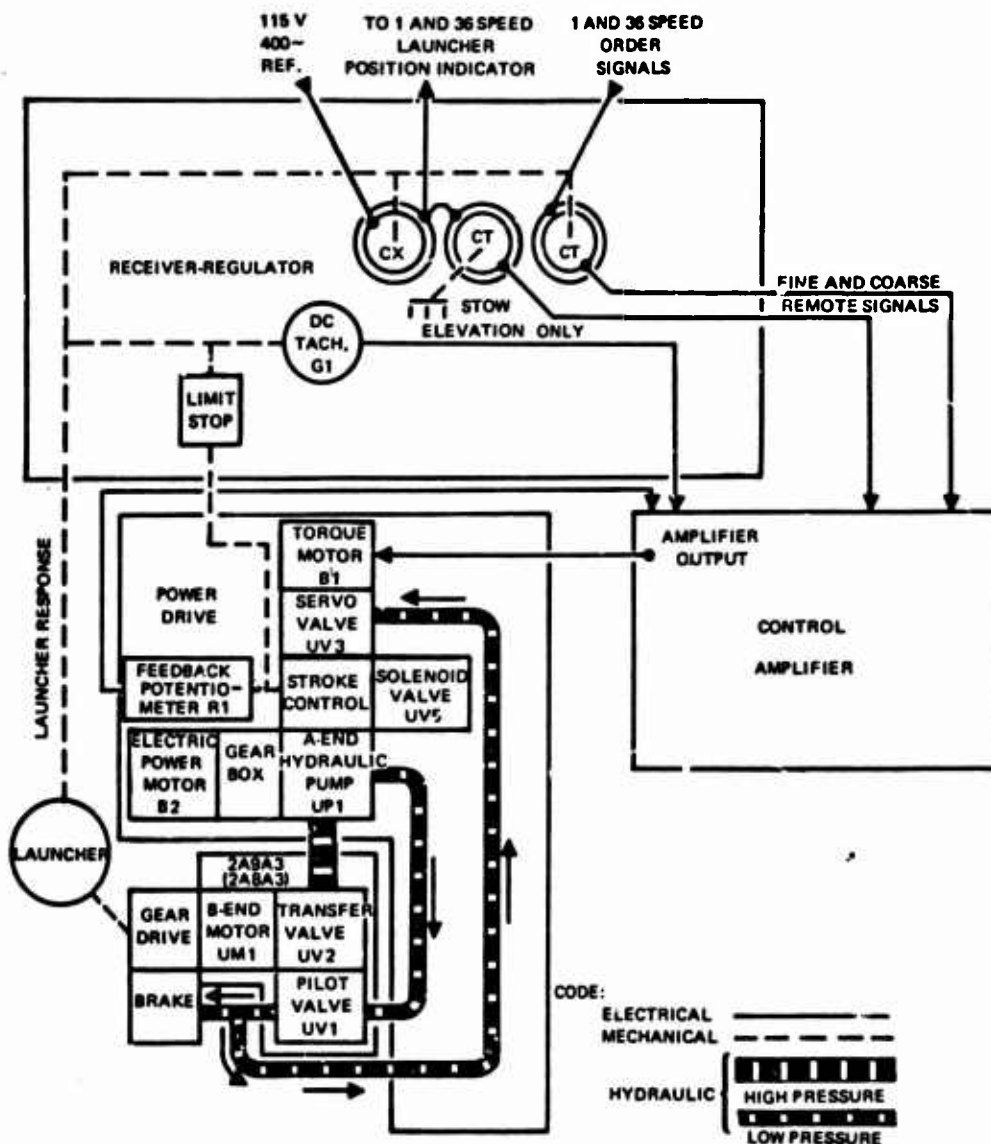


Figure 2-1. ASROC launcher functional block diagram.

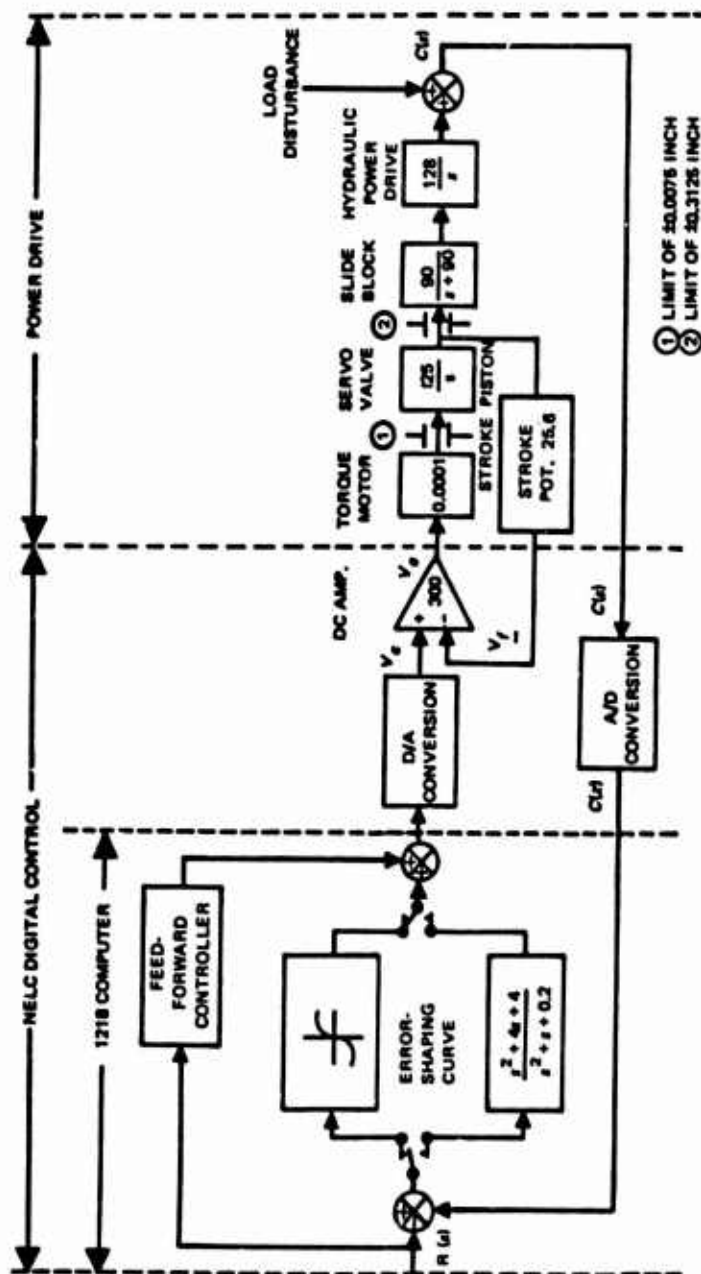


Figure 2-2. ASROC Mix 112 launcher digital system block diagram.

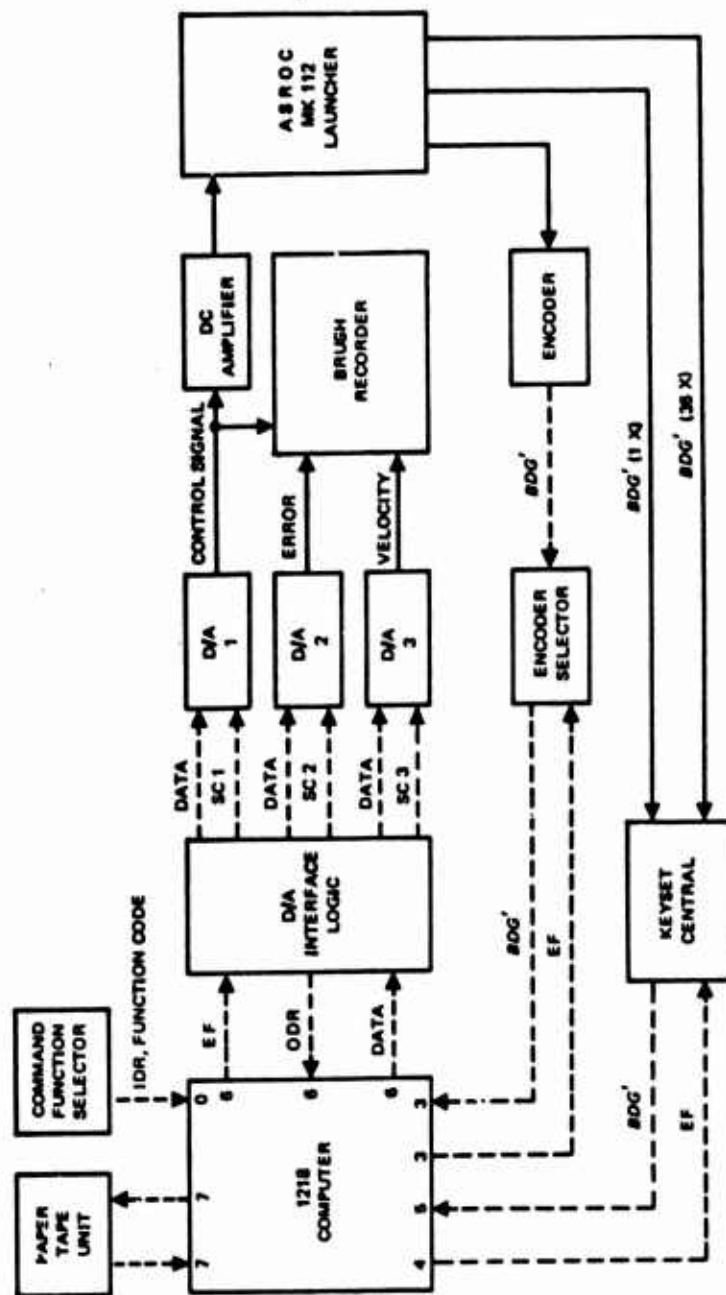


Figure 2-3. Configuration, block diagram.

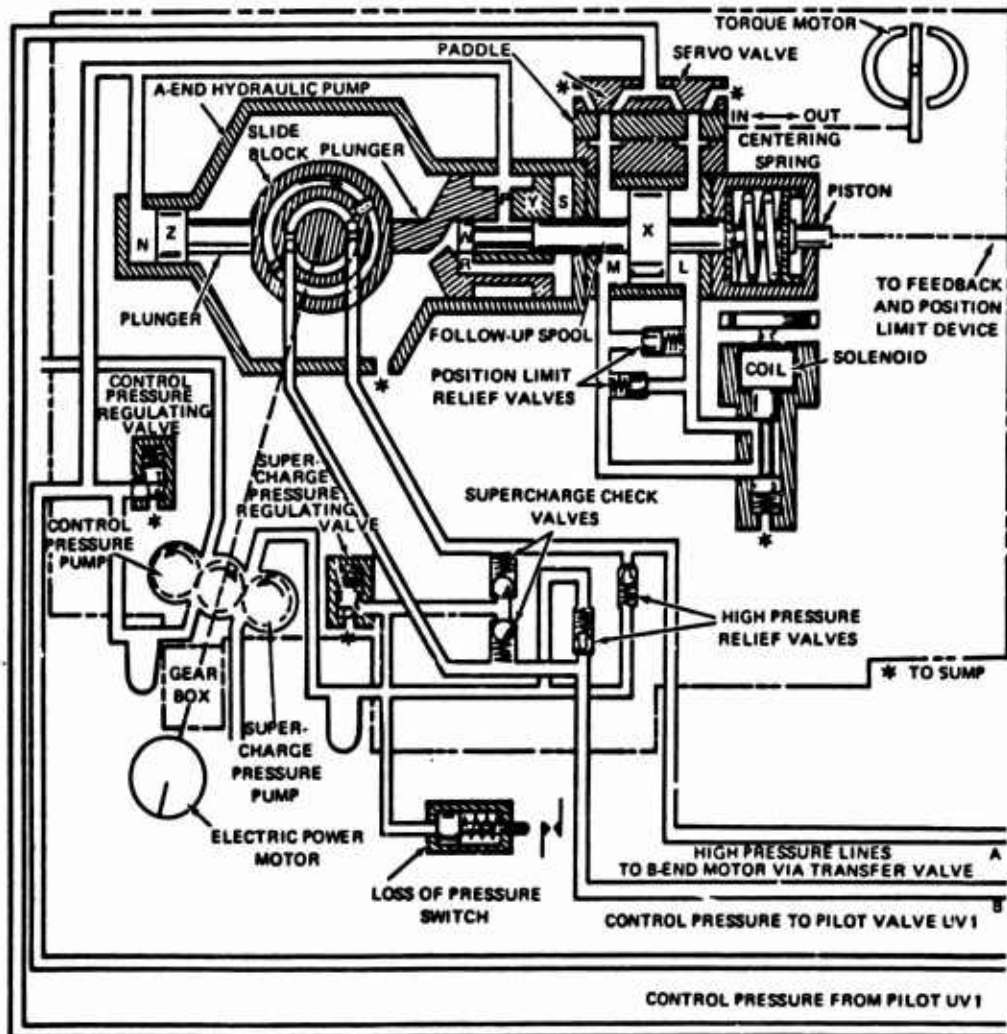


Figure 2-4. Electrohydraulic power drive.

amplifier controls the position of the slide block around the pistons in the cylinder body of the A-end hydraulic pump. The displacement of the block, which is proportional to launcher velocity, controls the volume and direction of flow of high-pressure fluid to the B-end hydraulic motor. The B-end motor positions the launcher via the gear train.

The digital program will provide plant dynamic compensation as well as position orders. Error calculation will be accomplished within the 1218 computer by comparing the digital position orders with the actual Launcher Position via signals converted to digital form by either the CV-1123/USQ-20(V) Keyset Central or the 15-bit shaft-position encoders.

3.2 Functional Summary

The digital program for testing the feasibility of digital control of the Mk 112 launcher system will be designed to be used with the UNIVAC 1218 computer. This program will provide comprehensive tests of both train and elevation operation and will be loaded from the UNIVAC 1232 I/O Console using Input Channel 7. Figure 2-3 shows the major equipment interfaces between the digital computer and the Mk 112 launcher. The position command (determined by the switch configuration of the Command Selector Control Panel) will be compared to the Launcher Position and any error present will be computed. Then the error signal is compensated by a digital filter or a nonlinear error-shaping function, depending on error magnitude.

The resultant control signal is summed with the feedforward velocity signal and transmitted on Channel 6 of the 1218 to the digital-to-analog (D/A) interface logic and then to D/A-1. The dc output of D/A-1 and the tachometer feedback are summed in the dc amplifier. This amplifier drives the torque motor of the launcher power drive, thereby closing the loop. The control signal from D/A-1, the error signal from D/A-2, and the launcher velocity from D/A-3 are displayed on a Brush Recorder (fig. 2-3). Output Channels 3 and 4 are used for external function commands to the Encoder Selector and Keyset Central, respectively. Input Channels 3 and 5 are used to receive Launcher Position information from either the Encoder Selector or Keyset Central. The Command Function Selector signal is received on Channel 0. The basic functional requirements of the computer program are shown in the flow diagram (fig. 2-5).

The program can be compartmented into seven major functions described in greater detail in the next sections. These functions are:

- a. Generate tables, initialize, and clear cells.
- b. Perform timing and establish remote-control operations.

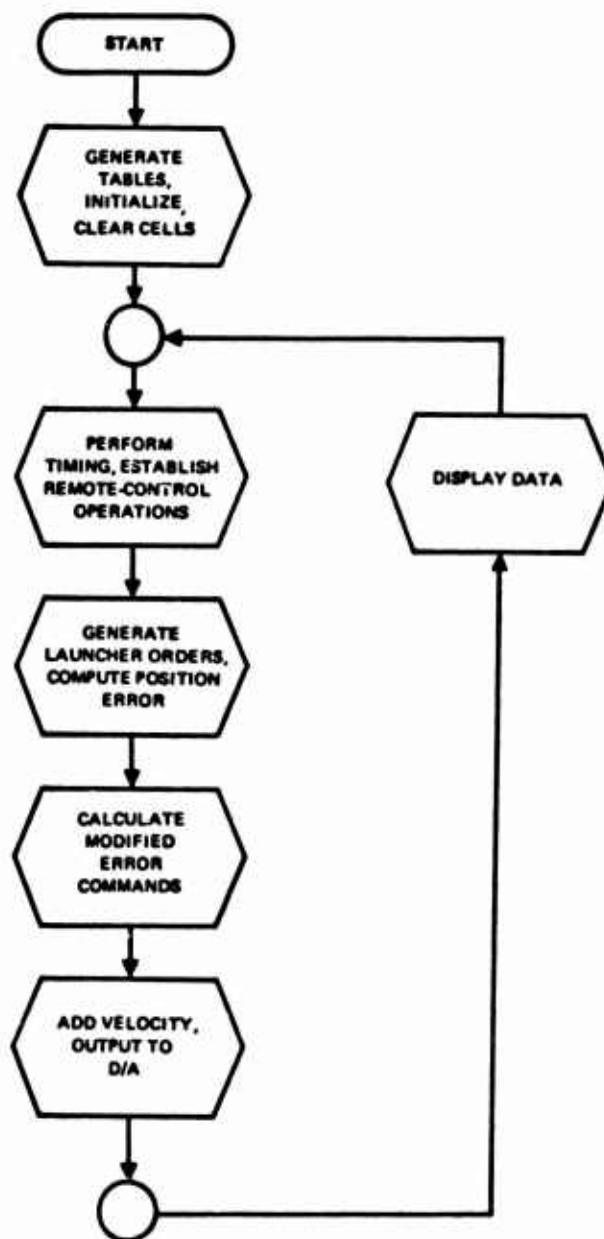


Figure 2-5. Computer program, functional block diagram.

- c. Generate launcher orders and compute position error.
- d. Form and output launcher orders to D/A.
- e. Calculate modified error commands.
- f. Add velocity and output to D/A.
- g. Display data.

3.3 Detailed Functional Requirements

The computer program will be required to perform the major functions outlined in Section 3.2. The specific requirements are included in the paragraphs that follow.

3.3.1 GENERATE TABLES, INITIALIZE, AND CLEAR CELLS

The first major function of the computer program is to prepare itself for a test operation. The program will be required to modify constants, clear past history, and set the initial conditions for a specific test. The program will be required to generate certain tables used in the runs.

3.3.2 PERFORM TIMING AND ESTABLISH REMOTE-CONTROL OPERATION

This is the second major function of the computer program. The basic system sampling rates will be established by using internally generated interrupts. The computer internal clock produces 1-kHz pulses. These will be utilized by a countdown subroutine to establish the desired sampling interval. The Command Function Selector will be used to specify the desired Launcher Position command. This portion of the program will establish the necessary communication with that panel.

3.3.3 GENERATE LAUNCHER ORDERS AND COMPUTE POSITION ERROR

This portion of the computer program is concerned with the generation of the Launcher-Position and velocity orders and the computation of the closed-loop position error. Step, ramp, and sinusoidal inputs, with and without additive noise, will be generated. The velocity order will be determined from the position order and passed through a 1st-order infinite memory filter for smoothing purposes. Loop error will be determined by the use of a subroutine comparing the position order and the feedback quantity from the Encoder or KSC.

3.3.4 CALCULATE MODIFIED ERROR COMMANDS

The computer will be required to carry out the compensation functions. The functions of the compensation selector will be performed by a routine that examines the error magnitude and decides whether the small-signal controller or the error curve should be used to modify the error signal. For errors outside the synchronized region, the error curve table will be utilized. The computer will modify the error by using a table lookup. For errors within the synchronized region, a linear digital filter subroutine will be utilized to develop the required control signals.

3.3.5 ADD VELOCITY AND OUTPUT TO D/A

Feedforward velocity will be added to the modified error to reduce the steady-state position error to a velocity command signal. The modified error commands will be applied to a D/A with dc voltage output.

3.3.6 DISPLAY DATA

The last major function of the computer is to provide the necessary communication with the recording equipment to allow an on-line Brush Recorder display of the various quantities of interest (fig. 2-3).

3.4 Adaptation

3.4.1 GENERAL ENVIRONMENT

Not applicable to this specification.

3.4.2 SYSTEM PARAMETERS

Certain constants used in the feasibility program will be capable of change at the discretion of the test conductor. The error window size may be varied to alter the crossover characteristics of the small- and large-signal controllers.

The error curve table may also be modified to show the effects on system performance. The constants that constitute this table will be programmed in such a manner as to facilitate modification.

3.4.3 SYSTEM CAPACITIES

Since this program is primarily designed for the purpose of determining the feasibility of digital control of the Mk 112 launcher, little consideration has been given to optimizing the time and storage allocations required. Many of the

functions performed would be unnecessary in an operational program. Approximately 7 milliseconds (msec) should be required for a complete program cycle. Approximately 4,000 cells of memory will be used for tables and program instructions.

3.5 Input/Output Interfaces

The computer program shall be designed to meet the requirements of input/output imposed by the intersubsystem specification defined in Section 2.2, Part 2.

3.6 Formats

The computer program will be written using the UNIVAC 1218 Trim II language (field-data code). All labels used in the program will be suffixed by the letter "N," the identification letter assigned to NELC. No requirements on input/output, displays, and operation control formats exist at this time.

4.0 QUALITY ASSURANCE PROVISIONS

Not applicable to this specification.

5.0 PREPARATION FOR DELIVERY

Not applicable to this specification.

6.0 NOTES

The Computer Program Design Specification, Part 3, provides a more comprehensive treatment of the program functions.

7.0 ANALOG COMPUTER SIMULATION

A block diagram of the modified system, including transfer functions of the various launcher components, is shown in figure 2-6. These transfer functions were used in developing the analog computer simulation of the launcher system. A time-scaling factor of 10 was used in the simulation to slow the solution, thereby providing more accurate recording of results on the X-Y plotter. Simulation was performed on a PACE TR-48 computer. A description of key portions of the simulation is included in the following paragraphs, 7.1 through 7.7.

7.1 Nonlinear Error-Shaping Curve

The nonlinear error-shaping curve can be approximated by the circuit shown in figure 2-7. In this circuit a straight-line approximation using a soft limiter is employed. For small values of error magnitude, the soft limiter on the output of Amplifier 01 has no effect. Therefore the gain is equal to the sum of the gains of the two paths and is represented by line A. As error magnitude increases, the soft limiter starts to take effect and the gain is reduced, i.e. it approaches line B. The result is a smooth curve that closely approximates the true error-shaping curve.

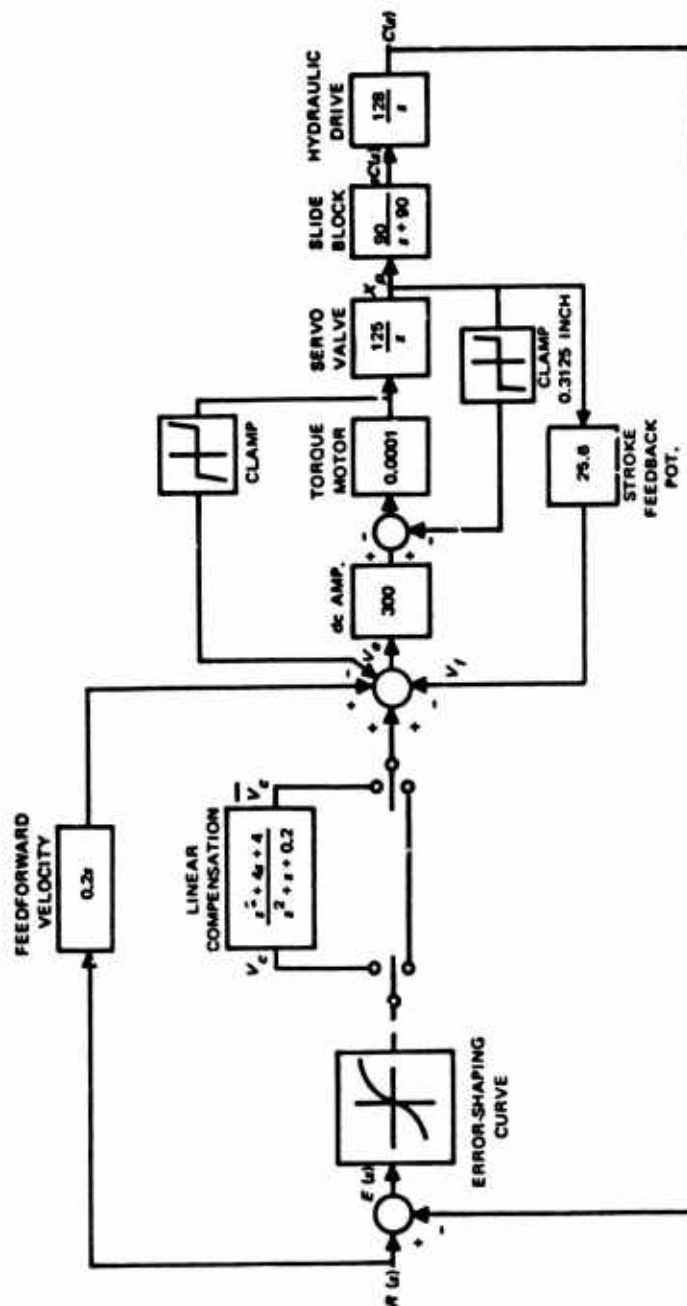


Figure 2-6. ASROC launcher block diagram.

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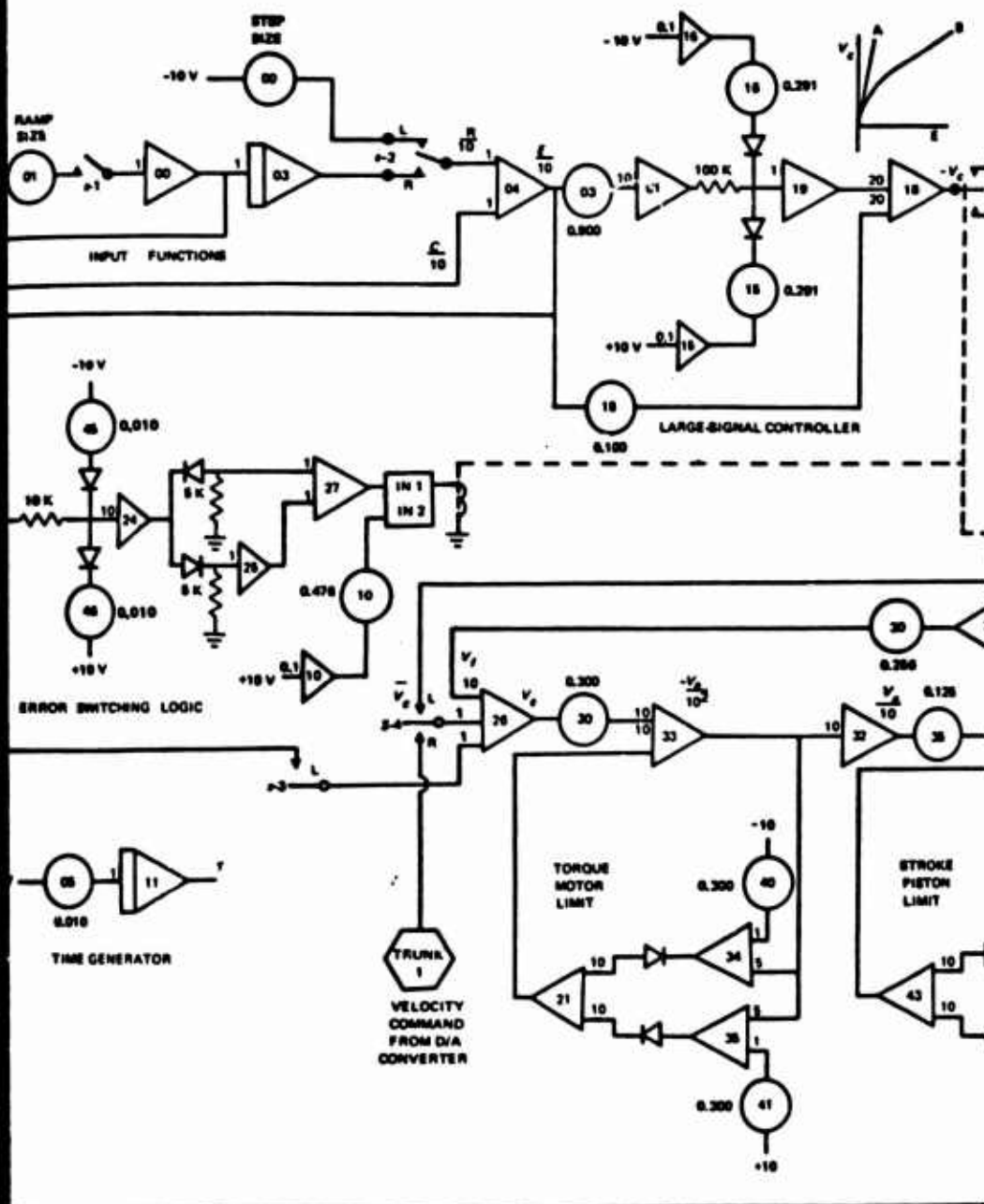
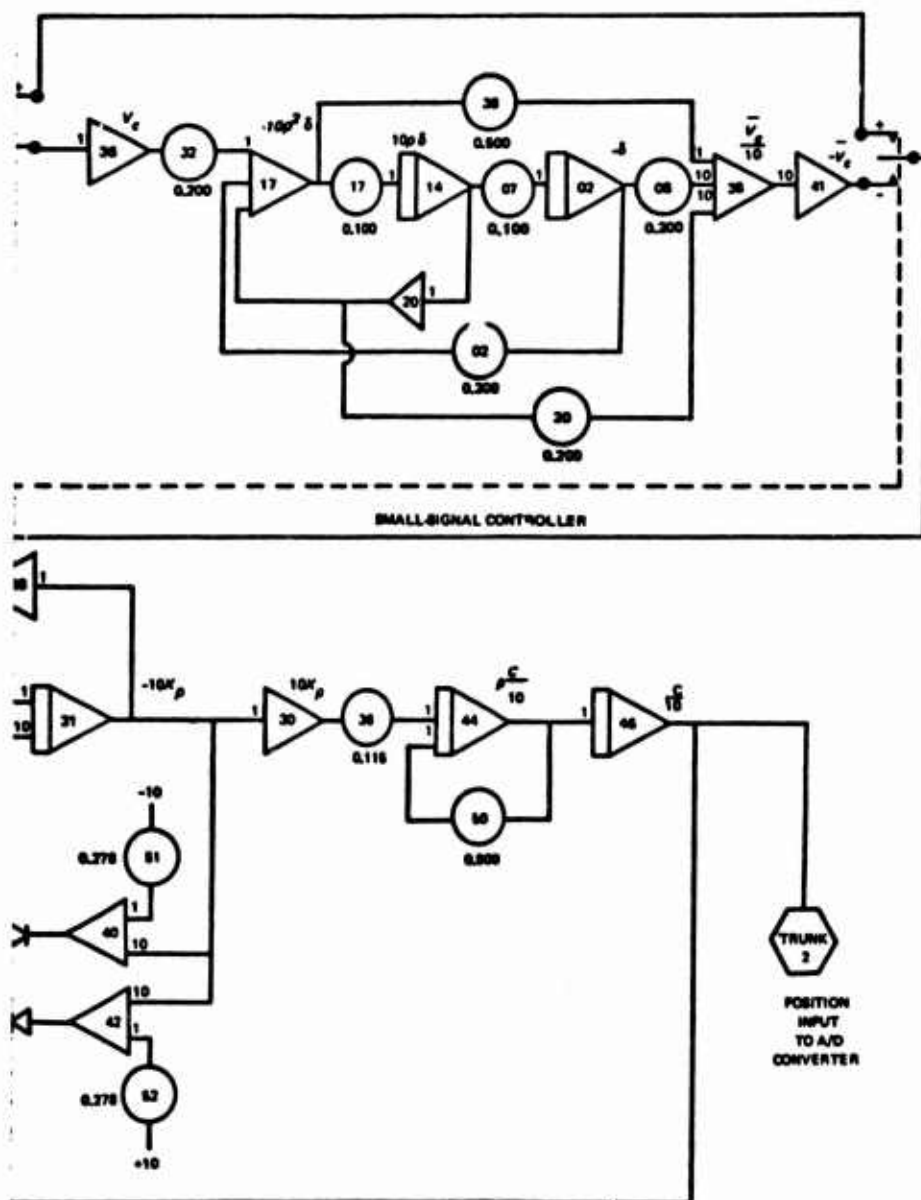


Figure 2-7. ASROC launcher analog computer diagram.



7.2 Small-Signal Compensation

The small-signal compensation transfer function is given in Laplace transform notation as:

$$\frac{\bar{V}_c}{V_c} = \frac{5s^2 + 20s + 20}{s^2 + 5s + 1} \quad (1)$$

Implementation of this equation requires the introduction of a dummy variable, δ .

Let

$$V_c = (5s^2 + 5s + 1) \delta = 5s^2 \delta + 5s\delta + \delta$$

Solving for the highest order of s ,

$$s^2 \delta = 0.2V_c - s\delta - 0.2\delta$$

Time scaling by a factor of 10, letting $s = 10p$,

$$10^2 p^2 \delta = 0.2V_c - 10p\delta - 0.2\delta \quad (2)$$

Referring back to equation (1), let

$$\bar{V}_c = 5s^2 \delta + 20s\delta + 20\delta$$

Time scaling this equation

$$\bar{V}_c = 5(10^2 p^2 \delta) + 20(10p\delta) + 20\delta$$

$$\frac{\bar{V}_c}{10} = 0.5(10^2 p^2 \delta) + 2(10p\delta) + 2\delta \quad (3)$$

Implementation of equations (2) and (3) leads to the small-signal compensation circuit portion of figure 2-7.

7.3 Mode Switching

The switching circuit is designed to switch the small-signal compensation network in when error magnitude falls below 0.5 degree. This operation may be accomplished using the relay comparator circuit (fig. 2-7). The output of Amplifier 27 is proportional to $\left| \frac{E}{10} \right|$. This absolute value is applied to the input of Relay Comparator 1 together with the bias from Amplifier 10, which controls the switching window size. This bias is adjusted so that as the signal decreases to 0.5 degree the comparator will be in the " - " position, thereby inserting the small-signal compensation into the system loop. When the error is greater than 0.5 degree, the comparator is in the " + " position, which bypasses the small-signal compensation.

The error curve remains in the loop at all times since it has a gain of 1 when the error is less than 0.5 degree and therefore does not affect the small-signal controller's operation.

7.4 Amplifier, Torque Motor, and Servo Valve

The open-loop transfer function, X_p / V_e for the amplifier, torque motor, and servo valve is,

$$\frac{X_p}{V_e} = \frac{3.75}{s}$$

or

$$sX_p = 3.75V_e$$

Time scaling,

$$10pX_p = 3.75V_e$$

7.5 Saturation Consideration

The maximum output of the amplifier is 125 V dc whereas only 75 V dc are needed to saturate the torque motor to ± 0.0075 inch of displacement. This corresponds to an acceleration saturation of 120 deg/sec per second. To incorporate acceleration saturation in the simulation, a hard limiter on Amplifier 33 was used. If the amplifier output magnitude is less than ± 75 V, the limiter circuit will not affect the circuit operation. The two diodes remain reverse-biased. When the amplifier output exceeds 75 V, one of the diodes (depending on the sign of V_a) will conduct, thus forming a high-gain negative feedback path around Amplifier 33. The effect of this high-gain negative feedback is to immediately cancel the normal input to the amplifier and cause the output to remain at the desired limiting value.

Velocity saturation of the launcher is caused by the stroke piston limit of ± 0.3125 inch, thus limiting the velocity to approximately 40 degrees per second. A limit of the same type used for acceleration saturation is used around Integrator 31 to simulate velocity saturation.

7.6 Piston and Slide Block

The closed-loop transfer function $\frac{C}{X_p}$ of the piston and slide block may be calculated from figure 2-6:

$$\frac{C}{X_p} = \frac{(128) 90}{s(s + 90)}$$

Expanding and time scaling,

$$\frac{p^2 C}{10} = 1.15(10X_p) - 0.9 pC \quad (4)$$

7.7 Conclusions

The analog computer simulation described in Section 7.0 of this Part was programmed on an Electronic Associates, Inc., PACE TR-48 analog computer. The simulation required is two-thirds of the full 48 amplifier complement of the computer. The computer has output voltage ranges of ± 10 V full-scale, and careful consideration of maximum voltage outputs was maintained to prevent saturation problems. Slightly different programming techniques could be used with other types of computers that could optimize the use of computing components on those machines. The simulation has been designed to be readily used in a hybrid computing arrangement with the UNIVAC 1218 to provide a means of laboratory testing of the dual-mode controllers and the digital computer program.

PART 3

COMPUTER PROGRAM DESIGN SPECIFICATION

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1.0 SCOPE

1.1 Identification

Part 3 contains all program design data for the ASROC Mk 112 Launcher Digital Control System as designed, implemented, and tested by NELC. The computer program was designed to demonstrate the feasibility of controlling the launcher by digital techniques, utilizing the UNIVAC 1218 (CP 789) Digital Data Computer. The program is self-contained and operates as an entity; therefore, all design information normally contained within the specification relating to computer subprograms has been integrated into Part 3.

1.2 Functional Summary

Since this is essentially a feasibility demonstration program, it provides for control of both axes of launcher movement, i.e. train and elevation. It also furnishes a choice of inputting Launcher Position via KSC or encoders. For convenience, all subprograms necessary to perform these operations are embodied in one program. The program controls the launcher in a digital, closed-loop fashion and demonstrates the capability of the digital computer to perform many functions, including command position generation and launcher compensation, using digital-to-analog converters to feed operational amplifiers that provide power to the launcher torque motors.

2.0 APPLICABLE DOCUMENTS

2.1 Performance Specifications

Part 2, Computer Program Performance Specification, is applicable to the content of Part 3.

2.2 Miscellaneous Documents

The following documents are applicable to the content of this specification.

- a. Univac PX 2526, 4 vols., *Technical Manual For Type 1218 Digital Data Computer*, May 1964
- b. Univac PX 2910, Revision A, *Programmers Reference Manual For UNIVAC 1218 Computer*, December 1963
- c. Naval Electronics Laboratory Center TD 57, *ASROC MK 112 Digital Control System, Part 4: Computer Program Operator's Manual* (In press)
- d. Naval Electronics Laboratory Center TD 57, *ASROC MK 112 Launcher Digital Control System, Part 5: Computer Program Test Plan* (In press)
- e. Naval Electronics Laboratory Center TD 57, *ASROC MK 112 Launcher Digital Control System, Part 6: Computer Program Test Specification* (In press)

3.0 REQUIREMENTS

The ASROC Mk 112 Launcher Digital Control System computer program includes all routines necessary to perform all functions of both train and elevation control. The program must be run as an entity, under the control of an integral Executive, with appropriate routines called on as needed. Since the program was designed for use in a non-operational environment, three tables are generated at the time of program initialization to provide the necessary operational atmosphere for the launcher: a noise table (NTABN), which simulates random noise approximating that which would occur in the operational environment, and the train-and-elevation error curve tables (TETABN and ELETBN, respectively), which provide digital compensation to the launcher during large signal excursions.

The Executive routine begins with the initialization of various memory areas, including the following:

- a. Storage of synchronizing interrupt instruction.
- b. Calculation of sampling rate.
- c. Generation of noise table.

d. Generation of train error curve table.

e. Generation of elevation error curve table.

Upon completing the initialization, the program "5-stops" and waits for the operator to manually set the synchronizing interrupt switches to ON and INTERNAL, which starts the internal real-time clock. The program is restarted, and routine CLOCKN is entered to control the sample period of the program. The real-time clock generates a series of interrupts at the rate of 1024 per second. Each interrupt advances the counter in routine CLOCKN until a predetermined value is reached; for example, a sampling rate of 20 per second requires a count of 10. In addition to its counting function, CLOCKN switches back to the main program after each interrupt until the counter has reached its precalculated value, at which time a jump is made to the portion of the Executive that starts program operation. The first routine, CNTRLN, called at the word CONTRN, interrogates the Command Selector Control Panel. The train and elevation position and feedforward velocity commands are now generated by the appropriate routines. At this point, the program stops performing elevation calculations and works only on train until all train calculations except the partial controller calculations for train are completed. If Computer Skip Key 2 is set, train position is inputted via an encoder. If Skip Key 2 is not set, train position is buffered in through Keyset Central. This position information is used by routine TRERKN to determine the difference between actual train position and commanded train position. At this point the program starts to perform the functions of the train compensating network.

A series of instructions is executed to determine the magnitude of train error and introduce error compensation so that the proper signal will be sent to train. The following series of actions occurs:

a. If train error is greater than 1 degree, an error flag is cleared and routine ECTABN is called to perform an error curve table lookup. The resultant value is saved, controller past history cells are cleared, the feedforward velocity is added to the error-compensated signal, and this command is sent to train by routine TROUTN.

b. If train error is greater than 1/2 degree, but less than 1 degree, a test of the error flag is made. If the error flag is set, routine CONCON is entered to complete the controller calculation, the velocity is added, and this signal is sent to train by routine TROUTN. If the error flag is cleared, the action described under a. above occurs.

c. If the train error is less than 1/2 degree, the error flag is set, routine CONCON is entered to complete the controller calculation, the feedforward velocity is added, and the signal sent to train by routine TROUTN. The preceding sequence of actions insures correct error compensation at all times. Large errors, greater than 1/2 degree, are compensated by the error curve. Once the error becomes less than 1/2 degree, the continuous small-signal controller makes the appropriate compensation until error increases to a value greater than 1 degree, at which time the large error compensation is again used.

This completes all train calculations except for the partial controller calculations. Here, elevation calculations are resumed. The same sequence of actions as described above for train is now performed for elevation: position is inputted by the appropriate routine, error

calculated, the correct compensation provided, feedforward velocity added, and this command outputted to elevation. Now the train-and-elevation small-signal controller is partially calculated for the next pass, and data are sent to the recorder.

It should be noted that after each pass in which the error curve table lookup is performed for train and/or elevation, the respective controller past-history cells are cleared. This action permits the appropriate routines, for completing train and/or elevation controller calculations, to operate, when called, without concern for generation of transient signals that might occur if the cells contained outdated information. In every pass, feedforward velocity is added to the new control orders before they are outputted to the launcher. Routines TROUTN and ELOUTN send data words to D/A converters feeding amplifiers that drive the appropriate launcher torque motors. The calculation of the controller outputs for the next pass takes into account the present and past history of the controller inputs and outputs.

3.1 Functional Allocation/Description

The routines and tables listed in table 3-1 are utilized by the computer program. They are presented in tabular form to facilitate identification of the mode in which each is used.

TABLE 3-1. FUNCTIONAL ALLOCATION/DESCRIPTION
(Continued through page 51)

Task	Description	Designator	Called by	Mode used in
Control all program functions	Executive	EXECTN	Initial-ization	Train and elevation
Generate a simulated random noise table	Noise table generator	NOISEN	EXECTN	Train and elevation
Generate train error curve table	Error curve table generator	ERRORN	ERSUBN	Train
Generate elevation error curve table	Error curve table generator	ERTBGN	EXECTN	Elevation
Control program sample period	Sample time clock	CLOCKN	SAMTMN	Train and elevation
Input command selector panel word	Command selector processing	CNTRLN	CONTRN	Train and elevation
Generate train position orders	Train position commands	TLNPSN	TNPOSN	Train
Generate elevation position orders	Elevation position commands	ELNPSN	EXECTN	Elevation
Form train velocity	Calculate velocity	TRVELN	EXECTN	Train
Form elevation feed-forward velocity	Calculate velocity	ELVELN	EXECTN	Elevation

TABLE 3-1. (Continued)

Task	Description	Designator	Called by	Mode used in
Input train position via encoder	Input train position	TRENIN	LNIN	Train
Input train position through keyset central	Input train position	TKSCIN	EXECTN	Train
Calculate difference between generated command and present position	Calculate train error	TRERRN	EXECTN	Train
Determine controller output based on precalculated error and error curve table	Error curve table lookup	ECTABN	ECTN	Train
Form controller output using precalculated data and new error values	Complete train controller calculations	CONCON	CNCOMN	Train
Output digital orders to train D/A	Output to train	TROUTN	EXECTN	Train
Input elevation position via an encoder	Input elevation position	ELENIN	EXECTN	Elevation
Input elevation position via keyset central	Input elevation position	EKSCIN	EXECTN	Elevation
Calculate difference between generated command and present position	Calculate elevation error	ELERRN	EXECTN	Elevation

TABLE 3-1. (Continued)

Task	Description	Designator	Called by	Mode used in
Determine controller output based on pre-calculated error and error curve table	Error curve table lookup	ELERLN	ELECTN	Elevation
Form controller output from precalculated data and new error values	Complete elevation controller calculation	COMCON	CMECON	Elevation
Output digital orders to elevation D/A	Output to elevation	ELOUTN	EXECTN	Elevation
Form partial train controller calculations for next pass	Calculate train $D(z)$ for next pass	TRPDZN	EXECTN	Train
Form partial elevation controller calculation for next pass	Calculate elevation $D(z)$ for next pass	ELPDZN	EXECTN	Elevation
Transmit train and elevation driving function and position error to recorder	Data to recorder	DATRDN	DISPLN	Train and elevation
Store generated random noise values	Noise table	NTABN	Provide operating environment	Train and elevation
Store generated train error curve values	Train error curve table	TETABN		Train
Store generated elevation error curve values	Elevation error curve table	ELETBN		Elevation

3.2 Functional Description

Paragraphs 3.2.1 through 3.2.16 describe in detail all functional routines contained within the ASROC digital-control-system computer program. (The tables that provide simulation of launcher operational environment, NTABN, TETABN, and ELETBN, are not included because the routines by which they are generated amply describe them. Since most of the train and elevation routines are identical, only those routines of elevation significantly different will be described separately. The arrangement of these paragraphs follows the order in which the general flow chart (fig. 3-1) is presented).

3.2.1 EXECTN, EXECUTIVE ROUTINE

EXECTN is the entrance to the Executive routine, under which all program functions are controlled. The Executive occupies memory locations 500-625 and performs two functions: (1) initialization (Locations 500 through 510), and (2) execution (Locations 511 through 625). All routines are under Executive control throughout program operation and are called as needed.

3.2.2 NOISEN, NOISE TABLE GENERATOR ROUTINE

This routine (fig. 3-2) is called by the Executive at the time of program initialization to generate a series of 1000 numbers whose distribution characteristics resemble the noise data that might be expected under operational conditions. These numbers are stored in the noise table (NTABN) beginning at Location 5177. The routine is self-contained and executed only at the time of program initialization. Noise values are selected from NTABN and may be added to the launcher commands as a function of operations performed by routines TLNPSN and ELNPSN.

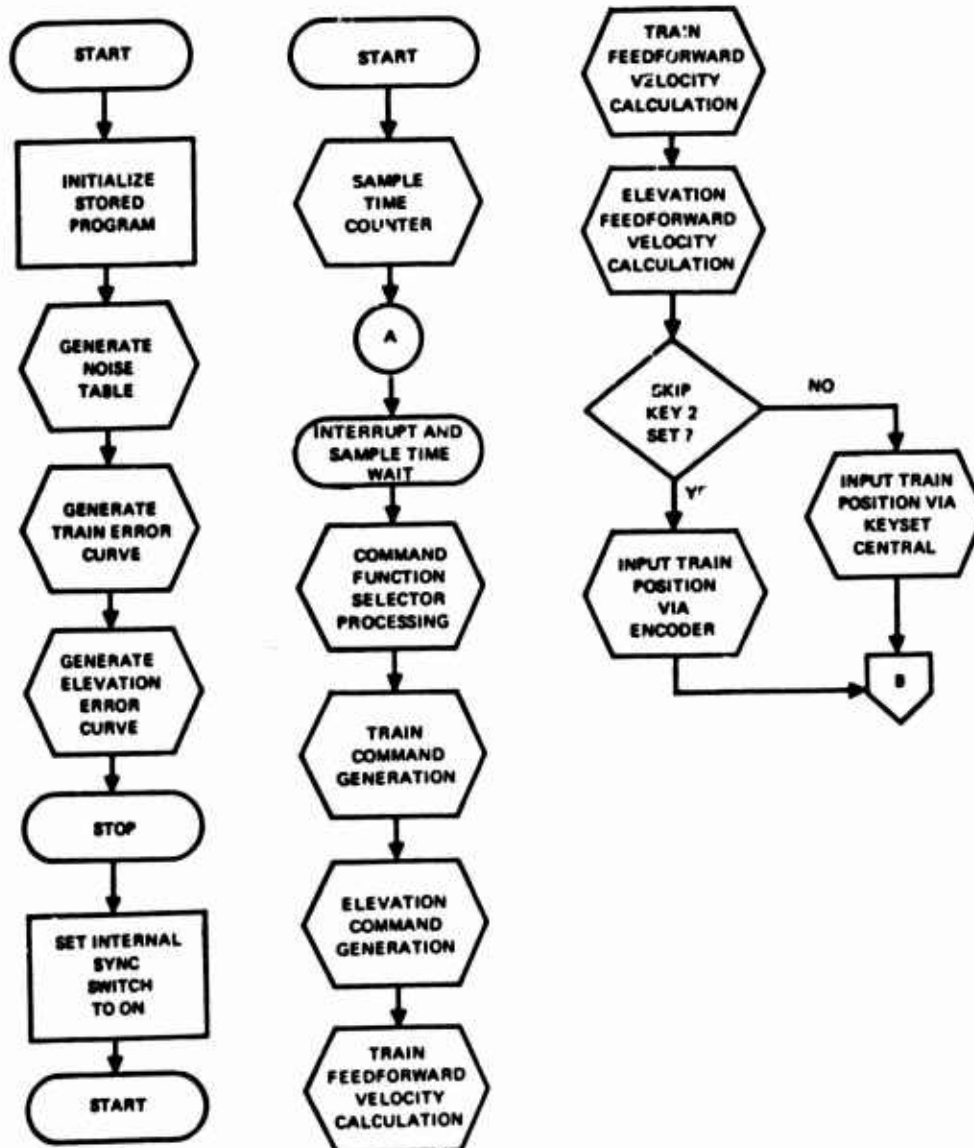


Figure 3-1. Launcher test program, overall flow diagram.

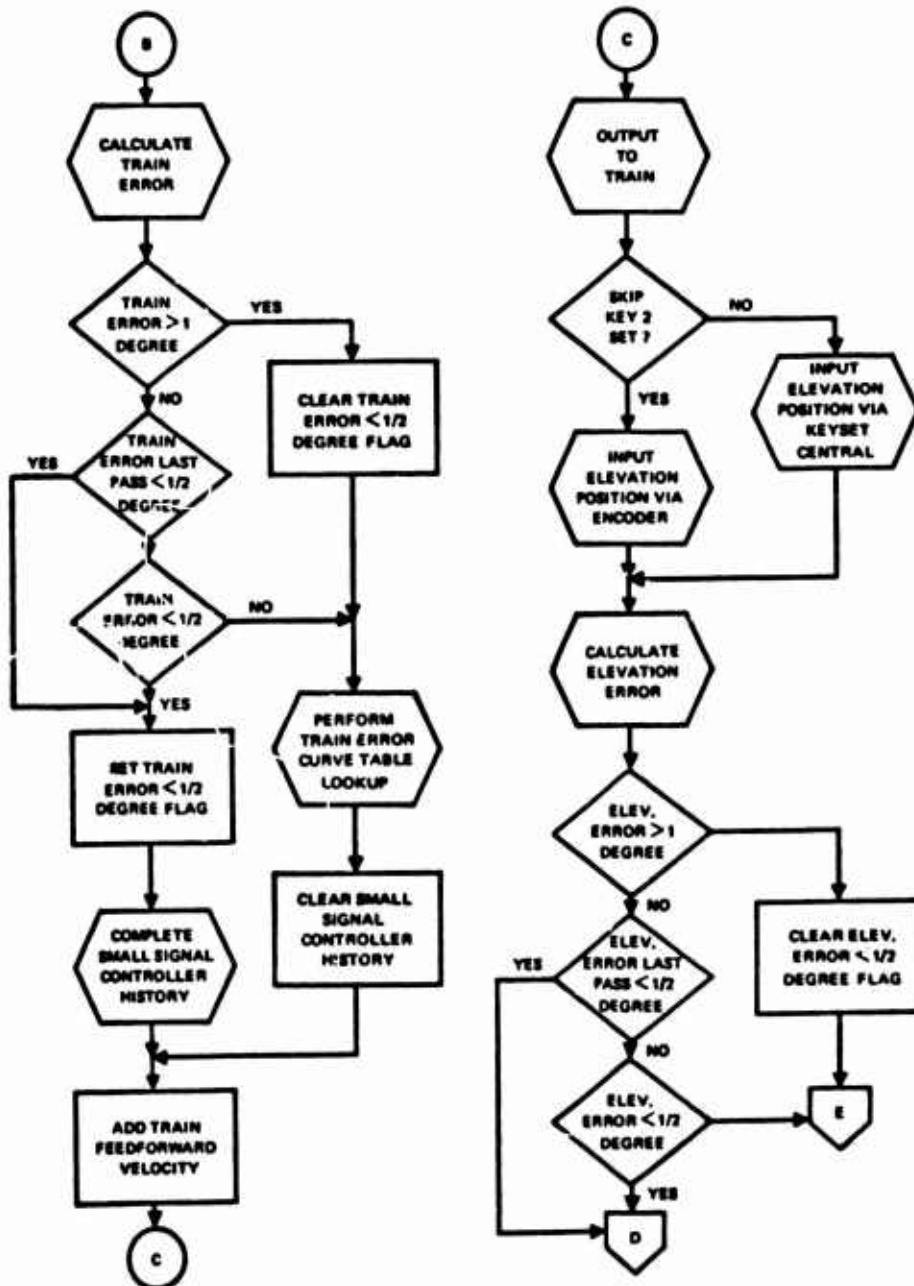


Figure 3-1. (Continued)

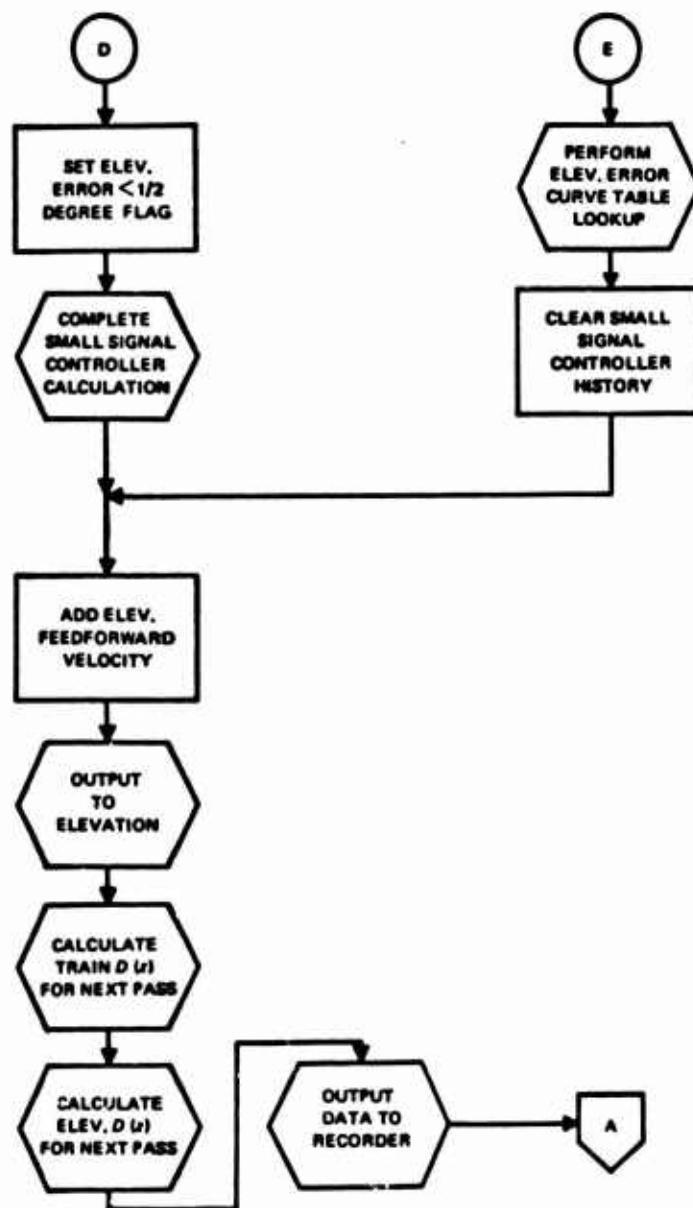


Figure 3-1. (Continued)

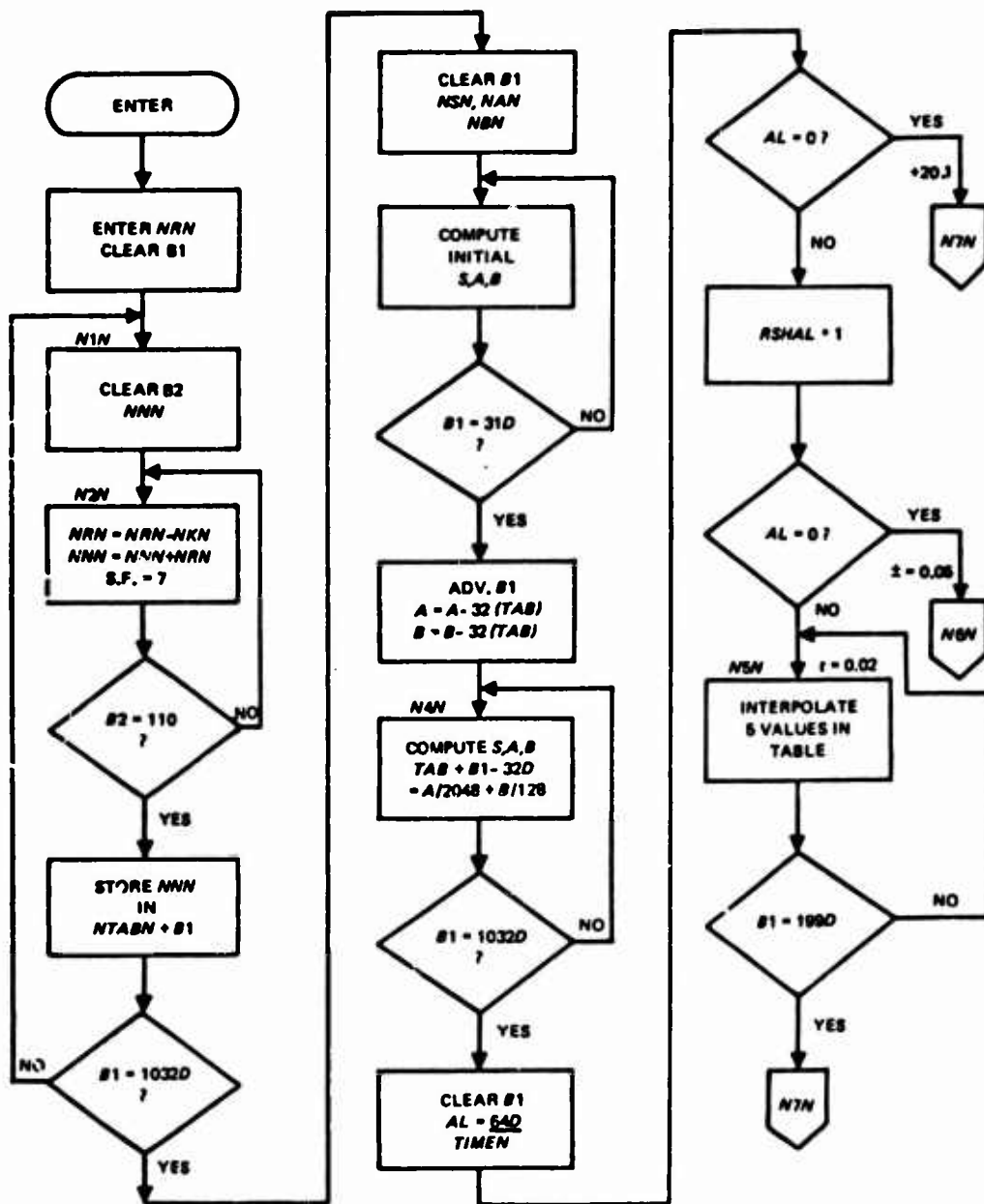


Figure 3-2. Noise table generator routine (NOISEN), flow diagram.

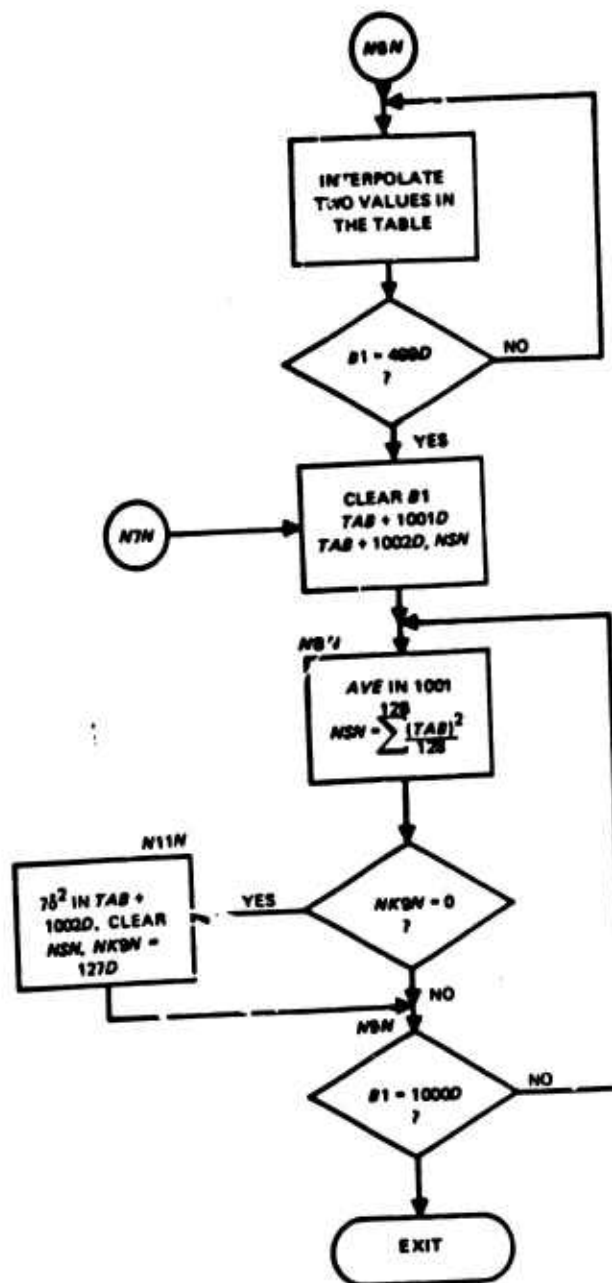


Figure 3-2. (Continued)

3.2.3 ERRORN, ERTBGN, ERROR CURVE TABLE GENERATOR ROUTINES

These routines (fig. 3-3) are called by the Executive at the time of program initialization to generate tables of weighted values stored in the error curve tables (TETABN, ELETBN) at Locations 3203 and 4213, respectively. The tables are used to introduce error compensation during large signal excursions. The magnitude of the stored values is determined by the following equation:

$$Y_n = Y_{n-1} + \frac{A}{Y_{n-1} + B}, \text{ where}$$

$$KN = A = 121727_8$$

$$K1N = B = 1027_8$$

$$K2N = Y_{n-1} @ 0.5^\circ = 700_8$$

The same error-curve coefficients are used in both train and elevation. The tables start at 0.4 degree and increment in 0.1-degree steps to 50 degrees. The values are stored with a scaling factor of 2^{10} .

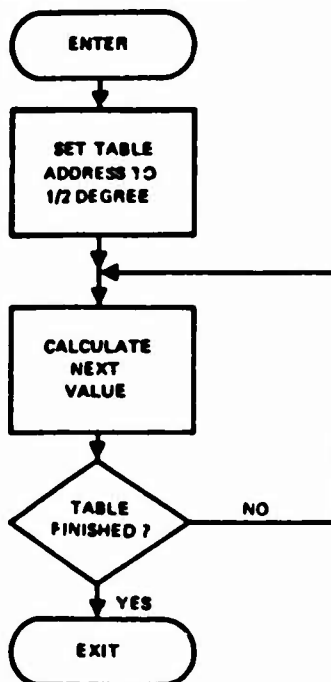


Figure 3-3. Error curve table generator routine (ERRORN for train; ERTBGN for elevation), flow diagram.

3.2.4 CLOCKN, SAMPLE PERIOD CLOCK ROUTINE

This routine (fig. 3-4) enables the real-time clock to regulate the sampling rate of the program that controls the time the Executive starts the program. Entry to CLOCKN occurs 1024 times per second (the interrupt cycle time) via a jump instruction stored in a special interrupt cell (address 16 of the computer). CLOCKN processes each interrupt by decrementing a register and then switching back to the main program. When the register reaches zero, the predetermined sample period has been reached, and the register is reinitialized. Routine CNTRLN is entered, and CLOCKN relinquishes control to the Executive.

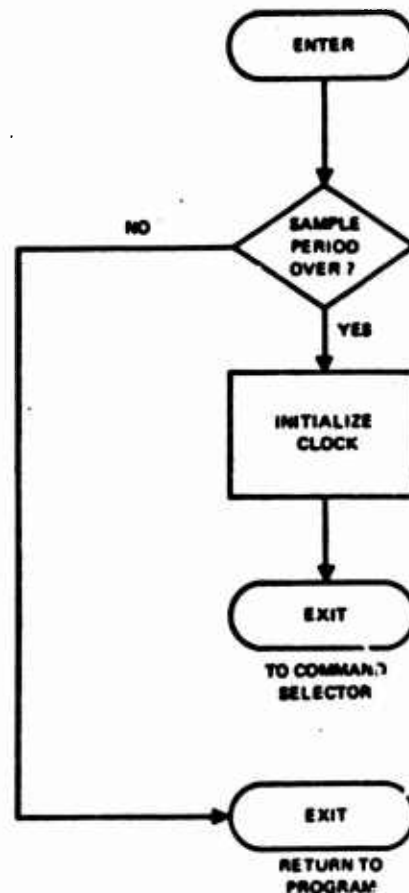


Figure 3-4. Sample period clock routine (CLOCKN), flow diagram.

3.2.5 CNTRLN, COMMAND SELECTOR PROCESSING ROUTINE

This routine (fig. 3-5) receives inputs from a remote Command Selector Control Panel. These inputs select the driving functions to be generated. The word format for selecting these functions is as follows:

$$2^{17} \quad 2^{16} \quad 2^{15} \quad 2^{14} \quad 2^{12} \quad 2^3 \quad 2^2 \quad 2^1 \quad 2^0$$

- a. Train function codes (bits 0-3).
- b. Noise set switch (bit 2¹²).
- c. Elevation function codes (bits 14-17).

When a code is selected and an input-data request button is pressed on the command control panel, the computer program buffers in the digital data and separates them into train, elevation, and noise words. The new train and elevation words are compared with the old train and elevation words, respectively. A difference in the words signifies a change in the driving functions; the program then initializes routines TLNPSN and ELNPSN by clearing the respective driving function storage cells. The noise word is saved for use by routines TLNPSN and ELNPSN to determine if noise is to be added to the driving function. Exit from this routine returns control to the Executive.

3.2.6 TLNPSN, ELNPSN, LAUNCHER POSITION COMMAND ROUTINES

TLNPSN (fig. 3-6) and ELNPSN (fig. 3-7) generate the selected train and elevation driving functions and, if specified, add the random noise component to these driving functions. TLNPSN starts by storing the existing driving function. The noise bit is removed, and the new driving function select code is examined for legality. If the new code is illegal, a zero position command is generated. If the code is legal, TLNPSN generates appropriate driving functions by utilizing steps, ramps, and sine waves (fig. 3-6). After function generation, noise is added, if required, by calling in the proper values from NTABN. Upon

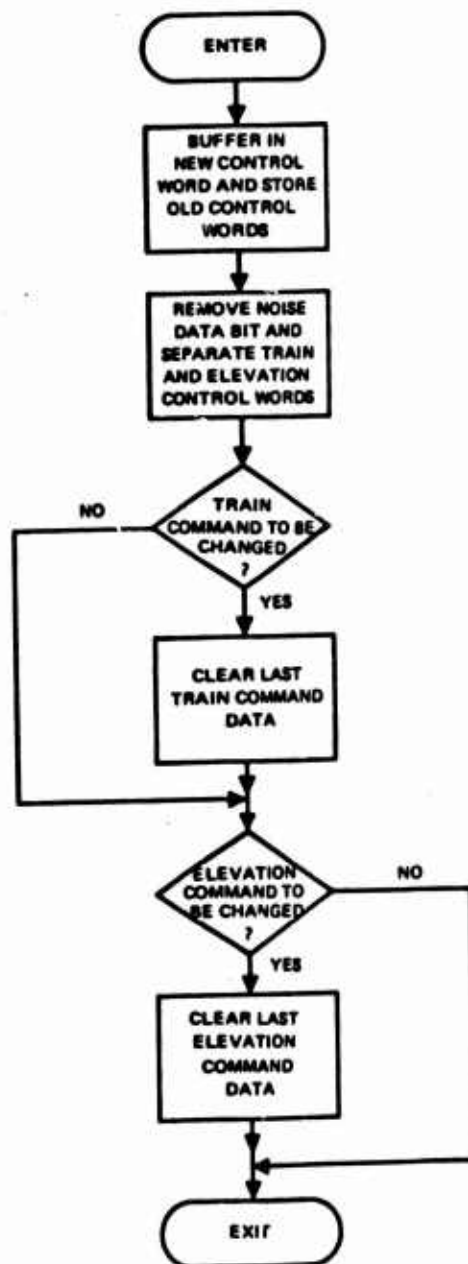


Figure 3-5. Command Function Selector processing routine (CNTRLN), flow diagram.

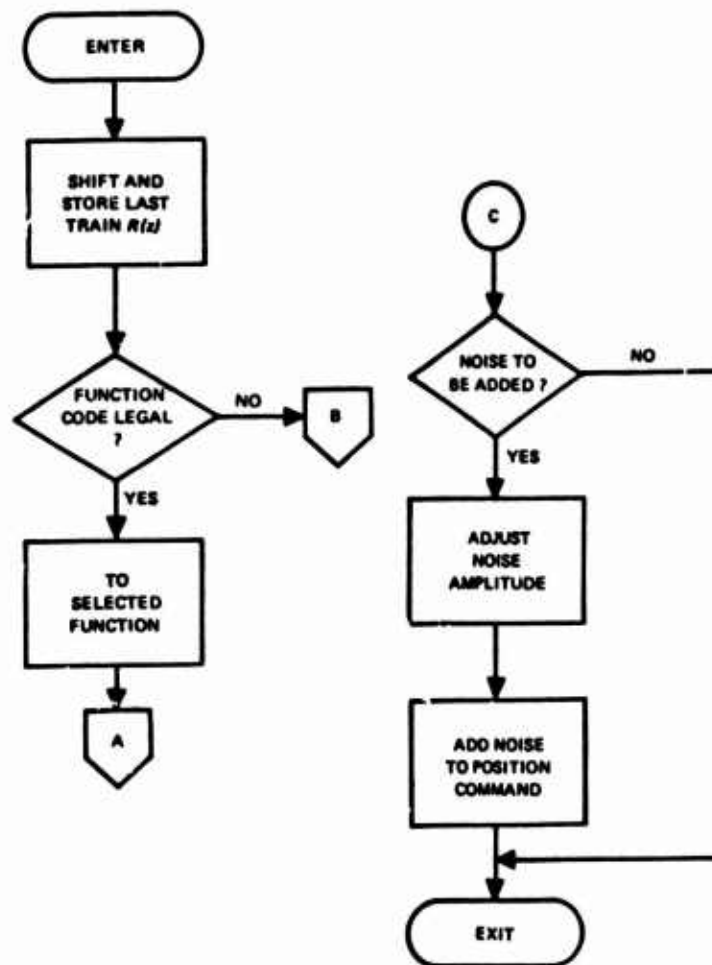


Figure 3-6. Train position commands routine (TLNPSN), flow diagram.

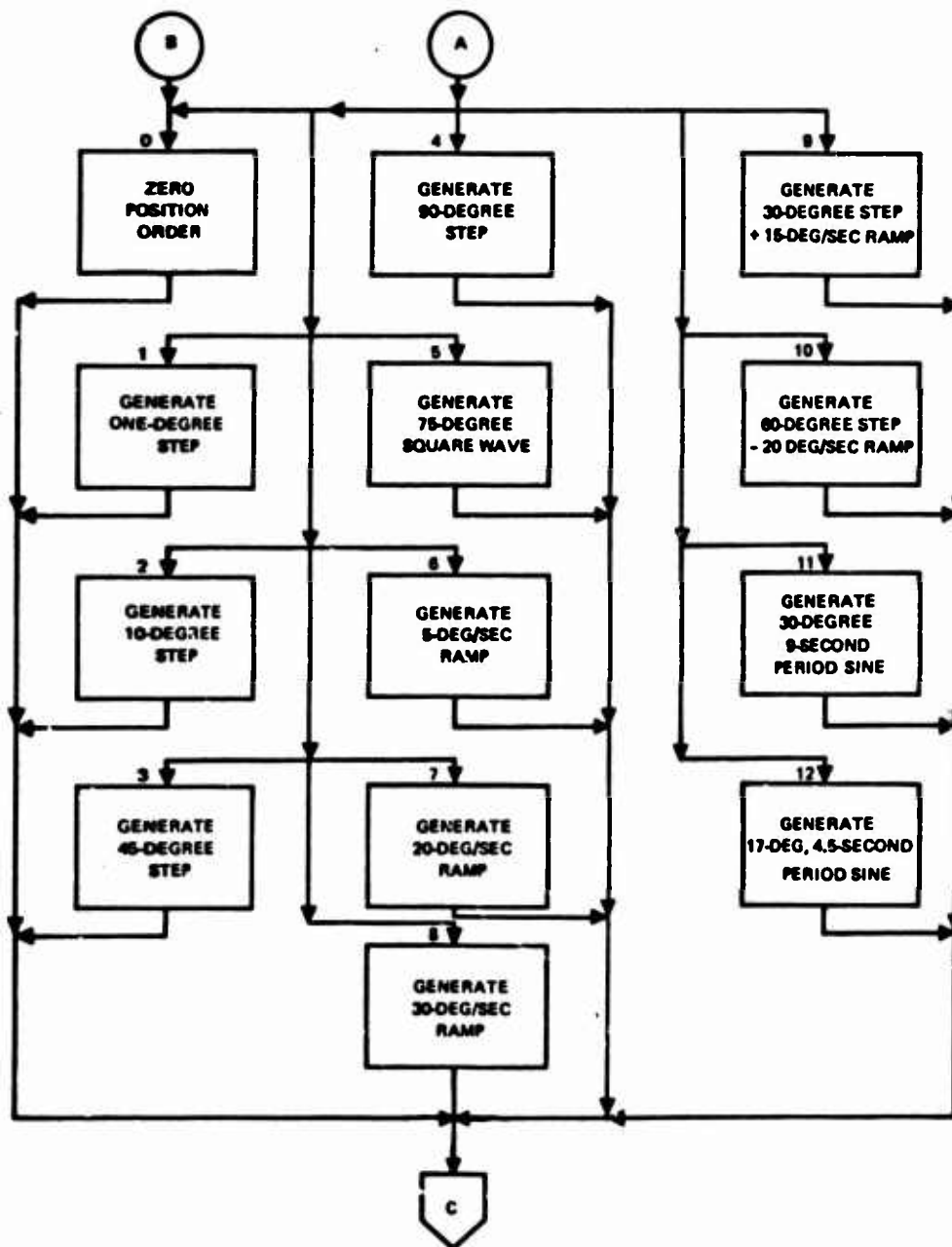


Figure 3-6. (Continued)

completion of TLNPSN, ELNPSN, is entered to generate elevation position commands. The only difference between TLNPSN and ELNPSN is that TLNPSN can generate one more ramp function than ELNPSN, and ELNPSN offsets the sine waves from zero since the elevation mode only depresses about 1 or 2 degrees. Upon completion, ELNPSN exits to the executive.

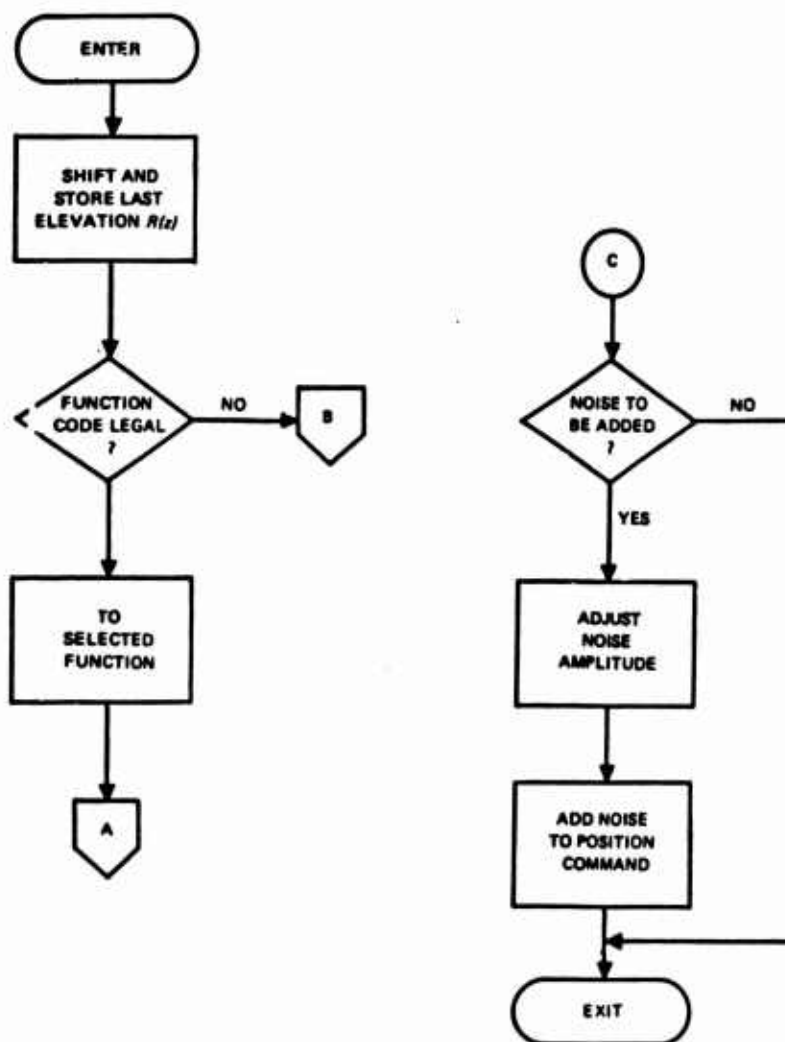


Figure 3-7. Elevation position commands routine (ELNPSN), flow diagram.

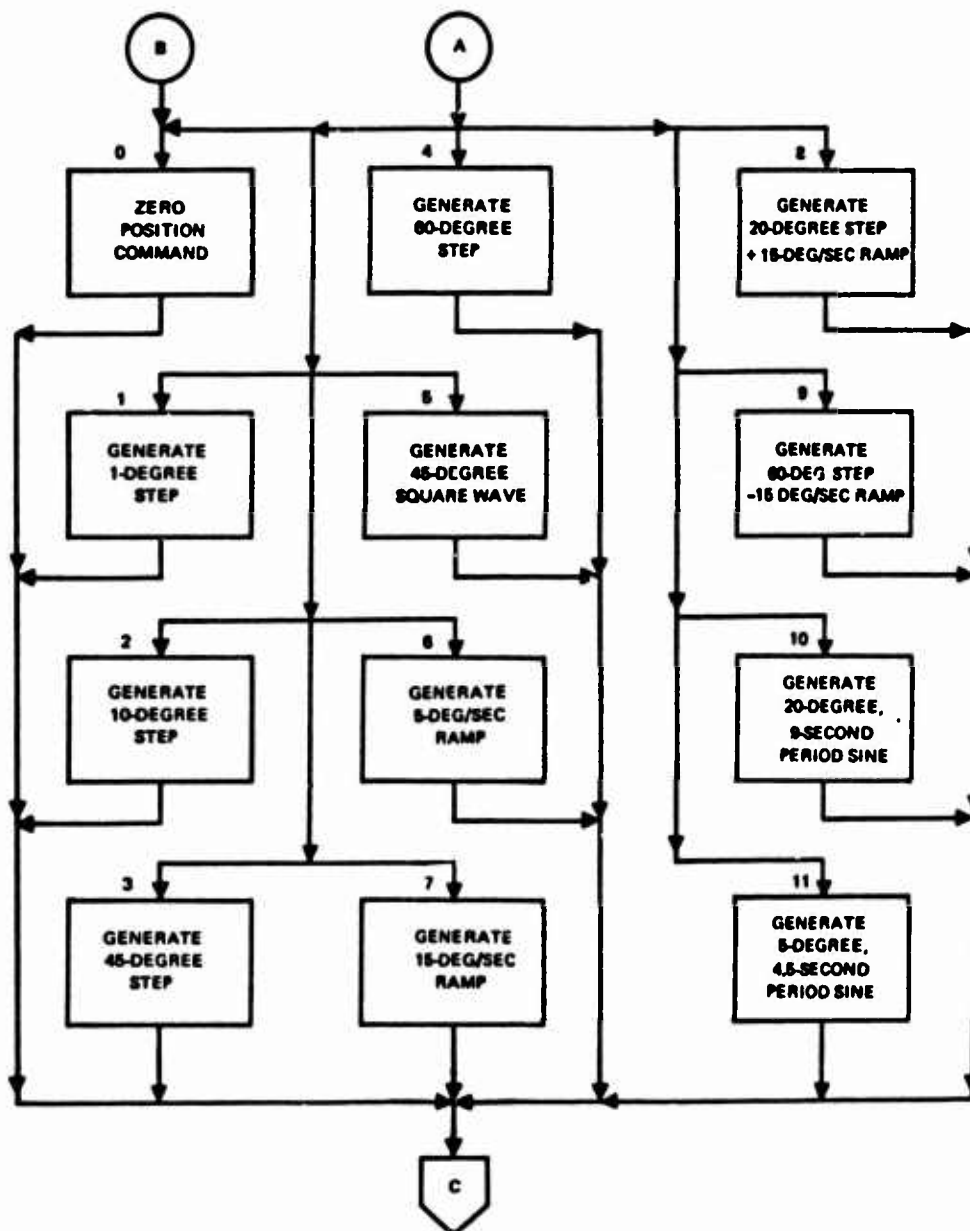


Figure 3-7. (Continued)

3.2.7 TRVELN, ELVELN, CALCULATE VELOCITY ORDER ROUTINES

These routines (fig. 3-8) are used to calculate the feedforward velocity components of the digital signals outputted to train and elevation. The velocity order is generated by solving the following equation:

$$V_n = (R_n - R_{n-1})F \times 0.109375 \text{ where}$$

R_n represents the present commanded position,

R_{n-1} represents the past commanded position,

F is the sampling rate, and

0.109375 is a constant that is approximately the reciprocal of the train plant gain.

The calculated velocity is filtered through use of the following equation:

$$\bar{V}_n = 0.25 (V_n - \bar{V}_{n-1}) + \bar{V}_{n-1}$$

TRVELN first calculates V_n , then filters it, and finally multiplies $\bar{V}_n$ by the feedforward gain factor. The routine now checks the command function select code to determine what kind of position order has been commanded. If a step or square wave has been ordered, TRVELN will zero in the velocity before returning to the Executive. If a command other than a step or square wave has been ordered, TRVELN returns to the Executive normally. This check is made and velocity zeroed to eliminate large transients that might occur because of step inputs. After TRVELN is executed, the Executive enters ELVELN to calculate the feedforward velocity to be used in elevation. The only difference between ELVELN and TRVELN is the constant used; ELVELN uses a constant of 0.144531, which is approximately the reciprocal of the elevation plant gain.

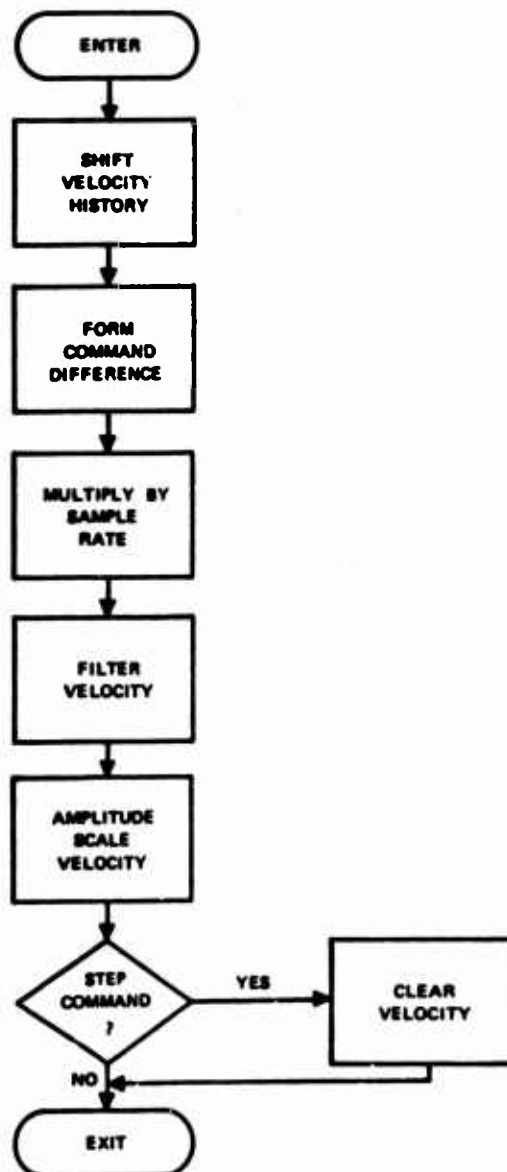


Figure 3-8. Calculate feedforward velocity command routine (TRVELN, train; ELVELN, elevation), flow diagram.

3.2.8 TRENIN, ELENIN, INPUT LAUNCHER POSITION VIA ENCODER ROUTINES

These routines (fig. 3-9) input the Launcher Position via DATEX, 15-bit, shaft-to-digital encoders on Computer Channel 6. Each routine (TRENIN and ELENIN) first selects the encoder designated for train and elevation through use of the external function command on Channel 6 and the appropriate external function code. Position is then buffered in, scaled, and stored for later use in the previously specified storage location. Control is now returned to the Executive.



Figure 3-9. Input position via encoder routine (TRENIN, train; ELENIN, elevation), flow diagram.

3.2.9 TKSCIN, TRAIN POSITION IN THROUGH KEYSET CENTRAL ROUTINE

This routine (fig. 3-10) inputs train position through KSC in a dual-channel operation using Computer Channels 4 and 5. TKSCIN first stores an interrupt instruction in Cell 112, then requests control of KSC and waits for an interrupt from KSC. The KSC interrupts are coded to signal the completion of operation or allow for error examination. Code "1" signals the successful completion of the request control operation; Code "2" signals the successful completion of an input operation, and any other code signals that an error in the operation has occurred. Each time a KSC interrupt occurs, the instruction in Cell 112 jumps to the place in routine TKSCIN where the interrupt lookout is released and the interrupt code is analyzed. If the interrupt code is "1," train position is buffered in a wait occurs, and a return is made to release the interrupt lookout and analyze the code. On this pass the interrupt code will not be "1" (since the position has been buffered in), but will be a "2," so the position is scaled and stored, and exit is made to the Executive. If the interrupt code is not "1" or "2," the program is stopped to permit examination of the KSC error.

3.2.10 EKSCIN, ELEVATION POSITION IN THROUGH KSC ROUTINE

This routine (fig. 3-11) inputs elevation position through KSC. Essentially the program is the same as TKSCIN except that it does not request control from KSC. This was granted during the execution of TKSCIN and therefore it does not check for interrupt code "1." After the interrupt instruction is stored in Cell 112, the position is buffered in, the interrupt lookout released, the interrupt code is analyzed, and the position is scaled and stored if the buffered position was completed properly. Exit is then made to the Executive.

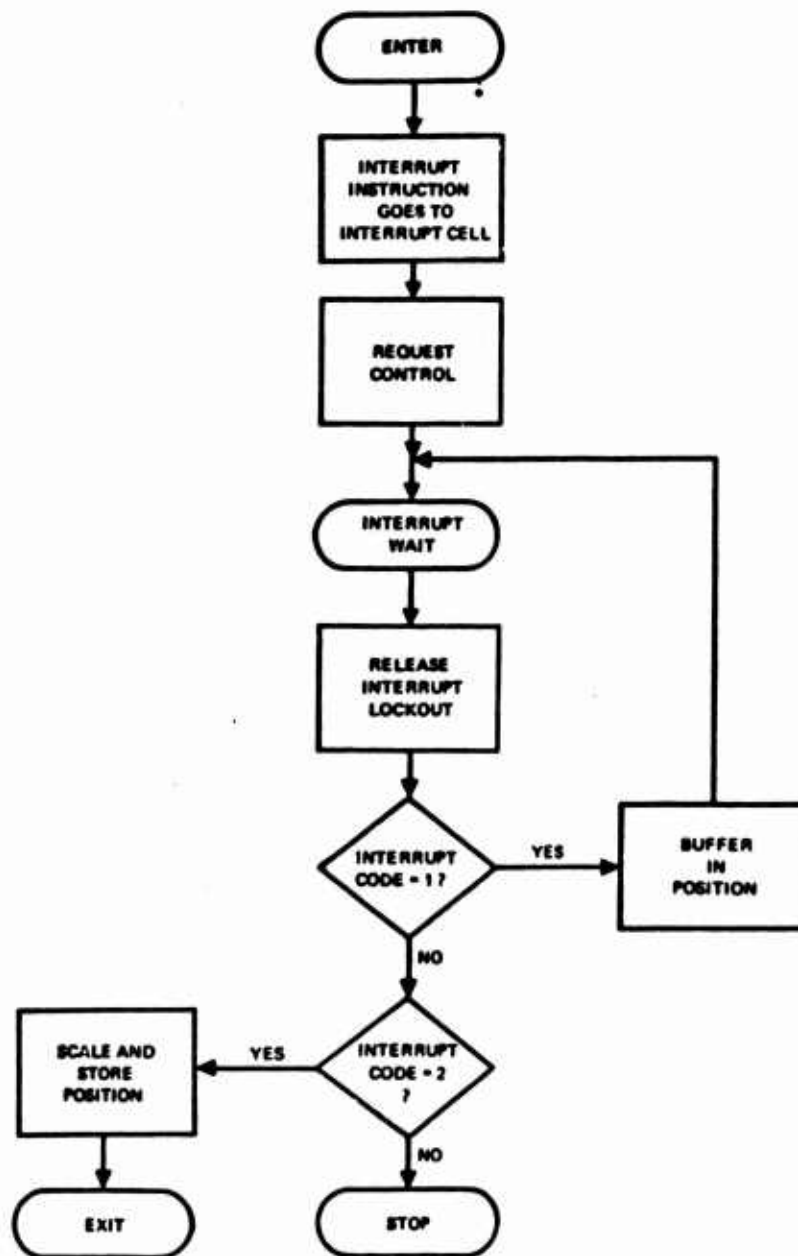


Figure 3-10. Input train position via Keyset Central routine (TKSCIN), flow diagram.

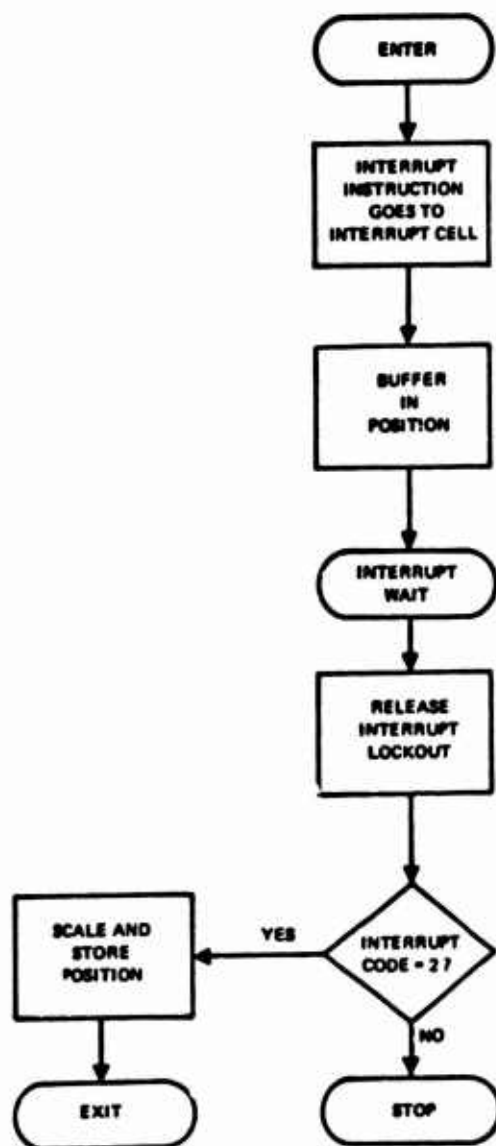


Figure 3-11. Input elevation position via K-yset central routine (EKSCIN), flow diagram.

3.2.11 TRERRN, ELERRN, CALCULATE LOOP ERROR ROUTINES

These routines (fig. 3-12) are entered to calculate the difference between the present Launcher Position and the commanded Launcher Position. The Launcher Position is subtracted from the driving function and stored for later use. A return is made to the Executive after error calculation.

3.2.12 ECTABN, ELERLN, ERROR CURVE TABLE LOOKUP ROUTINES

These routines (fig. 3-13) make use of the error curve tables TETABN and ELETBN, which were created at the time of program initialization. If the Executive determines that the initial loop error is greater than 1 degree, these routines are called to make the table lookup and appropriate error compensation. Exit is then made to the Executive. As long as loop error remains less than 1/2 degree, the program bypasses the error-curve lookup routines and goes to routines CONCON and COMCON, respectively. Error flags can be set such that routines ECTABN and ELERLN are called to make the error compensation when loop error exceeds 1/2 degree at any time during program operation.



Figure 3-12. Calculate error routine (TRERRN, train; ELERRN, elevation), flow diagram.

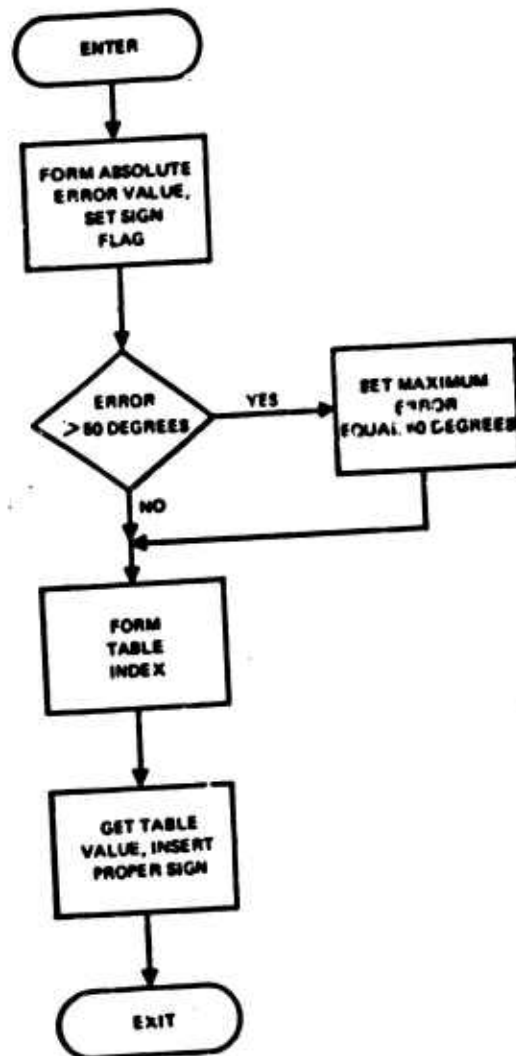


Figure 3-13. Error curve table lookup routine (ECTABN, train; ELERLN, elevation), flow diagram.

3.2.13 CONCON, COMCON, COMPLETE CONTROLLER CALCULATION ROUTINES

When the Executive determines that train and elevation loop error is less than $1/2$ degree, these routines (fig. 3-14) are entered to complete calculations of the control order (less feedforward velocity). Routines CONCON and COMCON are used only when conditions are such that the error-curve table lookup routines are not called. CONCON and COMCON scale the error, store position error history, multiply by the a_0 coefficient, add it to previously calculated position data from TRPDZN and ELPDZN, store the new controller output, and exit to the Executive.

3.2.14 TROUTN, ELOUTN, OUTPUT TO LAUNCHER ROUTINES

These routines (fig. 3-15) output the commands to train and elevation. The routines scale all inputs to system scale ($40 \text{ deg/sec} = 8 \text{ V}$); check for an overflow and make corrections as required; select the correct D/A converter; buffer the commands to the selected D/A; and exit to the Executive.

3.2.15 TRPDZN, ELPDZN, CALCULATE PARTIAL CONTROL FUNCTION FOR NEXT PASS ROUTINES

These routines (fig. 3-16) use stored train and elevation history and coefficients to form the partial control function calculation for the next pass. The outputs of these routines form part of the inputs to CONCON and COMCON and are used by CONCON and COMCON in their calculation of the controller's outputs. Upon completion, these routines return to the Executive.

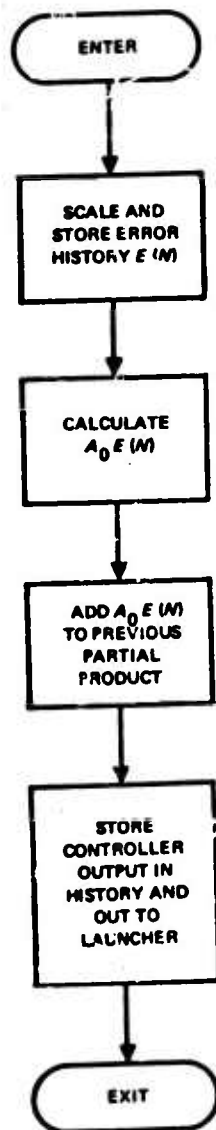


Figure 3-14. Complete controller calculations routine (CONCON, train; COMCON, elevation), flow diagram.

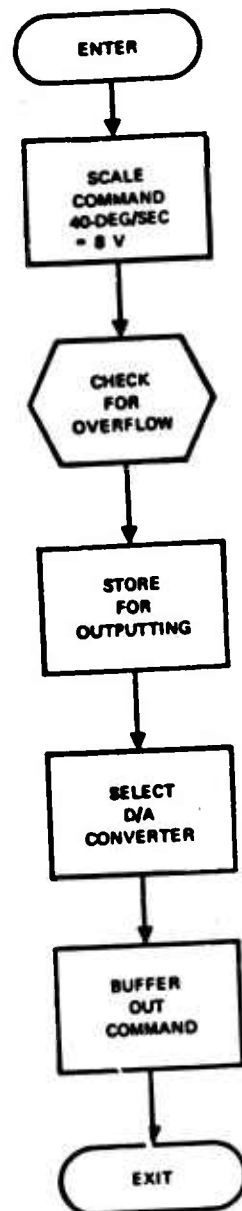


Figure 3-15. Output to launcher routine (TROUTN, train; ELOUTN, elevation), flow diagram.

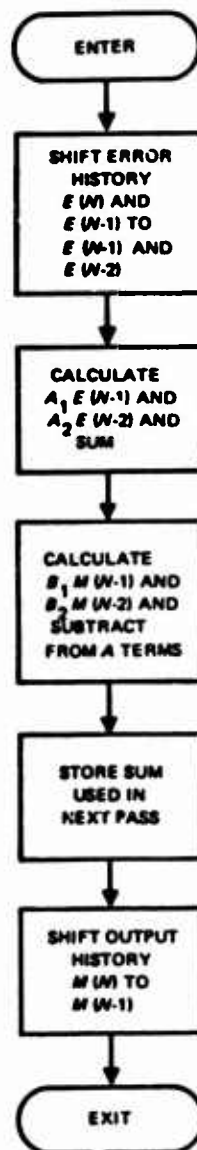


Figure 3-16. Calculate partial controller for next pass routine (TRPDZN, train; ELPDZN, elevation), flow diagram.

3.2.16 DATRDN, DATA TO BRUSH RECORDER ROUTINE

DATRDN (fig. 3-17) is used to output data to the Brush Recorder. The data are buffered to the recorder via D/A converters 1, 4, 5, and 6. Four parameters are recorded: train and elevation driving function ($TR(z)$ and $ER(z)$) and train and elevation position error ($TE(z)$ and $EE(z)$). The driving functions are scaled so that 10 degrees equal 1 volt out of the D/A converter, and the errors are scaled so that 1 degree equals 1 volt. The sequence is identical for each of the four parameters, as follows: the value is scaled as above and checked for overflow, making corrections as required; the proper D/A converter selected, and the scaled value buffered out to the recorder. At the end of this routine, return is made to the Executive, which waits for the next interrupt and sample time to reinitiate the sequence of routines.

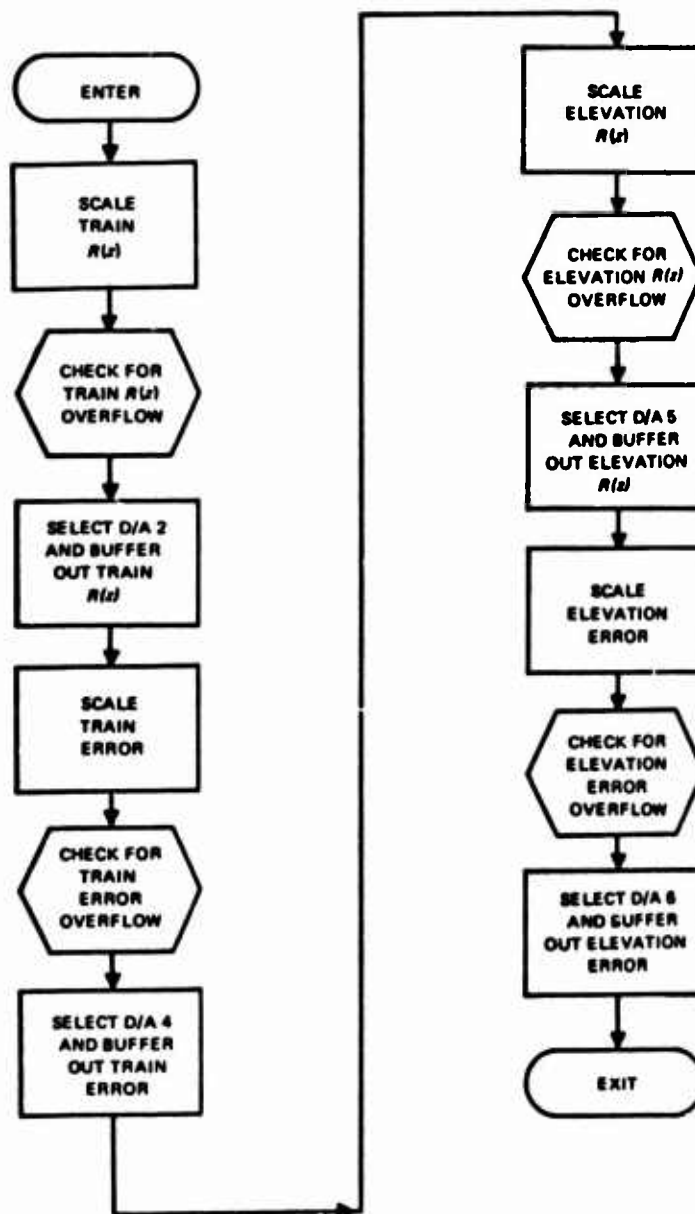


Figure 3-17. Data to Brush Recorder routine (DATRDN), flow diagram.

OVERFLOW SUBROUTINE

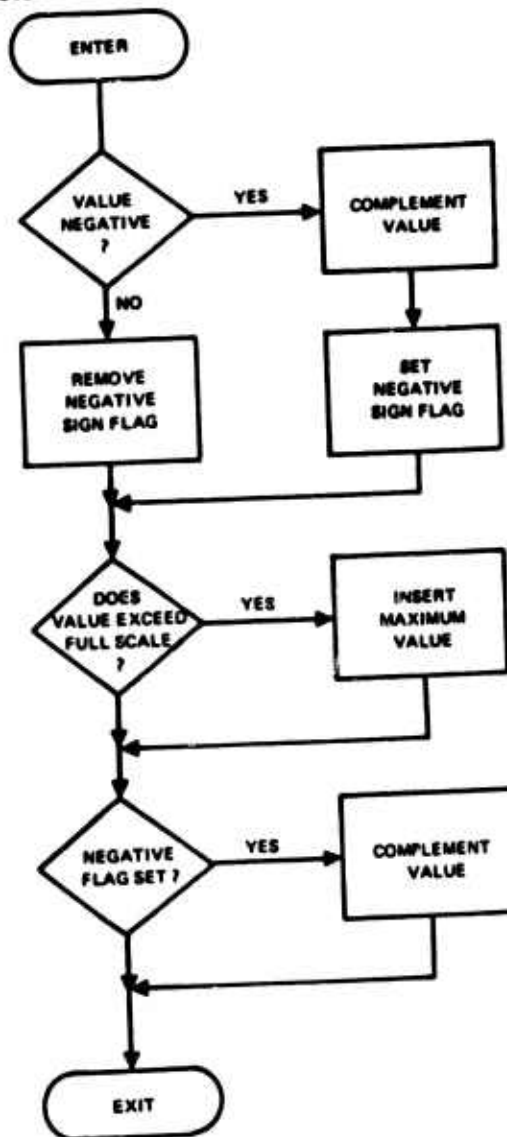


Figure 3-17. (Continued)

3.3 Storage Allocation

This program occupies memory locations 500 through 3204 octal, a total of 1348 (decimal) cells, allocated as shown in table 3-2 (see par. 5.3, Part 3, Program Listing). Table 3-2 also lists the storage locations for the three tables.

TABLE 3-2. STORAGE ALLOCATION

LOCATION	CONTENT
500-615	EXECTN
615-625	EXECTN data cells
626-1065	NOISEN
1066-1107	NOISEN data cells
1110-1132	ERRORN
1133-1141	ERRORN data cells
1142-1164	ERTBGN
1165-1170	ERTBGN data cells
1171-1177	CLOCKN
1200-1201	CLOCKN data cells
1201-1240	CNTRLN
1241-1247	CNTRLN data cells
1250-1643	TLNPSN
1644-1700	TLNPSN data cells
1701-2234	ELNPSN
2235-2270	ELNPSN data cells
2271-2312	TRVELN
2313-2317	TRVELN data cells
2320-2342	ELVELN
2343-2347	ELVELN data cells
2350-2367	TRENIN
2370-2372	TRENIN data cells
2373-2432	TKSCIN
2433-2444	TKSCIN data cells

TABLE 3-2. (Continued)

LOCATION	CONTENT
2445-2452	TRERRN
2453-2455	TRERRN data cells
2456-2507	ECTABN
2510-2513	ECTABN data cells
2514-2527	CGNCON
2530-2531	CONCON data cells
2532-2551	TROUTN
2552-2554	TROUTN data cells
2555-2574	ELENIN
2575-2600	ELENIN data cells
2601-2631	EKSCIN
2632-2634	EKSCIN data cells
2635-2642	ELERRN
2643-2644	ELERRN data cells
2645-2676	ELERLN
2677-2701	ELERLN data cells
2702-2715	COMCON
2716-2716	COMCON data cells
2717-2736	ELOUTN
2737-2740	ELOUTN data cells
2741-2774	TRPDZN
2775-3007	TRPDZN data cells
3010-3043	ELPDZN
3044-3056	ELPDZN data cells
3057-3150	DATRDN
3151-3163	DATRDN data cells
3164-3202	ATSTN
3202-3204	ATSTN data cells
3205-4214	TETABN
4215-5200	ELETBN
5201-7210	NTABN

3.4 Computer Program Functional Flow Diagrams

Figures 3-1 through 3-17 present a complete set of flow diagrams for the computer program. The diagrams are arranged in the same order as the discussions in paragraph 3.2. Only those elevation programs significantly different from train programs have their flow diagrams listed separately.

3.5 Control Functions

The program is executed under the control of an integral Executive routine. After program initialization, each routine is called in sequence by the Executive until the complete cycle has been run, then returns to the start to wait for a new order. Since this is not an operational program, neither start-over nor recovery functions were deemed necessary.

3.5.1 INPUT MODE SELECTION

The selection of input mode requires setting of a computer key. No reconfiguration of hardware is required nor it is necessary to stop and restart the computer program. Reselection can be made without noticeable interruption or interference with program operation.

3.6 Data Base Definitions

Routine, table, and item descriptions used in this program are, insofar as possible, assigned mnemonic names, which identify their functions in an abbreviated fashion. The suffix letter "N" attached to each description or label is the program identification letter assigned to the Naval Electronics Laboratory Center. The program, as written, is subject to the constraints imposed by the use of the Trim II language (field-data code) and conforms in all respects to Trim II requirements. Table 3-3 shows all program items

in alphabetical order. Each item is identified by the routine in which it is used and is further classified by a code letter, "T" for static items (those that do not change during program operation) or "D" for dynamic items (those that may change during program operation). Items that must be preset prior to program operation are identified by an asterisk (*) in the INIT. COND. column. As a further cross index to the printed output listing of table 3-5, Part 3, storage location is shown in the last column of the table.

TABLE 3-3. ALPHABETICAL ITEM INDEX

ITEM	ROUTINE	CLASS	INIT. CONT.	LOC.	ITEM	ROUTINE	CLASS	INIT. CONT.	LOC.
ACOEFN	TRPDZN	T	*	2777	CMECON	EXECTN	T		605
ADDN	TLNPSN	T		1620	CMELCN	CNTRLN	T		1232
ADDVLN	EXECTN	T		552	CNCOMN	EXECTN	T		551
AFLGN	ATSTN	D		3206	CNTRLN	ROUTINE	T		1202
AIRFFN	DATRDN	T		3163	COFTN	TRENIN	D		2373
AIRN	TRERRN	D		2455	COMCON	ROUTINE	T		2704
AIRIN	TRERRN	D		2454	CONCON	ROUTINE	T		2516
AKON	ATSTN	T		3205	CONTRN	EXECTN	T		515
AKIN	DATRDN	T		3153	CONWDN	CNTRLN	D		1247
AK2N	DATRDN	T		3154	CYCLEN	TLNPSN	T		1353
ALOOPN	ERRORN	T		1117	CYCLIN	TLNPSN	T		1416
AOUTN	DATRDN	D		3155	CYCL2N	TLNPSN	T		1456
ATSTN	ROUTINE	T		3166	CYCL3N	TLNPSN	T		1513
AZERON	ERRORN	T		1140	CYCL4N	TLNPSN	T		1537
BCOEFN	TRPDZN	T	*	3002	CYCL5N	TLNPSN	T		1557
BEGON	TRENIN	T		2374	CYCL6N	TLNPSN	T		1603
BOUTN	TROUTN	D		2554	DATRDN	ROUTINE	T		3061
BUFERN	TKSCIN	T		2414	DEGGSN	ELNPSN	T		1732
CENDN	CNTRLN	T		1240	DEGSPN	TLNPSN	T		1302
CLERP	FLNPSN	T		2137	DELTAN	TLNPSN	D		1652
CLOCKN	ROUTINE	T		1171	DELTEN	ELNPSN	D		2245
CLRP	TLNPSN	T		1526	DISPLN	EXECTN	T		0614

*Items marked by an asterisk must be preset prior to program operation.

TABLE 3-3. (Continued)

ITEM	ROUTINE	CLASS	INIT. CONT.	LOC.	ITEM	ROUTINE	CLASS	INIT. CONT.	LOC.
DWNRN	TLNPSN	T		1375	EEDIN	EKSCIN	T		2623
DWNR1N	TLNPSN	T		1440	EEH15N	ELPDZN	D		3053
DWNR2N	TLNPSN	T		1500	EFDGRN	ELNPSN	T		1770
D15N	TLNPSN	T		1656	EFDGSN	ELNPSN	T		1735
D20N	TLNPSN	T		1657	EFINSN	ELNPSN	T		2231
D30N	TLNPSN	T		1660	EFLAGN	ELVELN	D		2347
D45N	TLNPSN	T		1661	EFRDSN	ELNPSN	T		1740
D60N	TLNPSN	T		1662	EGNRPN	ELNPSN	T		2006
D75N	TLNPSN	T		1663	EHISTN	ELPDZN	D		3056
D90N	TLNPSN	T		1664	EKN	ERTBGN	T		1165
D160N	TLNPSN	T		1665	EKONEN	ELNPSN	T	•	2246
EACOFN	ELPDZN	T	•	3046	EKSCIN	ROUTINE	T		2603
EADDN	ELNPSN	T		2212	EK1N	ERTBGN	T		1166
EADVLN	EXECTN	T		606	EK2N	ERTBGN	T		1167
EAIRN	ELERRN	D		2645	ELCFGN	EXECTN	D		624
EAIR1N	ELERRN	D		2646	ELCTN	ERTBGN	D		1170
EAREFN	DATRDN	T		3165	ELECTN	EXECTN	T		571
EBCOFN	ELPDZN	T	•	3051	ELEFIN	ELENIN	T		2577
EBOUTN	ELOUTN	D		2741	ELEFN	ELOUTN	T		2742
ECNWDN	CNTRLN	D		1241	ELENIN	ROUTINE	T		2557
ECOFTN	ELENIN	D		2602	ELERLN	ROUTINE	T		2647
ECTABN	ROUTINE	T		2460	ELERRN	ROUTINE	T		2637
ECTN	EXECTN	T		535	ELESIN	EXECTN	T		603
ECYCLN	ELNPSN	T		2003	ELETBN	TABLE	T	•	4175
ECYC1N	ELNPSN	T		2045	ELNPSN	ROUTINE	T		1701
ECYC2N	ELNPSN	T		2103	ELOOPN	ERTBGN	T		1151
ECYC3N	ELNPSN	T		2124	ELOUTN	ROUTINE	T		2721
ECYC5N	ELNPSN	T		2147	ELPDZN	ROUTINE	T		3012
ECYC6N	ELNPSN	T		2174	ELPOSN	ELENIN	D		600
EDWNRN	ELNPSN	T		2025	ELVELN	ROUTINE	T		2322
EDWR1N	ELNPSN	T		2070	EMOFZN	ELERLN	D		2703

TABLE 3-3. (Continued)

ITEM	ROUTINE	CLASS	INIT. CONT.	LOC.	ITEM	ROUTINE	CLASS	INIT. CONT.	LOC.
EMZVLN	EXECTN	D		625	ESIZEN	ELVELN	T		2350
ENCOUN	ELNPSN	D		2251	ESPRPN	ELNPSN	T		2074
ENDIN	TKSCIN	T		2424	ESQWCN	ELNPSN	D		2242
ENOSTN	ELNPSN	T		2226	ESQWIN	ELNPSN	D		2240
ENSVLN	ELNPSN	T		2222	ESQWN	ELNPSN	D		1745
ENTVAN	TLNPSN	T		1326	ESTLIN	COMCON	T		2720
ENTVEN	ELNPSN	T		1756	ESTPUN	ELNPSN	T		1753
ENVALN	ELNPSN	D		2225	ESTRN	ELNPSN	T		1765
ENWDCN	EKSCIN	T		2635	ESWJPN	EXECTN	T		576
EOSWN	ELNPSN	T		1713	ETESTN	ELERLN	D		2701
EPSZRN	ELNPSN	T		1730	ETIMEN	ELVELN	T		2331
ERAMPN	ELNPSN	T		2031	ETWRPN	ELNPSN	T		2033
EREFN	DATRDN	T		3164	FVELCN	ELVELN	D		2351
ERENTN	COMCON	T		2616	EVELN	ELNPSN	T		2017
EROFTN	ELNPSN	D		2236	EVTMPN	ELVELN	T		2345
ERPISN	EKSCIN	T		2634	EXECTN	ROUTINE	T		500
ERRORN	ROUTINE	T		1110	EXEN	ELNPSN	T		1764
ERSUBN	EXECTN	T		507	EXN	TLNPSN	T		1334
ERTBCN	ROUTINE	T		1142	FDGSPN	TLNPSN	T		1305
ESAWN	ELNPSN	T		2115	FDSRPN	TLNPSN	T		1340
ESDCSN	ELNPSN	T		1743	FINSHN	TLNPSN	T		1637
ESETN	ELNPSN	T		2232	FRDSPN	TLNPSN	T		1310
ESINEN	ELNPSN	T		2141	GENRPN	TLNPSN	T		1356
ESINZN	ELNPSN	T		2255	GENRIN	ELNPSN	T		2051
ESIN1N	ELNPSN	D		2247	GENR2N	ELNPSN	T		2106
ESIN2N	ELNPSN	D		2250	GENR3N	ELNPSN	T		2127
ESIN3N	ELNPSN	D		2252	GNRP1N	TLNPSN	T		1421
ESIN4N	ELNPSN	D		2166	GNRP2N	TLNPSN	T		1461
ESIN5N	ELNPSN	D		2256	GNRP3N	TLNPSN	T		1516
ESIN6N	ELNPSN	D		2261	GNRP4N	TLNPSN	T		1542

TABLE 3-3. (Continued)

ITEM	ROUTINE	CLASS	INIT. CONT.	LOC.	ITEM	ROUTINE	CLASS	INIT. CONT.	LOC.
HGSPN	TLNPSN	T		1313	NKN	NOISEN	T		1066
INPOSN	TKSCIN	D		2440	NK1N	NOISEN	T		1067
INTCKN	EXECTN	T		616	NK2N	NOISEN	T		1070
INWDCN	TKSCIN	T		2442	NK3N	NOISEN	T		1071
IRPISN	TKSCIN	T		2435	NK9N	NOISEN	T		1077
KIN	TRENIN	T		2372	NNN	NOISEN	D		1102
KONEN	TLNPSN	D		1653	NOISEN	ROUTINE	T		626
KN	ERRORN	T		1133	NONEN	ELNPSN	T		2262
K1N	ERRORN	T		1134	NOSHTN	TLNPSN	D		1634
K2N	ERRORN	T		1175	NRN	NOISEN	D		1101
LCTN	ERRORN	D		1141	NSN	NOISEN	D		1103
LESSIN	EXECTN	T		547	NSVALN	TLNPSN	T		1630
LEVELN	TLNPSN	T		1367	NTABN	TABLE	T		5162
LEVLIN	ELNPSN	T		2062	NTENN	ELNPSN	T		54
LEXITN	TRERRN	T		2452	NVALN	TLNPSN	D		1633
LIMITN	ECTABN	T		2513	N11N	NOISEN	T		632
LNIN	EXECTN	T		524	N2N	NOISEN	T		635
LVEL1N	TLNPSN	T		1432	N3N	NOISEN	T		660
LVEL2N	TLNPSN	T		1472	N4AN	NOISEN	T		746
MASKN	CNTRLN	T		1245	NK4N	NOISEN	T		1072
MASK1N	CNTRLN	T		1246	NK5N	NOISEN	T		1073
MOFZN	CONCON	D		2533	NK6N	NOISEN	T		1074
MODJPN	EXECTN	T		617	NK7N	NOISEN	T		1075
MZVELN	EXECTN	D		622	NK8N	NOISEN	T		1076
NAN	NOISEN	D		1104	N4N	NOISEN	T		713
NBN	NOISEN	D		1105	N5N	NOISEN	T		760
NCN	NOISEN	T		1106	N6N	NOISEN	T		1013
NCOUN	TLNPSN	T		1670	N7N	NOISEN	T		1034
NDN	NOISEN	T		1107	N8N	NOISEN	T		1040
NFIVEN	ELNPSN	T		2263	N9N	NOISEN	T		1053
NKAN	NOISEN	T		1100	N11N	NOISEN	T		1056

TABLE 3-3. (Continued)

ITEM	ROUTINE	CLASS	INIT. CONT.	LOC.	ITEM	ROUTINE	CLASS	INIT. CONT.	LOC.
N15N	ELNPSN	T		2265	STEPUN	TLNPSN	T		1323
N20N	ELNPSN	T		2266	STLIN	CONCON	T		2532
N30N	ELNPSN	T		2267	SVSRPN	TLNPSN	T		1444
N45N	ELNPSN	T		2270	SWJPN	EXECTN	T		542
N60N	ELNPSN	T		2277	TCNWDN	CNTRLN	D		1243
PKN	TROUTN	T		2555	TEFN	TROUTN	T		2554
POSWN	TLNPSN	T		1262	TEHISN	TRPDZN	D		3004
POSZRN	TLNPSN	T		1300	TEMPN	ERRORN	D		1136
P180N	TKSCIN	T		2445	TEN	ECTABN	T		2512
P360N	TKSCIN	T		2446	TESTN	ECTABN	D		2514
REENTN	TKSCIN	T		2405	TETABN	TABLE	T		3210
REFN	DATRDN	T		3162	THISTN	TRPDZN	D		3007
REQCON	TKSCIN	T		2436	TIMEN	CLOCKN	T		1201
KESTRN	TLNPSN	T		1335	TIMERN	CLOCKN	D		1200
ROFTN	TLNPSN	D		1644	TKSCIN	ROUTINE	T		2375
ROFT1N	TLNPSN	D		1645	TLNPSN	ROUTINE	T		1250
SAFT1N	EXECTN	T		512	TNPOSN	EXECTN	T		516
SAFTN	TLNPSN	D		1504	TRENIN	ROUTINE	T		2352
SETN	TLNPSN	T		1640	TRERRN	ROUTINE	T		2447
SINEN	TLNPSN	T		1551	TROUTN	ROUTINE	T		2534
SEVE1N	TLNPSN	D		1654	TRPDZN	ROUTINE	T		2743
SINE2N	TLNPSN	D		1655	TRVELN	ROUTINE	T		2272
SINE4N	TLNPSN	D		1575	TSINEN	TLNPSN	D		1672
SINE6N	TLNPSN	T		1671	TSIN4N	TLNPSN	D		1675
SINZ1N	TLNPSN	D		1700	TWON	TKSCIN	T		2444
SFRPN	TLNPSN	T		1530	TWSRPN	TLNPSN	T		1403
SJWCH	TLNPSN	D		1647	VARCON	EXECTN	T		620
SJWCTN	TLNPSN	D		1650	VARNUN	EXECTN	T		621
SQWCTN	TLNPSN	D		1651	VARTMN	EXECTN	T		502
SQWLN	TLNPSN	D		1646	VELOCN	TRVELN	D		2321
SQWN	TLNPSN	D		1316	VFLAGN	TRVELN	D		2317

TABLE 3-3. (Continued)

ITEM	ROUTINE	CLASS	INIT. CONT.	LOC.
VSIZE	TRVELN	T		2320
VTEMP	TRVELN	D		2315
VTIMEN	TRVELN	T	•	2301
WAITIN	TKSCIN	T		2404
WAITSN	EXECTN	T		513
WONEN	TRERRN	T		2457
WON	TLNPSN	T		1667
ZRAMPN	TLNPSN	T		1401
ZRON	TLNPSN	T		1666

4.0 QUALITY ASSURANCE

Since the computer program described was designed for feasibility demonstration only and not for operational environment, no formal quality assurance procedures beyond those required to effectively implement the program were taken. Prior to the tests described in Parts 5 and 6, the control function portions of the program were rigorously tested at NELC. Control functions were tested by digital simulation of launcher functions; control equations were tested in a hybrid simulation using the EAI TR-48 analog computer and the UNIVAC CP 789 digital computer, and the results in all cases indicated the validity of the respective equations and program sequences.

No capability for simulating launcher input and output interfaces existed at NELC, and therefore complete program tests could not be run prior to the feasibility demonstrations that were held at NWTCP during the period 10 July - 28 August 1968. These tests conclusively demonstrated the validity of the program and the feasibility of launcher control by digital techniques. Comprehensive documentation of the tests will be found in Parts 5 and 6.

5.0 SUPPLEMENTARY STRUCTURAL DETAILS

5.1 General

The information contained in this section is presented to assist in understanding the computer program structure. Since the program was not designed for an operational environment, many functions contained within it will not be needed in order to achieve operational launcher control by digital techniques.

The Appendix contains a suggested format for an operational control program. The approach to the design and implementation of the program is predicated upon demonstrating the feasibility of digital control; therefore many variables are included to insure that all predictable operational functions can be thoroughly checked. No extensive effort has been made to optimize the program. The program, involving complete closed-loop digital control, represents a complex programming effort. The computer performs the functions of launcher order generation, error determination, and nonlinear and linear compensation. Table 3-4 shows a comparison between conventional analog fire-control symbols and the digital equivalents used in the program.

TABLE 3-4. SYMBOLOGY

Analog Symbol	Digital Equivalent	Definition
Bdg'	COFTN	Launcher train position
Edg'	ECOFTN	Launcher elevation position
$Bdgl'$	ROFTN	Train rotation order
$Edgl'$	EROFTN	Elevation position order
$DBdg'$	*VELOCN	Train velocity order
$DEdg'$	*EVELCN	Elevation velocity order

*Filtered and multiplied by a gain constant.

5.2 Philosophy

Program operation is as close an approach to launcher digital control as can be achieved in a nonoperational or test environment. All functions of launcher control are performed by the digital computer. The control signal is converted to an analog output and fed to an amplifier that feeds the launcher torque motor. The feedback path to the computer can take one of two paths: (1) through a digital data converter that converts coarse and fine synchro signals to digital quantities, and (2) through a 15-bit Brush encoder that converts the launcher shaft position directly to digital data. This feedback information is used by the computer in error determination. The two feedback paths were provided for failure back-up and to demonstrate the feasibility of using shaft-to-digital encoders in such a situation.

The total computer program comprises 25 routines and was designed and implemented, as previously stated, to demonstrate feasibility, but it is readily adaptable to modification for use in an operational environment. Storage allocation can be drastically reduced since only the error-curve tables would be required for reference. The routines used in the operational program can be optimized, and since only a single sampling rate would be used, those routines affected by sampling rate would become shorter and less complex.

5.3 Program Listing

This Section contains a printed output listing (table 3-5) of the current computer program. The listing contains all instructions and, with the material contained in the foregoing Sections of Part 3, constitutes a complete computer program design.

TABLE 3-5. PROGRAM LISTING

MEM. STRG. USED 2512

00500 THRU 03206

00321 THRU 00321

04175 THRU 04175

05162 THRU 05162

0 0 OPRPG'ASRUC'(WRITTEN IN 1968 BY R. NEWLIN)

R8

00500	12	0616	1	OEXECTN	CENTAL'INTCKNCSYNC INTERRUPT INSTR
00501	44	0016	2	O	OSTRAL'16
00502	10	0621	3	OVARIMN	CENTAU'VARNUNOCALCULATES SAMPLES/SEC
00503	50	4322	4	O	ORSHA'180
00504	26	1201	5	O	ODIVA'TIMEN
00505	44	0620	6	O	OSTRAL'VARCON
00506	76	0626	7	O	ORJP'N0ISEN
00507	76	1110	10	OERSUBN	ORJP'ERR0RNOTRAIN ERROR TABLE GENERATOR
00510	76	1142	11	O	ORJP'ERT0GN0ELEV ERR TAB GEN
00511	50	5540	12	O	OST0P'
00512	76	1171	13	OSAMIMN	ORJP'CL0CKNCSAMPLE TIME SUBROUTINE
00513	50	2400	14	OWAITN	OWTFI'OWAIT FOR SYNC INTERRUPT
00514	34	0513	15	O	OJP'WAITN
00515	76	1202	16	OC0NTRN	ORJP'CNTRLN0CENTREL PANEL SUBROUTINE
00516	76	1250	17	OTNP0SN	ORJP'ILNPSN0TRAIN POSITION COMMANDS
00517	76	1701	20	O	ORJP'ELNPSN0ELEV POS COMMANDS
00520	76	2272	21	O	ORJP'THVELN0CALCULATE TRAIN VELOCITY
00521	76	2322	22	O	ORJP'ELVELN0CALCULATE ELEV VELOCITY
00522	50	5004	23	O	OSKP'4
00523	34	0526	24	O	OJP'L0K+3
00524	76	2352	25	OLNIN	ORJP'TRENIN0INPUT TRAIN POS VIA ENCODER
00525	34	0527	26	O	OJP'L0K+2
00526	76	2375	27	O	ORJP'TKSCIN0INPUT TRAIN POS VIA KSC
00527	76	2447	30	O	ORJP'TREH0N0CALCULATE TRAIN ERROR
00530	10	2455	31	O	CENTAU'ALRN
00531	50	4412	32	O	OSF'100
00532	12	0017	33	O	CENTAL'17
00533	61	0542	34	O	OJPALZ'SWJPN
00534	40	0017	35	O	OCL'M00JPN
00535	76	2460	36	OECTN	ORJP'ECTA0NOTRAIN ERROR TABLE LOOKUP
00536	36	0005	37	O	OCL0AR'6'TEHISN
00537	41	3004			

TABLE 3-5. (Continued)

00540	73	0537			
00541	34	0552	40	□	QJP*ADVLN
00542	57	0617	41	QSWJPN	QISK*MDJPN
00543	34	0547	42	□	QJP*LESSIN
00544	50	4401	43	□	QSF*1
00545	12	0017	44	□	QENTAL*17
00546	63	0555	45	□	QJPALNZ*ECTN
00547	70	0001	46	QLESSIN	QENTALK*1
00550	44	0617	47	□	QSTRAL*MDJPN
00551	76	2516	50	QCNCCN	QKJP*CNCCNOCOMplete TRAIN CONTROLLER CALC
00552	12	2533	51	QADVLN	QENTAL*MDJPN
00553	14	2321	52	□	QADVAL*VELCNOCADS VELOCITY TO TRAIN M(Z)
00554	44	0622	53	□	QSTRAL*MDJPNSTORE FOR QUTPUTTING
00555	76	2534	54	□	QKJP*TRQUTNOOUTPUT TRAIN COMMAND
00556	50	5004	55	□	QSKP*4
00557	34	0562	56	□	QJP*LOK+3
00560	76	2557	57	□	QKJP*ELENINOINPUT ELEV POS VIA ENCODER
00561	34	0563	60	□	QJP*LOK+2
00562	76	2603	61	□	QKJP*EKSCINOINPUT ELEV POS VIA KSC
00563	76	2637	62	□	QKJP*ELEKRNOCALC ELEV EROR
00564	10	2645	63	□	QENTAL*EALRN
00565	50	4412	64	□	QSF*100
00566	12	0017	65	□	QENTAL*17
00567	61	0576	66	□	QJPALZ*ESWJPN
00570	40	0624	67	□	QCL*ELCFGN
00571	76	2647	70	QELECTN	QKJP*ELEKRLNOELEV ERROR TAB LOOKUP
00572	36	0005	71	□	QCLEAR*6*EEHISN
00573	41	3053			
00574	73	0573			
00575	34	0606	72	□	QJP*EADVLN
00576	57	0624	73	QESWJPN	QISK*ELCFGN
00577	34	0603	74	□	QJP*ELESIN
00600	50	4401	75	□	QSF*1
00601	12	0017	76	□	QENTAL*17
00602	63	0571	77	□	QJPALNZ*ELECTN
00603	70	0001	100	QELESIN	QENTALK*1
00604	44	0624	101	□	QSTRAL*ELCFGN
00605	76	2704	102	QCMCCN	QKJP*CMCCNOCOMplete ELEV CONT CALC
00606	12	2703	103	QEA	QENTAL*EMKFZN
00607	14	2351	104	□	QADVAL*EVELCNOCADS VEL TO ELEV M(Z)

TABLE 3-5. (Continued)

00610	44	0625	105	0	OSTRAL*EMZVLNOSTORE FOR OUTPUTTING
00611	76	2721	106	0	ORJP*ELDTNOUTPUT ELEV COMMAND
00612	76	2743	107	0	ORJP*TRPTZNOCALC TRAIN I(Z),NEXT PASS
00613	76	3012	110	0	ORJP*ELPDZNOCALC ELEV D(Z),NEXT PASS
00614	76	3061	111	DISPLN	ORJP*DATRNDATA TO BRUSH RECORDER
00615	34	0513	112	0	CJP*WAITSM
00616	76	1171	113	0INTCKN	ORJP*CLCKN
00617	00	0000	114	0MEDJPN	00*
00620	00	0000	115	0VARC0N	00*0SAMPLES PER SECOND
00621	00	2000	116	0VARHUN	010240*
00622	00	0000	117	0MZVELN	00*OTRAIN M(Z) PLUS VELOCITY, SF7
00623	00	0000	120	0	00*
00624	00	0000	121	0ELCFGW	00*
00625	00	0000	122	0EMZVLN	00*DELEV M(Z) PLUS VEL,SF7
00626	00	0000	123	0NGISEN	00*ONWISE TABLE RTN
00627	12	1067	124	0	0ENTAL*MXIN
00630	44	1101	125	0	OSTRAL*NRN
00631	40	0001	126	0	OCL*1
00632	50	7202	127	0VIN	0ENTICK*2
00633	40	0002	130	0	OCL*2
00634	40	1102	131	0	OCL*NNV
00635	12	1101	132	0M2N	0ENTAL*NRN
00636	52	1106	133	0	0SLCL*NCN
00637	14	0001	134	0	0ADPAL*1
00640	14	0002	135	0	0ADPAL*2
00641	24	1070	136	0	0MULAL*MX2N
00642	44	1101	137	0	OSTRAL*NRN
00643	50	4212	140	0	0KSHAL*12
00644	14	1102	141	0	0ADPAL*NNN
00645	44	1102	142	0	OSTPAL*NRN
00646	56	1071	143	0	0BSK*NRKN
00647	34	0635	144	0	0JP*N2V
00650	50	7201	145	0	0ENTICK*1
00651	45	5162	146	0	OSTRAL*NTARN
00652	56	1072	147	0	0BSK*NRKN
00653	34	0632	150	0	0JP*N1N
00654	40	0001	151	0	OCL*1
00655	40	1103	152	0	OCL*NSN
00656	40	1104	153	0	OCL*NSN
00657	40	1105	154	0	OCL*NSN

TABLE 3-5. (Continued)

00660	13	5162	155	DN3N	CENTRAL B*NTABN
00661	14	1103	156	□	CADIAL *NSN
00662	44	1103	157	□	OSTRAL *NSN
00663	13	5162	160	□	CENTRAL B*NTABN
00664	50	4606	161	□	CLSHAL *S
00665	16	1103	162	□	OSUBAL *NSN
00666	16	1103	163	□	OSUBAL *NSN
00667	16	1103	164	□	OSUBAL *NSN
00670	14	1104	165	□	CADIAL *NAN
00671	44	1104	166	□	OSTRAL *NAN
00672	13	5162	167	□	CENTRAL B*NTABN
00673	50	4605	170	□	CLSHAL *S
00674	16	1103	171	□	OSUBAL *NSN
00675	16	1103	172	□	OSUBAL *NSN
00676	14	1105	173	□	CADIAL *NBN
00677	44	1105	174	□	OSTRAL *NBN
00700	56	1073	175	□	OSK *NKN
00701	34	0660	176	□	CJP *NSN
00702	37	0001	177	□	CENTRAL B*NTABN
00703	12	5162	200	□	CENTRAL *NTABN
00704	50	4605	201	□	CLSHAL *S
00705	44	1102	202	□	OSTRAL *NNN
00706	14	1104	203	□	CADIAL *NAN
00707	44	1104	204	□	OSTRAL *NAN
00710	12	1102	205	□	CENTRAL *NNN
00711	50	4203	206	□	CLSHAL *S
00712	44	1105	207	□	OSTRAL *NBN
00713	13	5162	210	DN4N	CENTRAL B*NTABN
00714	17	5122	211	□	OSUBAL B*NTABN-40
00715	14	1103	212	□	CADIAL *NSN
00716	44	1103	213	□	OSTRAL *NSN
00717	13	5162	214	□	CENTRAL B*NTABN
00720	15	5162	215	□	CADIAL B*NTABN
00721	15	5123	216	□	CADIAL B*NTABN-37
00722	50	4605	217	□	CLSHAL *S
00723	16	1103	220	□	OSUBAL *NSN
00724	16	1103	221	□	OSUBAL *NSN
00725	16	1103	222	□	OSUBAL *NSN
00726	14	1104	223	□	CADIAL *NAN
00727	44	1104	224	□	OSTRAL *NAN

TABLE 3-5. (Continued)

00730	13	5162	225	□	DENTALB*NTABN
00731	15	5123	226	□	CAUDALB*NTABN-37
00732	50	4605	227	□	CLSHAL*5
00733	16	1103	230	□	OSUBAL*NSN
00734	16	1103	231	□	OSUBAL*NSN
00735	14	1105	232	□	CAUDAL*NSN
00736	44	1105	233	□	OSTRAL*NSN
00737	12	1104	234	□	DENTAL*NSN
00740	50	4204	235	□	ORSHAL*4
00741	14	1105	236	□	CAUDAL*NSN
00742	50	4207	237	□	ORSHAL*7
00743	45	5122	240	□	OSTRALB*NTABN-40
00744	56	1072	241	□	OSK*NK4N
00745	34	0713	242	□	CJP*N4N
00746	40	0001	243	CH4AN	OCL*1
00747	70	0000	244	□	DENTALK*0
00750	10	1074	245	□	DENTALU*NK6N
00751	50	4301	246	□	ORSHA*1
00752	26	1201	247	□	ODIVA*TIMEN
00753	44	1066	250	□	OSTRAL*NNN
00754	50	4213	251	□	ORSHAL*110
00755	61	1034	252	□	CJPALZ*N7N
00756	50	4201	253	□	ORSHAL*1
00757	61	1013	254	□	CJPALZ*N6N
00760	13	6622	255	ON5N	DENTALB*NTABN+8000
00761	44	1103	256	□	OSTRAL*NSN
00762	17	6623	257	□	OSUBALB*NTABN+8010
00763	50	4722	260	□	CLSHA*180
00764	50	4322	261	□	ORSHA*180
00765	26	1107	262	□	ODIVA*NNN
00766	50	6100	263	□	CCPAL*
00767	44	1104	264	□	OSTRAL*NSN
00770	42	1105	265	□	OSTRB*NSN
00771	12	1105	266	□	DENTAL*NSN
00772	50	4602	267	□	CLSHAL*2
00773	14	1105	270	□	CAUDAL*NSN
00774	44	0001	271	□	OSTRAL*1
00775	12	1103	272	□	DENTAL*NSN
00776	45	5162	273	□	OSTRALB*NTABN
00777	14	1104	274	□	CAUDAL*NSN

TABLE 3-5. (Continued)

01000	45	5163	275	□	OSTRALB*NTABN+1
01001	14	1104	276	□	OADDAL*NSN
01002	45	5164	277	□	OSTRALB*NTABN+2
01003	14	1104	300	□	OADDAL*NSN
01004	45	5165	301	□	OSTRALB*NTABN+3
01005	14	1104	302	□	OADDAL*NSN
01006	45	5166	303	□	OSTRALB*NTABN+4
01007	32	1105	304	□	OENTB*NSN
01010	56	1075	305	□	OBSK*NSN
01011	34	0760	306	□	OJP*NSN
01012	34	1034	307	□	OJP*NSN
01013	13	6146	310	ON 6N	OENTALB*NTABN+5000
01014	44	1103	311	□	OSTRAL*NSN
01015	17	6147	312	□	OSUBALB*NTABN+5010
01016	50	4201	313	□	ORSHAL*1
01017	50	6100	314	□	OCPAL*
01020	44	1104	315	□	OSTRAL*NSN
01021	42	1105	316	□	OSTRB*NSN
01022	12	1105	317	□	OENTAL*NSN
01023	50	4601	320	□	OLSHAL*1
01024	44	0001	321	□	OSTRAL*1
01025	12	1103	322	□	OENTAL*NSN
01026	45	5162	323	□	OSTRALB*NTABN
01027	14	1104	324	□	OADDAL*NSN
01030	45	5163	325	□	OSTRALB*NTABN+1
01031	32	1105	326	□	OENTB*NSN
01032	56	1076	327	□	OBSK*NSN
01033	34	1013	330	□	OJP*NSN
01034	40	0001	331	ON 7N	OCL*1
01035	40	7133	332	□	OCL*NTABN+10010
01036	40	7134	333	□	OCL*NTABN+10020
01037	40	1103	334	□	OCL*NSN
01040	13	5162	335	ON 8N	OENTALB*NTABN
01041	14	7133	336	□	OADDAL*NTABN+10010
01042	44	7133	337	□	OSTRAL*NTABN+10010
01043	13	5162	340	□	OENTALB*NTABN
01044	25	5162	341	□	OMULAI*NTABN
01045	50	4307	342	□	ORSHAL*1
01046	14	1103	343	□	OADDAL*NSN
01047	44	1103	344	□	OSTRAL*NSN

TABLE 3-5. (Continued)

01050	57 1077	345	O	DISK'NK9N
01051	34 1053	346	O	OJP'N9N
01052	34 1056	347	O	OJP'N11N
01053	56 1100	350	ON9N	O3SK'NKAN
01054	34 1040	351	O	OJP'N8N
01055	55 0625	352	O	O1JP'N6ISEN
01056	12 1103	353	ON11N	OENTAL'NSN
01057	50 4207	354	O	ORSHAL'7
01060	14 7134	355	O	OADIAL'NTA3N+1002D
01061	44 7134	356	O	OSTRAL'NTABN+1002D
01062	40 1103	357	O	OCL'NSN
01063	70 0177	360	O	OENTALK'127D
01064	44 1077	361	O	OSTRAL'NK9N
01065	34 1053	362	O	OJP'N9N
01066	00 0000	363	ONKN	00'
01067	17 5631	364	ONK1N	0175631'
01070	23 0455	365	ONK2N	0230455'
01071	00 0013	366	ONK3N	013'
01072	00 2010	367	ONK4N	02010'
01073	00 0037	370	ONK5N	037'
01074	00 0001	371	ONK6N	01'
01075	00 0307	372	ONK7N	01990'
01076	00 0763	373	ONK8N	04990'
01077	00 0177	374	ONK9N	01270'
01100	00 1750	375	ONKAN	010000'
01101	00 0000	376	ONRN	00'
01102	00 0000	377	ONNN	00'
01103	00 0000	400	ONSN	00'
01104	00 0000	401	ONAN	00'
01105	00 0000	402	ONBN	00'
01106	37 7777	403	ONCN	0377777'
01107	00 0005	404	ONDN	05'
01110	00 0000	405	ONRRN	00'OTRAIN ERROR CURVE TABLE GENERATOR
01111	10 1140	406	O	OENTAU'AZERKNOCLEARS AU REG
01112	12 1135	407	O	OENTAL'K2N
01113	44 0325	410	O	OSTRAL'TETABN+4
01114	44 1136	411	O	OSTRAL'TEMP
01115	50 7201	412	O	OENTICK'1
01116	36 0005	413	O	OENTBK'SOSTARTS STORING AT 1 DEGREE
01117	12 1136	414	CALORPN	OENTAL'TEMPNOSTART CALCULATING VALUE

TABLE 3-5. (Continued)

01120	14	1134	415	□	QADUAL*KN
01121	44	1137	416	□	QSTHAL*TEMPN+1
01122	12	1133	417	□	QENTAL*KN
01123	26	1137	420	□	QDIVA*TEMPN+1
01124	14	1136	421	□	QADUAL*TEMPN
01125	44	1136	422	□	QSTHAL*TEMPN
01126	45	0321	423	□	QSTHALB*ETABNO STORES VALUE IN TABLE
01127	10	1140	424	□	QENTAU*AZERON
01130	56	1141	425	□	QBSK*ELCTN0500
01131	34	1117	426	□	QJP*AL00PN001 FINISHED
01132	55	1110	427	□	QIJP*ERR0RNOEXIT
01133	12	1727	430	OKN	Q121727°
01134	00	1027	431	OKIN	Q1027°
01135	00	0700	432	OK2N	Q700°
01136	00	0000	433	QTEMPN	Q0°
01137	00	0000	434	□	Q0°
01140	00	0000	435	QAZERON	Q0°
01141	00	0764	436	QELCTN	Q5000°
01142	00	0000	437	QERTBGN	Q0°CELEV ERROR CURVE TAB GENERATOR
01143	10	1140	440	□	QENTAU*AZERON
01144	12	1167	441	□	QENTAL*EK2N
01145	44	4201	442	□	QSTHAL*ELET3N+4
01146	44	1136	443	□	QSTHAL*TEMPN
01147	50	7201	444	□	QENTICK°I
01150	36	0005	445	□	QENT9K°S
01151	12	1136	446	QEL00PN	QENTAL*TEMPN
01152	14	1166	447	□	QADUAL*EKIN
01153	44	1137	450	□	QSTHAL*TEMPN+1
01154	12	1165	451	□	QENTAL*EKN
01155	26	1137	452	□	QDIVA*TEMPN+1
01156	14	1136	453	□	QADUAL*TEMPN
01157	44	1136	454	□	QSTHAL*TEMPN
01160	45	4175	455	□	QSTHALB*ELET9N
01161	10	1140	456	□	QENTAU*AZERON
01162	56	1170	457	□	QBSK*ELCTN
01163	34	1151	460	□	QJP*EL00PN
01164	55	1142	461	□	QIJP*ERT3GN
01165	12	1727	462	QEKIN	Q121727°
01166	00	1027	463	QEK1N	Q1027°
01167	00	0700	464	QEK2N	Q700°

TABLE 3-5. (Continued)

01170	00 0764	465	SELCTN	OSUEN
01171	00 0800	466	COLCKN	OU'CEAMPLE PERIOD SUBROUTINE
01172	57 1200	467	□	CISA'TIMERNOCOUNTS TIME
01173	54 1171	470	□	OJPER'CLECKNOPT TIME YET
01174	12 1201	471	□	CENTAL'TIMENDINITIALIZE TIME PERIOD
01175	44 1200	472	□	OSTRAL'TIMER
01176	50 0800	473	□	ORIL'DENABE ALL INTERRUPTS
01177	34 0915	474	□	OJP'CONTRNCTO CONTROL PANEL SUBROUTINE
01200	00 0000	475	OTIMERN	OU'VALUE BEING DECREMENTED
01201	00 0002	476	OTIMEN	OSU'OU.02 SEC PERIOD
01202	00 0000	477	CONTRLN	OU'
01203	12 1247	500	□	CENTAL'CONWDM
01204	50 1100	501	□	OSUFIN'0'AD'1'CONWDM
01205	50 1247			
01206	00 1247			
01207	52 1245	502	□	CSLCL'MASKN
01210	10 1140	503	□	CENTAU'AZEREN
01211	50 4704	504	□	CLSHA'4
01212	50 4204	505	□	ORSHAL'4
01213	46 1242	506	□	OSTRAU'ECNWDN+1
01214	44 1244	507	□	OSTRAL'ICNWDN+1
01215	50 1500	510	□	OINSTP'0
01216	12 1247	511	□	CENTAL'CONWDM
01217	52 1245	512	□	CSLCL'MASKN
01220	10 1140	513	□	CENTAU'AZEREN
01221	50 4704	514	□	CLSHA'4
01222	50 4204	515	□	ORSHAL'4
01223	46 1241	516	□	OSTRAU'ECNWDN
01224	44 1243	517	□	OSTRAL'ICNWDN
01225	02 1244	520	□	CCNAL'ICNWDN+1
01226	61 1232	521	□	OJPER'CMELCN
01227	35 0007	522	□	CCLEAR'00'ERFTN
01230	41 1644			
01231	73 1230			
01232	50 4322	523	CCMELCN	ORSHF'1KT
01233	02 1242	524	□	CCMAL'ECNWDN+1
01234	61 1240	525	□	OJPER'CONDM
01235	36 0010	526	□	CCLEAR'00'ERFTN
01236	41 2236			
01237	73 1236			

TABLE 3-5. (Continued)

01240	55	1202	527	OCENDN	OJJP'CNTRLN
01241	00	0000	530	OCENWEN	00'
01242	00	0000	531	O	00'
01243	00	0000	532	OTCNWEN	00'
01244	00	0000	533	O	00'
01245	74	0017	534	OMASKN	0740017'
01246	01	0000	535	OMASKIN	0010000'
01247	00	0000	536	OCUNWEN	00'
01250	00	0000	537	CTLNPSN	00'OTRAIN POSITION COMMANDS
01251	12	1644	540	O	CENTAL'R/FTNOSHIFT P(T)
01252	44	1645	541	O	OSTRAL'R/FTIN
01253	50	7201	542	O	CENTICH'I
01254	12	1243	543	O	CENTAL'TCNWEN
01255	52	1245	544	O	OSLCL'MASKNOREMOVES NOISE BITS
01256	44	0001	545	O	OSTRAL'ICCNTRL WORD INTO 31
01257	70	0014	546	O	CENTALA'12DCHECKS TO SEE IF REQUESTED
01260	16	0001	547	O	OSUBAL'ICFUNCTION EXISTS
01261	67	1263	550	O	OJPALNG'PLSN+ICILLEGAL FUNCTION CODE
01262	35	1263	551	OPCSN	OJP3'PUSH+1
01263	34	1300	552	O	OJP'PUSZRNCJUMPS TO ZERO COMMAND
01264	34	1302	553	O	OJP'DEGSPN01 DEGREE STEP
01265	34	1305	554	O	OJP'FDGSPN010 DEGREE STEP
01266	34	1310	555	O	OJP'FHDSPN045 DEGREE STEP
01267	34	1313	556	O	OJP'HDGSPN090 DEGREE STEP
01270	34	1316	557	O	OJP'SOUN075 DEGREE SQUARE WAVE
01271	34	1340	560	O	OJP'FDRHPN05 DEGREE/SEC RAMP
01272	34	1403	561	O	OJP'TVL'HPN020 DEGREE/SEC RAMP
01273	34	1444	562	O	OJP'SVSHPN030 DEGREE/SEC RAMP
01274	34	1530	563	O	OJP'SPRPN030 STEP, 15 RAMP
01275	34	1504	564	O	OJP'SAUN0SANTLTH
01276	34	1551	565	O	OJP'SIN0SINEWAVE, 30/9
01277	34	1575	566	O	OJP'SINE40SINEWAVE, 17/4.5
01300	40	1644	567	CP0SZRN	OCL'R/FTN0ZERES POSITION P(T)
01301	34	1620	570	O	OJP'ADN00LES TO ADD NOISE
01302	70	1200	571	COEGSPN	CENTALA'20001 DEGREE STEP
01303	44	1644	572	O	OSTRAL'R/FTIN
01304	34	1620	573	O	OJP'ADN'
01305	70	2400	574	CFDGSPN	CENTALA'240010 DEGREE STEP
01306	44	1644	575	O	OSTRAL'R/FTIN
01307	34	1620	576	O	OJP'ADN'

TABLE 3-5. (Continued)

01310	12	1661	577	CFRDSRN	CENTAL'D45N045 DEG STEP
01311	44	1644	600	□	OSTRAL'R0FTN
01312	34	1620	601	□	OJP'ADDN
01313	12	1664	602	OHGSPN	CENTAL'D90N090 DEGREE STEP
01314	44	1644	603	□	OSTRAL'R0FTN
01315	34	1620	604	□	OJP'ADDN
01316	70	0012	605	OSQWN	CENTALK'100010SEC PERIOD
01317	24	0620	606	□	OMULAL'VARC0N0SAMPLES PER SECOND
01320	44	1647	607	□	OSTRAL'SQWCN0SAMPLES PER CYCLE
01321	50	4201	610	□	ORSHAL'I
01322	44	1650	611	□	OSTRAL'SQWCIN0HALF PERIOD
01323	57	1646	612	OSTEPUN	OISK'SQWINDIS CYCLE COMPLETED
01324	34	1326	613	□	OJP'ENTVAN0N0
01325	34	1335	614	□	OJP'RESTRN0YES
01326	12	1663	615	CENTVAN	CENTAL'D75N075 DEGREE STEP SIZE
01327	44	1644	616	□	OSTRAL'R0FTN
01330	12	1650	617	□	CENTAL'SQWCIN0HALF PERIOD
01331	16	1646	620	□	OSUBAL'SQWINDINDEX COUNT
01332	67	1334	621	□	OJPALN0'EXN0JUMP IF STEP IS TO BE 75 DEG
01333	40	1644	622	□	OCL'R0FTN0ZER0S R(T)
01334	34	1620	623	CEXN	OJP'ADDN
01335	12	1647	624	ORESTRN	CENTAL'SQWCN0REST0RES INDEX
01336	44	1646	625	□	OSTRAL'SQWIN
01337	34	1323	626	□	OJP'STEPUN
01340	12	1652	627	CFDSRPN	CENTAL'DELTAN0ZER0 ON FIRST PASS
01341	63	1353	630	□	OJPALN0'CYCLEN0SKIPS GEN 0F C0NST AFTER
01342	70	0022	631	□	CENTALK'1800GENERATE CYCLE SWITCH POINTS
01343	24	0620	632	□	OMULAL'VARC0N
01344	44	1651	633	□	OSTRAL'SQWC2N018 SECONDS
01345	50	4201	634	□	ORSHAL'I
01346	14	1651	635	□	OADIAL'SQWC2N
01347	44	1650	636	□	OSTRAL'SQWCIN027 SECONDS
01350	14	1651	637	□	OADIAL'SQWC2N
01351	44	1647	640	□	OSTRAL'SQWCN045 SECONDS
01352	34	1354	641	□	OJP'LN0+2
01353	57	1647	642	OCYCLEN	OISK'SQWCN0RAMP FINISHED
01354	34	1356	643	□	OJP'GENRPN0N0
01355	34	1401	644	□	OJP'ZRAMPN0YES
01356	70	1200	645	CGENRPN	CENTALK'12000CALCULATE RAMP DELTA
01357	24	1667	646	□	OMULAL'W0N

TABLE 3-5. (Continued)

01360	26	0620	647	□	ODIVA*VARGON
01361	44	1652	650	□	OSTRAL*DELTA
01362	14	1644	651	□	OADIAL*REFIN
01363	44	1644	652	□	OSTRAL*REFINNEW RAMP SIZE
01364	12	1650	653	□	OENTAL*SQWCIN
01365	16	1647	654	□	OSUBAL*SQWCNOHAS TOP OF RAMP BEEN REACHED
01366	67	1620	655	□	OJPALNG*ADDNONG
01367	12	1644	656	□	LEVELN OENTAL*REFINNOYES SUBTRACT DELTA
01370	16	1652	657	□	OSUBAL*DELTA
01371	44	1644	660	□	OSTRAL*REFIN
01372	12	1651	661	□	OENTAL*SQWC2NOTIME TO COME DOWN RAMP
01373	16	1647	662	□	OSUBAL*SQWCN
01374	67	1620	663	□	OJPALNG*ADDNONG
01375	12	1644	664	□	OENTAL*REFINODOWN RAMP
01376	16	1652	665	□	OSUBAL*DELTA
01377	67	1401	666	□	OJPALNG*ZRAMPN
01400	34	1303	667	□	OJP*DEGSPN+1
01401	40	1644	670	□	OZRAMPN OCL*REFINZERO OUTPUT
01402	34	1620	671	□	OJP*ADDN
01403	12	1652	672	□	OENTAL*DELTAZERO ON FIRST PASS
01404	63	1416	673	□	OJPALVZ*CYCLINOSKIPS GEN OF CONST AFTER
01405	70	0005	674	□	OENTALK*5
01406	24	0620	675	□	OMULAL*VARGON
01407	44	1651	676	□	OSTRAL*SQWC2NO5 SECONDS
01410	50	4201	677	□	ORSHAL*1
01411	14	1651	700	□	OADIAL*SQWC2N
01412	44	1650	701	□	OSTRAL*SQWCIN07.5 SECONDS
01413	14	1651	702	□	OADIAL*SQWC2N
01414	44	1647	703	□	OSTRAL*SQWCNO12.5 SECONDS
01415	34	1417	704	□	OJP*LOOK+2
01416	57	1647	705	□	OISK*SQWCN
01417	34	1421	706	□	OJP*GNRPIN
01420	34	1401	707	□	OJP*ZRAMPNZERO OUTPUT
01421	12	1657	710	□	OGNRPIN OENTAL*DEONOCALCULATE RAMP DELTA
01422	24	1667	711	□	OMULAL*WEN
01423	26	0620	712	□	ODIVA*VARGON
01424	44	1652	713	□	OSTRAL*DELTA
01425	14	1644	714	□	OADIAL*REFIN
01426	44	1644	715	□	OSTRAL*REFINNEW RAMP SIZE
01427	12	1650	716	□	OENTAL*SQWCIN

TABLE 3-5. (Continued)

01430	16	1647	717	□	OSUBAL'SQWCNOHAS TOP BEEN REACHED
01431	67	1620	720	□	OJPALNG'ADDNON0
01432	12	1644	721	OLVELIN	0ENTAL'R0FTNOYES SUBTRACT DELTA
01433	16	1652	722	□	OSUBAL'DELTAN
01434	44	1644	723	□	OSTRAL'R0FTN
01435	12	1651	724	□	0ENTAL'SQWC2NOTIME TO COME DOWN RAMP
01436	16	1647	725	□	OSUBAL'SQWCN
01437	67	1620	726	□	OJPALNG'ADDNON0
01440	12	1644	727	DOWNRIN	0ENTAL'R0FTNDOWN RAMP
01441	16	1652	730	□	OSUBAL'DELTAN
01442	67	1401	731	□	OJPALNG'ZRAMPN
01443	34	1303	732	□	OJP'DEGSPN+1
01444	12	1652	733	OSVSRPN	0ENTAL'DELTANOZERO ON FIRST PASS
01445	63	1456	734	□	OJPALNZ'CYCL2NOSKIP CONSTANT CALCULATION
01446	70	0003	735	□	0ENTALK'30GEN CYCLE SWITCH POINTS
01447	24	0620	736	□	0MULAL'VARC0N
01450	44	1651	737	□	OSTRAL'SQWC2NO3 SECONDS
01451	50	4201	740	□	ORSHAL'LOADDAL'SQWC2N
01452	44	1650	741	□	OSTRAL'SQWCINO4.5 SECONDS
01453	14	1651	742	□	0ADDAL'SQWC2N
01454	44	1647	743	□	OSTRAL'SQWCNO7.5 SECONDS
01455	34	1457	744	□	OJP'LOK+2
01456	57	1647	745	OCYCL2N	0ISK'SQWCN
01457	34	1461	746	□	OJP'GNRP2N
01460	34	1401	747	□	OJP'ZRAMPN
01461	12	1660	750	OGNRP2N	0ENTAL'D30N
01462	24	1667	751	□	0MULAL'W0N
01463	26	0620	752	□	0DIVA'VARC0N
01464	44	1652	753	□	OSTRAL'DELTAN
01465	14	1644	754	□	0ADDAL'R0FTN
01466	44	1644	755	□	OSTRAL'R0FTN
01467	12	1650	756	□	0ENTAL'SQWCIN
01470	16	1647	757	□	OSUBAL'SQWCN
01471	67	1620	760	□	OJPALNG'ADDN
01472	12	1644	761	OLVEL2N	0ENTAL'R0FTN
01473	16	1652	762	□	OSUBAL'DELTAN
01474	44	1644	763	□	OSTRAL'R0FTN
01475	12	1651	764	□	0ENTAL'SQWC2N
01476	16	1647	765	□	OSUBAL'SQWCN
01477	67	1620	766	□	OJPALNG'ADDN

TABLE 3-5. (Continued)

01500	12	1644	767	ODWNR2N	0ENTAL'R0FTN
01501	16	1652	770	0	0SUBAL'DELTAN
01502	67	1401	771	0	0JPALNG'ZRAMPN
01503	34	1303	772	0	0JP'DEGSPN+1
01504	12	1652	773	0SAWN	0ENTAL'DELTAN
01505	67	1513	774	0	0JPALNG'CYCL3N
01506	70	0006	775	0	0ENTALK'6
01507	24	0620	776	0	0MULAL'VARCON
01510	44	1647	777	0	0STRAL'SQWCN
01511	12	1662	1000	0	0ENTAL'D60N
01512	44	1644	1001	0	0STRAL'R0FTN
01513	57	1647	1002	0CYCL3N	0ISK'SQWCN
01514	34	1516	1003	0	0JP'GNRP3N
01515	34	1526	1004	0	0JP'CLRPN
01516	12	1657	1005	0GNRP3N	0ENTAL'D20N
01517	24	1667	1006	0	0MULAL'W0N
01520	26	0620	1007	0	0DIVA'VAPCON
01521	50	6100	1010	0	0CPAL'
01522	44	1652	1011	0	0STRAL'DELTAN
01523	14	1644	1012	0	0ADDAL'R0FTN
01524	44	1644	1013	0	0STRAL'R0FTN
01525	34	1620	1014	0	0JP'ADDN
01526	40	1652	1015	0CLRPN	0CL'DELTAN
01527	34	1620	1016	0	0JP'ADDN
01530	12	1652	1017	0SPRYN	0ENTAL'DELTAN
01531	63	1537	1020	0	0JPALN2'CYCL4N
01532	70	0004	1021	0	0ENTALK'4
01533	24	0620	1022	0	0MULAL'VARCON
01534	44	1647	1023	0	0STRAL'SQWCN
01535	12	1660	1024	0	0ENTAL'D30N
01536	44	1644	1025	0	0STRAL'R0FTN
01537	57	1647	1026	0CYCL4N	0ISK'SQWCN
01540	34	1542	1027	0	0JP'GNRP4N
01541	34	1620	1030	0	0JP'ADDN
01542	12	1656	1031	0GNRP4N	0ENTAL'D15N
01543	24	1667	1032	0	0MULAL'W0N
01544	26	0620	1033	0	0DIVA'VARCON
01545	44	1652	1034	0	0STRAL'DELTAN
01546	14	1644	1035	0	0ADDAL'R0FTN
01547	44	1644	1036	0	0STRAL'R0FTN

TABLE 3-5. (Continued)

01550	34	1620	1037	□	QJP*ADDN
01551	12	1653	1040	□SINEN	QENTAL*KØNEN
01552	63	1557	1041	□	QJPALNZ*CYCL5N
01553	36	0002	1042	□	QMOVE*3*TSINEN*KØNEN
01554	11	1672			
01555	47	1653			
01556	73	1554			
01557	12	1653	1043	□CYCL5N	QENTAL*KØNEN
01560	24	1654	1044	□	QMLAL*SINEIN
01561	50	4320	1045	□	QORSHA*20
01562	50	6100	1046	□	QCPAL*
01563	14	1654	1047	□	QADDAL*SINEIN
01564	16	1655	1050	□	QSUBAL*SINE2N
01565	14	1654	1051	□	QADDAL*SINEIN
01566	10	1654	1052	□	QENTAU*SINEIN
01567	46	1655	1053	□	QSTRAU*SINE2N
01570	44	1654	1054	□	QSTRAL*SINEIN
01571	24	1671	1055	□	QMLAL*SINZEN
01572	50	4311	1056	□	QORSHA*9D
01573	44	1644	1057	□	QSTRAL*ROFTN
01574	34	1620	1060	□	QJP*ADDN
01575	12	1653	1061	□SINE4N	QENTAL*KØNEN
01576	63	1603	1062	□	QJPALNZ*CYCL6N
01577	36	0002	1063	□	QMOVE*3*TSIN4N*KØNEN
01600	11	1675			
01601	47	1653			
01602	73	1600			
01603	12	1653	1064	□CYCL6N	QENTAL*KØNEN
01604	24	1654	1065	□	QMLAL*SINEIN
01605	50	4324	1066	□	QORSHA*20D
01606	50	6100	1067	□	QCPAL*
01607	14	1654	1070	□	QADDAL*SINEIN
01610	16	1655	1071	□	QSUBAL*SINE2N
01611	14	1654	1072	□	QADDAL*SINEIN
01612	10	1654	1073	□	QENTAU*SINEIN
01613	46	1655	1074	□	QSTRAU*SINE2N
01614	44	1654	1075	□	QSTRAL*SINEIN
01615	24	1700	1076	□	QMLAL*SINZ4N
01616	50	4311	1077	□	QORSHA*9D
01617	44	1644	1100	□	QSTRAL*ROFTN

TABLE 3-5. (Continued)

01620	12	1247	1101	QADDN	CENTAL'CENWDN
01621	52	1246	1102	Q	QSLCL'MASKIN
01622	10	1666	1103	Q	CENTAU'ZR0N
01623	50	4706	1104	Q	QLSHA'6
01624	60	1637	1105	Q	QJPAUZ'FINSHN
01625	57	1670	1106	Q	QISK'NC0UN
01626	34	1630	1107	Q	QJP'NSVALN
01627	76	1640	1110	Q	QJJP'SETN
01630	70	5162	1111	QNSVALN	CENTALK'NTABN
01631	14	1670	1112	Q	QADDAL'NC0UN
01632	74	1633	1113	Q	QSTRADR'NVALN
01633	12	0000	1114	QONVALN	CENTAL'0
01634	50	4204	1115	QON0SHIN	QORSHAL'4
01635	14	1644	1116	Q	QADDAL'R0FTN
01636	44	1644	1117	Q	QSTRAL'R0FTN
01637	55	1250	1120	QFINSHN	QIJP'TLNPSN
01640	00	0000	1121	QSETN	00'
01641	70	1750	1122	Q	CENTALK'10000
01642	44	1670	1123	Q	QSTRAL'NC0UN
01643	55	1640	1124	Q	QIJP'SETN
01644	00	0000	1125	QROFTN	00'ONEW POSITION R(T)
01645	00	0000	1126	QROFTIN	00'OPPOSITION ONE SAMPLE OLD
01646	00	0000	1127	QSQWIN	00'
01647	00	0000	1130	QSQWCN	00'
01650	00	0000	1131	QSQWCIN	00'
01651	00	0000	1132	QSQWC2N	00'
01652	00	0000	1133	QDELTA	00'
01653	00	0000	1134	QK0NEN	00'
01654	00	0000	1135	Q0SINE1N	00'
01655	00	0000	1136	Q0SINE2N	00'
01656	00	3600	1137	Q015N	03600'015 DEG
01657	00	5000	1140	Q020N	05000'020 DEG
01660	00	7400	1141	Q030N	07400'030 DEG
01661	01	3200	1142	Q045N	013200'045 DEG
01662	01	7000	1143	Q060N	017000'060 DEG
01663	02	2600	1144	Q075N	022600'075 DEG
01664	02	6400	1145	Q090N	026400'090 DEG
01665	05	0000	1146	Q0160N	050000'0160 DEG
01666	00	0000	1147	QZRCN	00'
01667	00	0001	1150	QW0N	01'

TABLE 3-5. (Continued)

01670	00	1750	1151	ONCOUN	010000' ONWISE TABLE INDEX
01671	00	0053	1152	OSINZEN	053' GAIN FACTOR OF 9 SEC SINE
01672	00	0116	1153	OTSINEN	0116'
01673	00	3004	1154	0	03004'
01674	00	6010	1155	0	06010'
01675	01	2020	1156	OTSIN4N	012020'
01676	00	4012	1157	0	04012'
01677	01	0023	1160	0	010023'
01700	00	0044	1161	OSINZ4N	044' GAIN FACTOR OF 4.5 SEC SINE
01701	00	0000	1162	OELNPSN	00' DELEV POSITION COMMANDS
01702	12	2236	1163	0	0ENTAL'ER0FTN
01703	44	2237	1164	0	0STRAL'ER0FTN+1
01704	50	7201	1165	0	0ENTICK'I
01705	12	1241	1166	0	0ENTAL'ECNWDN
01706	52	1245	1167	0	0SLCL'MASKN
01707	44	0001	1170	0	0STRAL'I
01710	70	0014	1171	0	0ENTALK'I2D
01711	16	0001	1172	0	0SUBAL'I
01712	67	1714	1173	0	0JPALNG'E0SWN+1
01713	35	1714	1174	0E0SWN	0JP0'E0SWN+1
01714	34	1730	1175	0	0JP'EPSZRN0JUMPS TO ZERO COMMAND
01715	34	1732	1176	0	0JP'E0EGSN01 DEG STEP
01716	34	1735	1177	0	0JP'E0EGSN010 DEG STEP
01717	34	1740	1200	0	0JP'E0RDSN045 DEG STEP
01720	34	1743	1201	0	0JP'E0EGSN060 DEG STEP
01721	34	1746	1202	0	0JP'E0SWN045 DEG SQUARE WAVE
01722	34	1770	1203	0	0JP'E0DGRN05 DEG/SEC RAMP
01723	34	2033	1204	0	0JP'E0WRPN015 DEG/SEC RAMP
01724	34	2074	1205	0	0JP'E0SPRN020 STEP, 15 RAMP
01725	34	2115	1206	0	0JP'E0AWN0SAW100TH
01726	34	2141	1207	0	0JP'E0SINEN0SINE WAVE, 20/9
01727	34	2166	1210	0	0JP'E0SIN4N0SINE WAVE, 5/4.5
01730	40	2236	1211	0EPSZRN	0CL'ER0FTN0ZER0S POSITION COMMAND
01731	34	2212	1212	0	0JP'E0ADIN
01732	12	2262	1213	0E0EGSN	0ENTAL'N0NEN01 DEG STEP
01733	44	2236	1214	0	0STRAL'ER0FTN
01734	34	2212	1215	0	0JP'E0ADIN
01735	12	2264	1216	0E0EGSN	0ENTAL'NTEN010 DEG STEP
01736	44	2236	1217	0	0STRAL'ER0FTN
01737	34	2212	1220	0	0JP'E0ADIN

TABLE 3-5. (Continued)

01740	12	2270	1221	DEFRDSN	CENTAL 'N45N045 DEG STEP
01741	44	2236	1222	□	OSTRAL 'ER0FTN
01742	34	2212	1223	□	OJP'EADDN
01743	12	2271	1224	DES DGSN	CENTAL 'N60N060 DEG STEP
01744	44	2236	1225	□	OSTRAL 'ER0FTN
01745	34	2212	1226	□	OJP'EADDN
01746	70	0012	1227	DESQWN	CENTAL '100 SQUARE WAVE
01747	24	0620	1230	□	CMULAL 'VARC0N
01750	44	2242	1231	□	OSTRAL 'ESQWCN
01751	50	4201	1232	□	ORSHAL '1
01752	44	2243	1233	□	OSTRAL 'ESQWCN+1
01753	57	2240	1234	DESTPUN	OISK 'ESQWIN
01754	34	1756	1235	□	OJP'ENTVEN
01755	34	1765	1236	□	OJP'ESTRN
01756	12	2270	1237	CENTVEN	CENTAL 'N45N
01757	44	2236	1240	□	OSTRAL 'ER0FTN
01760	12	2243	1241	□	CENTAL 'ESQWCN+1
01761	16	2240	1242	□	OSUBAL 'ESQWIN
01762	67	1764	1243	□	OJPALNG'EXEN
01763	40	2236	1244	□	OCL'ER0FTN
01764	34	2212	1245	EXEN	OJP'EADDN
01765	12	2242	1246	ESTRN	CENTAL 'ESQWCN
01766	44	2240	1247	□	OSTRAL 'ESQWIN
01767	34	1753	1250	□	OJP'ESTPUN
01770	12	2245	1251	DEFDGRN	CENTAL 'DEL TEN05 DEG/SEC RAMP
01771	63	2003	1252	□	OJPALNZ'ECYCLN
01772	70	0417	1253	□	CENTAL '150
01773	24	0620	1254	□	CMULAL 'VARC0N
01774	44	2244	1255	□	OSTRAL 'ESQWCN+2015 SEC
01775	50	4201	1256	□	ORSHAL '1
01776	14	2244	1257	□	OADDAL 'ESQWCN+2
01777	44	2243	1260	□	OSTRAL 'ESQWCN+1022.5 SEC
02000	14	2244	1261	□	OADDAL 'ESQWCN+2
02001	44	2242	1262	□	OSTRAL 'ESQWCN037.5 SEC
02002	34	2004	1263	□	OJP'LOK+2
02003	57	2242	1264	DECYCLN	OISK 'ESQWCN
02004	34	2006	1265	□	OJP'EGRNPN
02005	34	2031	1266	□	OJP'ERAMPN
02006	12	2263	1267	EGNRPN	CENTAL 'NFIVEN
02007	24	1667	1270	□	CMULAL 'W0N

TABLE 3-5. (Continued)

02010	26 0620	1271	□	ODIVA'VARCON
02011	44 2245	1272	□	OSTRAL'DELTEN
02012	14 2236	1273	□	OADDAL'EROFIN
02013	44 2236	1274	□	OSTRAL'EROFIN
02014	12 2243	1275	□	OENTAL'ESQWCN+1
02015	16 2242	1276	□	OSUBAL'ESQWCN
02016	67 2212	1277	□	OJPALNG'EADDN
02017	12 2236	1300	OEVELN	OENTAL'EROFIN
02020	16 2245	1301	□	OSUBAL'DELTEN
02021	41 2236	1302	□	OSTRAL'EROFIN
02022	12 2244	1303	□	OENTAL'ESQWCN+2
02023	16 2242	1304	□	OSUBAL'ESQWCN
02024	67 2212	1305	□	OJPALNG'EADDN
02025	12 2236	1306	OEDWNRN	OENTAL'EROFIN
02026	16 2245	1307	□	OSUBAL'DELTEN
02027	65 2031	1310	□	OJPALP'ERAMPN
02030	34 1733	1311	□	OJP'EDEGSN+1
02031	40 2236	1312	OCERAMPN	OCL'EROFIN
02032	34 2212	1313	□	OJP'EADDN
02033	12 2245	1314	OETWRPN	OENTAL'DELTEN015 DEG/SEC RAMP
02034	63 2046	1315	□	OJPALNZ'ECYCIN
02035	70 0004	1316	□	OENTALN'4
02036	24 0620	1317	□	OMULAL'VARCON
02037	44 2244	1320	□	OSTRAL'ESQWCN+204 SEC
02040	50 4201	1321	□	ORSHAL'!
02041	14 2244	1322	□	OADDAL'ESQWCN+2
02042	44 2243	1323	□	OSTRAL'ESQWCN+106 SEC
02043	14 2244	1324	□	OADDAL'ESQWCN+2
02044	44 2242	1325	□	OSTRAL'ESQWCN010 SEC
02045	34 2047	1326	□	OJP'LOK+2
02046	57 2242	1327	OECYCIN	OISK'ESQWCN
02047	34 2051	1330	□	OJP'GENRIN
02050	34 2031	1331	□	OJP'ERAMPN
02051	12 2265	1332	OGENRIN	OENTAL'N15N
02052	24 1667	1333	□	OMULAL'WON
02053	26 0620	1334	□	ODIVA'VARCON
02054	44 2245	1335	□	OSTRAL'DELTEN
02055	14 2236	1336	□	OADDAL'EROFIN
02056	44 2236	1337	□	OSTRAL'EROFIN
02057	12 2243	1340	□	OENTAL'ESQWCN+1

TABLE 3-5. (Continued)

02060	16	2242	1341	□	OSUBAL'ESQWCN
02061	67	2212	1342	□	OJPALNG'EADDN
02062	12	2236	1343	□	OLEVLIN DENTAL'ERØFTN
02063	16	2245	1344	□	OSUBAL'DELTEN
02064	44	2236	1345	□	OSTRAL'ERØFTN
02065	12	2244	1346	□	DENTAL'ESQWCN+2
02066	16	2242	1347	□	OSUBAL'ESQWCN
02067	67	2212	1350	□	OJPALNG'EADDN
02070	12	2236	1351	□	OEDWRIN DENTAL'ERØFTN
02071	16	2245	1352	□	OSUBAL'DELTEN
02072	65	2031	1353	□	OJPALP'ERAMPN
02073	34	1755	1354	□	OJP'EDEGSN+1
02074	12	2245	1355	□	OESPRPN DENTAL'DELTENOSTEP + RAMP
02075	63	2103	1356	□	OJPALNZ'ECYC2N
02076	70	0003	1357	□	DENTALK'3
02077	24	0620	1360	□	OMULAL'VARCØN
02100	44	2242	1361	□	OSTRAL'ESQWCN
02101	12	2266	1362	□	DENTAL'N2ØN
02102	44	2236	1363	□	OSTRAL'ERØFTN
02103	57	2242	1364	□	OISK'ESQWCN
02104	34	2106	1365	□	OJP'GENR2N
02105	34	2212	1366	□	OJP'EADDN
02106	12	2265	1367	□	OGENR2N DENTAL'N15N
02107	24	1667	1370	□	OMULAL'WØN
02110	26	0620	1371	□	ODIVA'VARCØN
02111	44	2245	1372	□	OSTRAL'DELTEN
02112	14	2236	1373	□	OADUAL'ERØFTN
02113	44	2236	1374	□	OSTRAL'ERØFTN
02114	34	2212	1375	□	OJP'EADDN
02115	12	2245	1376	□	OESAWN DENTAL'DELTENOSAWTØTH
02116	63	2124	1377	□	OJPALNZ'ECYC3N
02117	70	0004	1400	□	DENTALK'4
02120	24	0620	1401	□	OMULAL'VARCØN
02121	44	2242	1402	□	OSTPAL'ESQWCN
02122	12	2271	1403	□	DENTAL'N6ØN
02123	44	2236	1404	□	OSTRAL'ERØFTN
02124	57	2242	1405	□	OISK'ESQWCN
02125	34	2127	1406	□	OJP'GENR3N
02126	34	2137	1407	□	OJP'CLERPN
02127	12	2265	1410	□	OGENR3N DENTAL'N15N

TABLE 3-5. (Continued)

02130	24	1667	1411	□	CMULAL*W0N
02131	26	0620	1412	□	CDIVA*VARC0N
02132	50	6100	1413	□	CCPAL*
02133	44	2245	1414	□	OSTRAL*DELTEH
02134	14	2236	1415	□	OADDAL*ER0FTN
02135	44	2236	1416	□	OSTRAL*ER0FTN
02136	34	2212	1417	□	CJP*EADDH
02137	40	2245	1420	□	OCLEPH OCL*DELTEH
02140	34	2212	1421	□	CJP*EADDH
02141	12	2246	1422	□	OCESINEN CENTAL*EK0NEN020/9 SINE
02142	63	2147	1423	□	CJPALNZ*ECYC5N
02143	36	0002	1424	□	CM0VE*3*ESIN3N*EK0NEN
02144	11	2252			
02145	47	2246			
02146	73	2144			
02147	12	2246	1425	□	OCYC5N CENTAL*EK0NEN
02150	24	2247	1426	□	CMULAL*ESININ
02151	50	4324	1427	□	ORSHA*200
02152	50	6100	1430	□	CCPAL*
02153	14	2247	1431	□	OADDAL*ESININ
02154	16	2250	1432	□	OSUBAL*ESIN2N
02155	14	2247	1433	□	OADPAL*ESININ
02156	10	2247	1434	□	CENTAU*ESININ
02157	46	2250	1435	□	OSTRAU*ESIN2N
02160	44	2247	1436	□	OSTRAL*ESININ
02161	24	2255	1437	□	CMULAL*ESINZH
02162	50	4311	1440	□	ORSHA*90
02163	14	2267	1441	□	OADDAL*N30N
02164	44	2236	1442	□	OSTRAL*ER0FTN
02165	34	2212	1443	□	CJP*EADDH
02166	12	2246	1444	□	OCESIN4N CENTAL*EK0NEN05/4.5 SINE
02167	63	2174	1445	□	CJPALNZ*ECYC6H
02170	36	0002	1446	□	CM0VE*3*ESIN5N*EK0NEN
02171	11	2256			
02172	47	2246			
02173	73	2171			
02174	12	2246	1447	□	OCYC6H CENTAL*EK0NEN
02175	24	2247	1450	□	CMULAL*ESININ
02176	50	4324	1451	□	ORSHA*200
02177	50	6100	1452	□	CCPAL*

TABLE 3-5. (Continued)

02200	14	2247	1453	□	QADDA'ESININ
02201	16	2250	1454	□	QSUBAL'ESIN2N
02202	14	2247	1455	□	QADDA'ESININ
02203	10	2247	1456	□	QENTAU'ESININ
02204	46	2250	1457	□	QSTRAU'ESIN2N
02205	44	2247	1460	□	QSTRAL'ESININ
02206	24	2261	1461	□	QULAL'ESIN6N
02207	50	4311	1462	□	QKSHA'9D
02210	14	2266	1463	□	QADDA'N20N
02211	44	2230	1464	□	QSTRAL'EROFIN
02212	12	1247	1465	QADDN	QENTAL'CONWDN
02213	52	1246	1466	□	QSLCL'MASKIN
02214	10	1666	1467	□	QENTAU'ZR0N
02215	50	4706	1470	□	QLSHA'6
02216	60	2231	1471	□	QJPAUZ'EFINSN
02217	57	2251	1472	□	QISK'ENC0UN
02220	34	2222	1473	□	QJP'ENSVLN
02221	76	2232	1474	□	QJJP'ESETN
02222	70	5162	1475	QENSVLN	QENTALK'NTABN
02223	14	2251	1476	□	QADDA'ENC0UN
02224	74	2225	1477	□	QSTRAU'ENVALN
02225	12	0000	1500	QENVALN	QENTAL'0
02226	50	4202	1501	QEN0STI	QKSHA'2
02227	14	2236	1502	□	QADDA'EROFIN
02230	44	2236	1503	□	QSTRAL'EROFIN
02231	55	1701	1504	QEFINSN	QIIP'ELNPSN
02232	00	0000	1505	QESETN	Q0'
02233	70	1750	1506	□	QENTALK'1000D
02234	44	2251	1507	□	QSTRAL'ENC0UN
02235	55	2232	1510	□	QIJP'ESETN
02236	00	0000	1511	QEROFIN	Q0'
02237	00	0000	1512	□	Q0'
02240	00	0000	1513	QESQWIN	Q0'
02241	00	0000	1514	□	Q0'
02242	00	0000	1515	QESQWCN	Q0'
02243	00	0000	1516	□	Q0'
02244	00	0000	1517	□	Q0'
02245	00	0000	1520	QDELTEN	Q0'
02246	00	0000	1521	QEK0NEN	Q0'
02247	00	0000	1522	QESININ	Q0'

TABLE 3-5. (Continued)

02250	00	0000	1523	DESIN2N	00°
02251	00	1750	1524	DENCOUN	010000°
02252	00	2404	1525	DESIN3N	02404°
02253	00	4012	1526	0	04012°
02254	01	0023	1527	0	010023°
02255	00	0026	1530	DESINZN	026°
02256	01	2020	1531	DESIN5N	012020°
02257	00	4012	1532	0	04012°
02260	01	0023	1533	0	010023°
02261	00	0014	1534	DESIN6N	014°
02262	77	7577	1535	ONCEN	0777577°
02263	77	6577	1536	ONFIVEN	0776577°
02264	77	5377	1537	ONTENN	0775377°
02265	77	4177	1540	ON15N	0774177°
02266	77	2777	1541	ON20N	0772777°
02267	77	0377	1542	ON30N	0770377°
02270	76	4577	1543	ON45N	0764577°
02271	76	0777	1544	ON60N	0760777°
02272	00	0000	1545	OTRVELN	00° CALCULATE TRAIN VELOCITY COMMAND
02273	12	2315	1546	0	02AL'VTEMPNOSHIFT VELOCITY HISTORY
02274	44	2316	1547	0	02TRAL'VTEMPN+1
02275	12	1644	1550	0	02AL'R0FTN
02276	16	1645	1551	0	02UBAL'R0FTINNEW VELOCITY
02277	24	0620	1552	0	02ULAL'VARCON
02300	16	2316	1553	0	02UBAL'VTEMPN+1 VELOCITY FILTER
02301	50	4202	1554	0VTIMEN	02SHAL'20SAMPLE TIME DEPENDENT
02302	14	2316	1555	0	02ADAL'VTEMPN+1
02303	44	2315	1556	0	02TRAL'VTEMPN
02304	24	2320	1557	0	02ULAL'VSIZE
02305	50	4316	1560	0	02SHA'140
02306	44	2321	1561	0	02TRAL'VELCN
02307	70	0005	1562	0	02TALK'5
02310	16	1243	1563	0	02UBAL'TCNWPN
02311	65	2313	1564	0	02PALP'LGK+2
02312	55	2272	1565	0	02JP'TRVELN
02313	40	2321	1566	0	02L'VELCN
02314	55	2272	1567	0	02JP'TRVELNEXIT
02315	00	0000	1570	0VTEMPN	00°
02316	00	0000	1571	0	00°
02317	00	0000	1572	0VFLAGN	00°

TABLE 3-5. (Continued)

02320	00 3400	1573	QVSIZE	Q3400
02321	00 0000	1574	QVELCN	Q0'CFILTERED VELOCITY
02322	00 0000	1575	QELVELN	Q0'CCALCULATES ELEV VEL COMMAND
02323	12 2345	1576	Q	QENTAL'EVIMPN
02324	44 2346	1577	Q	QSTRAL'EVIMPN+1
02325	12 2236	1600	Q	QENTAL'EROFTN
02326	16 2237	1601	Q	QSUBAL'EROFTN+1
02327	24 0620	1602	Q	QMLAL'VARCON
02330	16 2346	1603	Q	QSUBAL'EVIMPN+1
02331	50 4202	1604	QETIMEN	QORSHAL'2
02332	14 2346	1605	Q	QADDAL'EVIMPN+1
02333	44 2345	1606	Q	QSTRAL'EVIMPN
02334	24 2350	1607	Q	QMLAL'ESIZE
02335	50 4316	1610	Q	QORSHA'140
02336	44 2351	1611	Q	QSTRAL'EVELCN
02337	70 0005	1612	Q	QENTALK'5
02340	16 1241	1613	Q	QSUBAL'ECNWDN
02341	65 2343	1614	Q	QJPALP'L0K+2
02342	55 2322	1615	Q	QIJP'ELVELN
02343	40 2351	1616	Q	QCL'EVELCN
02344	55 2322	1617	Q	QIJP'ELVELN
02345	00 0000	1620	QEVIMPN	Q0'
02346	00 0000	1621	Q	Q0'
02347	00 0000	1622	QEFLAGN	Q0'
02350	00 4500	1623	QESIZE	Q4500'
02351	00 0000	1624	QEVELCN	Q0'
02352	00 0000	1625	QOTRENIN	Q0'QTRAIN POS IN VIA ENCODER
02353	50 1306	1626	Q	QEXFCT'6'AD'1'BEGON
02354	00 2375			
02355	00 2374			
02356	50 2706	1627	Q	QEXF0W'6
02357	50 1106	1630	Q	QBUFIN'6'AD'1'INP0SN
02360	00 2440			
02361	00 2440			
02362	50 2106	1631	Q	QSKPIIN'6
02363	34 2362	1632	Q	QJP'L0K-1
02364	12 2440	1633	Q	QENTAL'INP0SN
02365	50 4725	1634	Q	QLSHA'210
02366	50 4306	1635	Q	QORSA'6
02367	26 2372	1636	Q	QDIVA'KIN

TABLE 3-5. (Continued)

02370	44	2373	1637	□	OSTRAL'CQFTN
02371	55	2352	1640	□	OJJP'TRENIN
02372	05	5404	1641	OKIN	O55404'
02373	00	0000	1642	OCQFTN	00'
02374	00	1000	1643	OBEGON	O1000'
02375	00	0000	1644	OTKSCIN	00'OTRAIN PWS IN THRU KSC
02376	12	2435	1645	□	OENTAL'IRPISN
02377	44	0112	1646	□	OSTRAL'112
02400	50	1305	1647	□	OEXFCT'5'AD'2'REQCCN
02401	00	2440			
02402	00	2436			
02403	50	2705	1650	□	OEXFCT'5
02404	34	2404	1651	OWAITIN	OJP'WAITIN
02405	50	3000	1652	OREENTN	ORIL'
02406	12	0113	1653	□	OENTAL'113
02407	02	2436	1654	□	OCNAL'REQCCN
02410	61	2414	1655	□	OJPEQ'BUERN
02411	02	2444	1656	□	OCNAL'TWON
02412	61	2424	1657	□	OJPEQ'ENDIN
02413	50	5640	1660	□	OSTUP'
02414	50	1105	1661	OBUFERN	OBUFIN'5'AD'2'INPDSN
02415	00	2441			
02416	00	2440			
02417	50	1305	1662	□	OEXFCT'5'AD'2'INWDCN
02420	00	2444			
02421	00	2442			
02422	50	2705	1663	□	OEXFCT'5
02423	34	2423	1664	□	OJP'LOK-0
02424	12	2440	1665	OENDIN	OENTAL'INPDSN
02425	50	4202	1666	□	ORSHAL'2
02426	14	2440	1667	□	OADDAL'INPDSN
02427	02	2445	1670	□	OCNAL'P180N
02430	67	2432	1671	□	OJPMGR'LOK+2
02431	16	2446	1672	□	OSUHAL'P360N
02432	50	6100	1673	□	OCPAL'
02433	44	2373	1674	□	OSTRAL'CQFTN
02434	55	2375	1675	□	OJJP'TKSCIN
02435	34	2405	1676	OIRPISN	OJP'REENTN
02436	00	0001	1677	OREQCCN	0000001'
02437	00	0000	1700	□	00'

TABLE 3-5. (Continued)

02440	00 0000	1701	OINP0SN	00'
02441	00 0000	1702	□	00'
02442	10 0400	1703	OINWDCN	0100400'
02443	00 1000	1704	□	0001000'
02444	00 0002	1705	OTW0N	0000002'
02445	05 5000	1706	OP180N	0230400'
02446	13 2000	1707	OP360N	0460800'
02447	00 0000	1710	OTRERRN	00'0CALCULATE TRAIN ERROR
02450	12 1644	1711	□	CENTAL'R0FTN0NEW POSITION COMMAND
02451	16 2373	1712	□	OSUBAL'C0FTN0PRESENT TRAIN POSITION
02452	44 2455	1713	OLEXITN	OSTRAL'AIRN0STORE ERROR
02453	44 2456	1714	□	OSTRAL'AIRIN
02454	55 2447	1715	□	OIJPT'0TRERN0EXIT
02455	00 0000	1716	CAIRN	00'0LATEST ERROR
02456	00 0000	1717	CAIRIN	00'
02457	00 0200	1720	OW0NEN	01280'01 SF7
02460	00 0000	1721	0ECTABN	00'0TRAIN ERROR CURVE TABLE LOOKUP
02461	50 7201	1722	□	CENTICR'I
02462	36 0000	1723	□	CENTBK'00ZER0S B BOX1
02463	12 2455	1724	□	CENTAL'AIRN
02464	05 2470	1725	□	OJPALP'L0K+40JUMP IF ERROR POSITIVE
02465	50 0100	1726	□	0CPAL'0MAKE VALUE ABSOLUTE
02466	44 2514	1727	□	OSTRAL'TESTN0FLAG, NEGATIVE NUMBER
02467	34 2471	1730	□	OJP'L0K+2
02470	40 2514	1731	□	0CL'TESTN0FLAG, POSITIVE NUMBER
02471	44 2515	1732	□	OSTRAL'TESTN+10SAVE ABSOLUTE ERROR
02472	16 2513	1733	□	OSUBAL'LIMITN
02473	65 2476	1734	□	OJPALP'L0K+3
02474	12 2515	1735	□	CENTAL'TESTN+10ABSOLUTE VALUE
02475	34 2477	1736	□	OJP'L0K+2
02476	12 2513	1737	□	CENTAL'LIMITN0MAXIMUM ERROR
02477	24 2512	1740	□	0MULAL'TEN0TENTHS OF DEGREES
02500	50 4307	1741	□	ORSHA'70REMOVES SF
02501	44 2515	1742	□	OSTRAL'TESTN+10STORE ERROR TABLE INDEX
02502	32 2515	1743	□	CENTB'TESTN+1
02503	13 0321	1744	□	CENTALB'TETABN
02504	10 2514	1745	□	CENTAU'TESTN0CHECK SIGN OF ERROR
02505	60 2507	1746	□	OJPAUZ'L0K+20JUMP IF SIGN POSITIVE
02506	50 6100	1747	□	0CPAL'0NEGATIVE ERROR
02507	50 4203	1750	□	ORSHAL'30REDUCE SF7

TABLE 3-5. (Continued)

02510	44	2533	1751	□	QSTRAL'MØFZNQCONTAINS OUTPUT
02511	55	2460	1752	□	QIJP'ECTABN
02512	00	0012	1753	CTEN	QIØD'
02513	01	4363	1754	QLIMITN	Q6387D'Q49.9 DEGREES
02514	00	0000	1755	QTESTN	QØ'QSIGN FLAG STORAGE
02515	00	0000	1756	□	QØ'
02516	00	0000	1757	QØNCØN	QØ'QCOMPLETE TRAIN CONTROLLER CAL
02517	12	2455	1760	□	QENTAL'AIROPØSITION ERROR E(N)
02520	24	2532	1761	□	QØULAL'STLIN
02521	50	4314	1762	□	QØSHA'12D
02522	44	3004	1763	□	QSTRAL'TEHISNQSAVE TRAIN ERROR HISTORY
02523	24	2777	1764	□	QØULAL'ACØEFNQØ TIMES E(N) SF22
02524	50	4310	1765	□	QØSHA'8DOSF 14
02525	14	3011	1766	□	QATØAL'THISTN+2QPREVIOUS PARTIAL PRØDUCT
02526	44	3007	1767	□	QSTRAL'THISTN
02527	50	4207	1770	□	QØSHAL'7
02530	44	2533	1771	□	QSTRAL'MØFZNQØ(Z) ØUT TØ TRAIN
02531	55	2516	1772	□	QIJP'QØNCØN
02532	00	6443	1773	QSTLIN	Q3363D'Q.821 SF12
02533	00	0000	1774	QØFZN	QØ'QØ(Z) SF7
02534	00	0000	1775	QTRØUTN	QØ'QØUTPUT TØ TRAIN
02535	12	0622	1776	□	QENTAL'MZVELNQØ(Z) PLUS VELOCITY
02536	24	2555	1777	□	QØULAL'PKN
02537	50	4307	2000	□	QØSHA'7
02540	76	3166	2001	□	QØJP'ATSTN
02541	44	2556	2002	□	QSTRAL'ØØTN
02542	50	1306	2003	□	QØXFCT'6'AD'1'TEFN
02543	00	2555			
02544	00	2554			
02545	50	2706	2004	□	QØXFØV'6
02546	50	1206	2005	□	QØUFØUT'6'AD'1'ØØTN
02547	00	2557			
02550	00	2556			
02551	50	2206	2006	□	QØKPØIN'6
02552	34	2551	2007	□	QØP'ØØK-1
02553	55	2534	2010	□	QIJP'TRØUTN
02554	00	0002	2011	QTEFN	Q2'QØA NØ. 2
02555	00	2400	2012	QØPN	Q2400'
02556	00	0000	2013	QØØTN	QØ'
02557	00	0000	2014	QØLENIN	QØ'QØLEV PØS BUFFERED IN

TABLE 3-5. (Continued)

02560	50	1306	2015	□	CEXFCT'6'AD'1'ELEFIN
02561	00	2600			
02562	00	2577			
02563	50	2706	2016	□	CEXFOW'6
02564	50	1106	2017	□	CEBUFIN'6'AD'1'ELP0SN
02565	00	2600			
02566	00	2600			
02567	50	2106	2020	□	CEKPIIN'6
02570	34	2567	2021	□	CEJP'L0K-1
02571	12	2600	2022	□	CEENTAL'ELP0SN
02572	50	4725	2023	□	CELSHA'2ID
02573	50	4306	2024	□	CEORSHA'6
02574	26	2372	2025	□	CEDIVA'KIN
02575	44	2602	2026	□	CESTRAL'EC0FTN
02576	55	2557	2027	□	CEIJP'ELENIN
02577	00	2000	2030		CELEFIN CE000'
02600	00	0000	2031		CELP0SN 00'
02601	00	0000	2032		00'
02602	00	0000	2033		CEC0FTN 00'
02603	00	0000	2034		CEKSCIN 00'CELEV P0S IN THRU KSC
02604	12	2634	2035		CEENTAL'ERPISN
02605	44	0112	2036		CESTRAL'112
02606	50	1105	2037		CEBUFIN'5'AD'2'ELP0SN
02607	00	2601			
02610	00	2600			
02611	50	1305	2040	□	CEXFCT'5'AD'2'ENWDCN
02612	00	2637			
02613	00	2635			
02614	50	2705	2041	□	CEXFOW'5
02615	34	2614	2042	□	CEJP'L0K-1
02616	50	3000	2043		CEERENTN ORIL'
02617	12	0113	2044	□	CEENTAL'113
02620	02	2444	2045	□	CECMAL'TW0N
02621	61	2623	2046	□	CEJPEQ'EEDIN
02622	50	5640	2047	□	CESTUP'
02623	12	2600	2050		CECEDIN CEENTAL'ELP0SN
02624	50	4202	2051	□	CEORSHAL'2
02625	14	2600	2052	□	CEADDAL'ELP0SN
02626	02	2445	2053	□	CECMAL'P180N
02627	67	2631	2054	□	CEJPMGR'L0K+2

TABLE 3-5. (Continued)

02630	16	2446	2055	C	OSUBAL'P360N
02631	50	6100	2056	O	CCPAL'
02632	44	2602	2057	O	OSTRAL'ECØFTN
02633	55	2603	2060	O	OIJP'EKSCIN
02634	34	2616	2061	OERPISN	OJP'ERENTN
02635	11	0400	2062	OENWDCN	O110400'
02636	00	1100	2063	O	O001100'
02637	00	0000	2064	OELERRN	O0'OCALC ERROR ,ELEV
02640	12	2236	2065	O	OENTAL'ERØFTN
02641	16	2602	2066	O	OSUBAL'ECØFTN
02642	44	2645	2067	O	OSTRAL'EAIRN
02643	44	2646	2070	O	OSTRAL'EAIRIN
02644	55	2637	2071	O	OIJP'ELERRN
02645	00	0000	2072	OEAIRN	O0'
02646	00	0000	2073	OEAIRIN	O0'
02647	00	0000	2074	OELERLN	O0'OELV ERROR CLVE TAB LOOKUP
02650	50	7201	2075	O	OENTICR'I
02651	36	0000	2076	O	OENTBK'Ø
02652	12	2645	2077	O	OENTAL'EAIRN
02653	65	2657	2100	O	OJPALP'LØK+4
02654	50	6100	2101	O	CCPAL'
02655	44	2701	2102	O	OSTRAL'ETESTN
02656	34	2660	2103	O	OJP'LØK+2
02657	40	2701	2104	O	OCL'ETESTN
02660	44	2702	2105	O	OSTRAL'ETESTN+1
02661	16	2513	2106	O	OSUBAL'LIMITN
02662	65	2665	2107	O	OJPALP'LØK+3
02663	12	2702	2110	O	OENTAL'ETESTN+1
02664	34	2666	2111	O	OJP'LØK+2
02665	12	2513	2112	O	OENTAL'LIMITN
02666	24	2512	2113	O	OMULAL'TEN
02667	50	4307	2114	O	ORSHA'7
02670	44	2702	2115	O	OSTRAL'ETESTN+1
02671	32	2702	2116	O	OENTB'ETESTN+1
02672	13	4175	2117	O	OENTALB'ELETBN
02673	10	2701	2120	O	OENTAU'ETESTN
02674	60	2676	2121	O	OJPAUZ'LØK+2
02675	50	6100	2122	O	CCPAL'
02676	50	4203	2123	O	ORSHAL'3
02677	44	2703	2124	O	OSTRAL'EMØFZN

TABLE 3-5. (Continued)

02700	55 2647	2125	□	QIJP'ELERLN
02701	00 0000	2126	QETESTN	Q0'
02702	00 0000	2127	□	Q0'
02703	00 0000	2130	QEMOFZN	Q0'
02704	00 0000	2131	QCMCEN	Q0'OCOMPLETE ELEV CONT CALC
02705	12 2645	2132	□	QENTAL'EAIRN
02706	24 2720	2133	□	QULAL'ESTLIN
02707	50 4314	2134	□	ORSHA'120
02710	44 3053	2135	□	QSTRAL'EEHISN
02711	24 3046	2136	□	QULAL'EACOFN
02712	50 4310	2137	□	ORSHA'80
02713	14 3060	2140	□	QADDAL'EHISN+2
02714	44 3056	2141	□	QSTRAL'EHISN
02715	50 4207	2142	□	ORSHAL'7
02716	44 2703	2143	□	QSTRAL'EMOFZN
02717	55 2704	2144	□	QIJP'CMCEN
02720	00 6443	2145	QESTLIN	Q6443'
02721	00 0000	2146	QELQTN	Q0'OELEV OUTPUT TO LAUNCHER
02722	12 0625	2147	□	QENTAL'EMZVLN
02723	24 2555	2150	□	QULAL'PKN
02724	50 4307	2151	□	ORSHA'7
02725	76 3166	2152	□	ORJP'ATSTN
02726	44 2741	2153	□	QSTRAL'EBQTN
02727	50 1306	2154	□	QEXFCT'6'AD'1'ELEFN
02730	00 2743			
02731	00 2742			
02732	50 2706	2155	□	QEXFCT'6
02733	50 1206	2156	□	QBUFCT'6'AD'1'EBQTN
02734	00 2742			
02735	00 2741			
02736	50 2206	2157	□	QSKPQIN'6
02737	34 2736	2160	□	QJP'LNK-1
02740	55 2721	2161	□	QIJP'ELQTN
02741	00 0000	2162	QEBQTN	Q0'
02742	00 0104	2163	QELEFN	Q4'QDA NO 3
02743	00 0000	2164	QTRPDZN	Q0'OCALCULATE TRAIN D(Z) FOR NEXT PASS
02744	12 3005	2165	□	QENTAL'TEHISN+1
02745	44 3006	2166	□	QSTRAL'TEHISN+2
02746	12 3004	2167	□	QENTAL'TEHISN
02747	44 3005	2170	□	QSTRAL'TEHISN+1

TABLE 3-5. (Continued)

02750	24	3000	2171	□	CMULAL'ACDEFN+10A1 TIMES E(N-1)
02751	50	4310	2172	□	ORSHA'8D
02752	44	3011	2173	□	OSTRAL'THISTN+2
02753	12	3006	2174	□	CENTAL'TEHISN+2
02754	24	3001	2175	□	CMULAL'ACDEFN+2
02755	50	4310	2176	□	ORSHA'8D
02756	14	3011	2177	□	CADDAL'THISTN+2
02757	44	3011	2200	□	OSTRAL'THISTN+2
02760	12	3007	2201	□	CENTAL'THISTN
02761	24	3002	2202	□	CMULAL'BCDEFNOB1 TIMES M(Z)
02762	50	4317	2203	□	ORSHA'15D
02763	50	6100	2204	□	CCPAL'
02764	14	3011	2205	□	CADDAL'THISTN+2
02765	44	3011	2206	□	OSTRAL'THISTN+2
02766	12	3010	2207	□	CENTAL'THISTN+1
02767	24	3003	2210	□	CMULAL'BCDEFN+1
02770	50	4317	2211	□	ORSHA'15D
02771	50	6100	2212	□	CCPAL'
02772	14	3011	2213	□	CADDAL'THISTN+2
02773	44	3011	2214	□	OSTRAL'THISTN+2
02774	12	3007	2215	□	CENTAL'THISTN
02775	44	3010	2216	□	OSTRAL'THISTN+1
02776	55	2743	2217	□	OIJP'TRPDZN
02777	10	0000	2220	□	QACDEFN OI000000'QAO SF 15
03000	61	4642	2221	□	O614642'QAI SF 15
03001	06	3636	2222	□	O063636'QAI SF 15
03002	60	3115	2223	□	OBCDEFN O603115'QBI SF 15
03003	07	4702	2224	□	O074702'QB2 SF 15
03004	00	0000	2225	□	QTEHISN O0'
03005	00	0000	2226	□	O0'QSF 7
03006	00	0000	2227	□	O0'QSF 7
03007	00	0000	2230	□	QTHISTN O0'
03010	00	0000	2231	□	O0'QSF 14
03011	00	0000	2232	□	O0'QWORKING CELL
03012	00	0000	2233	□	QELPDZN O0'QELV D(Z) FOR NEXT PASS
03013	12	3054	2234	□	CENTAL'EEHISN+1
03014	44	3055	2235	□	OSTRAL'EEHISN+2
03015	12	3053	2236	□	CENTAL'EEHISN
03016	44	3054	2237	□	OSTRAL'EEHISN+1
03017	24	3047	2240	□	CMULAL'EACDEFN+1

TABLE 3-5. (Continued)

03020	50 4310	2241	0	ORSHA'8D
03021	44 3060	2242	0	OSTRAL'EHISTN+2
03022	12 3055	2243	0	OENTAL'EENISN+2
03023	24 3050	2244	0	OMULAL'EACOFN+2
03024	50 4310	2245	0	ORSHA'8D
03025	14 3060	2246	0	OADDAL'EHISTN+2
03026	44 3060	2247	0	OSTRAL'EHISTN+2
03027	12 3056	2250	0	OENTAL'EHISTN
03030	24 3051	2251	0	OMULAL'EBCOFN
03031	50 4317	2252	0	ORSHA'15D
03032	50 6100	2253	0	OCPAL'
03033	14 3060	2254	0	OADDAL'EHISTN+2
03034	44 3060	2255	0	OSTRAL'EHISTN+2
03035	12 3057	2256	0	OENTAL'EHISTN+1
03036	24 3052	2257	0	OMULAL'EBCOFN+1
03037	50 4317	2260	0	ORSHA'15D
03040	50 6100	2261	0	OCPAL'
03041	14 3060	2262	0	OADDAL'EHISTN+2
03042	44 3060	2263	0	OSTRAL'EHISTN+2
03043	12 3056	2264	0	OENTAL'EHISTN
03044	44 3057	2265	0	OSTRAL'EHISTN+1
03045	55 3012	2266	0	OIJPI'ELPDZN
03046	10 0000	2267	OEACOF'	O100000'
03047	61 4642	2270	0	O614642'
03050	06 3636	2271	0	O063636'
03051	60 3115	2272	OEBCOFN	O603115'
03052	07 4702	2273	0	O074702'
03053	00 0000	2274	OEENISN	O0'
03054	00 0000	2275	0	O0'
03055	00 0000	2276	0	O0'
03056	00 0000	2277	OEHISTN	O0'
03057	00 0000	2300	0	O0'
03060	00 0000	2301	0	O0'
03061	00 0000	2302	ODATRDH	O0'QUATA TO BRUSH RECORDER
03062	12 1644	2303	0	OENTAL'ROFTN
03063	24 3153	2304	0	OMULAL'AKIN
03064	50 4306	2305	0	ORSHA'6
03065	76 3166	2306	0	ORJP'ATSTN
03066	44 3156	2307	0	OSTRAL'AOUTN+1
03067	50 1306	2310	0	OEXFCT'6'AD'1'REFN

TABLE 3-5. (Continued)

03070	00	3163			
03071	00	3162			
03072	50	2706	2311	□	CEXF0V'6
03073	50	1206	2312	□	OBUF0UT'6'AD'1'AQUTN+1
03074	00	3157			
03075	00	3156			
03076	50	2206	2313	□	OSKP0IN'6
03077	34	3076	2314	□	OJP'L0K-1
03100	12	2456	2315	□	CENTAL'AIRIN
03101	24	3154	2316	□	OMULAL'AK2N
03102	50	4303	2317	□	ORSHA'3
03103	76	3166	2320	□	ORJP'ATSTN
03104	44	3157	2321	□	OSTRAL'AQUTN+2
03105	50	1306	2322	□	CEXFCT'6'AD'1'AIREFN
03106	00	3164			
03107	00	3163			
03110	50	2706	2323	□	CEXF0V'6
03111	50	1206	2324	□	OBUF0UT'6'AD'1'AQUTN+2
03112	00	3160			
03113	00	3157			
03114	50	2206	2325	□	OSKP0IN'6
03115	34	3114	2326	□	OJP'L0K-1
03116	12	2236	2327	□	CENTAL'ER0FTN
03117	24	3153	2330	□	OMULAL'AKIN
03120	50	4306	2331	□	ORSHA'6
03121	76	3166	2332	□	ORJP'ATSTN
03122	44	3160	2333	□	OSTRAL'AQUTN+3
03123	50	1306	2334	□	CEXFCT'6'AD'1'EREFN
03124	00	3165			
03125	00	3164			
03126	50	2706	2335	□	CEXF0V'6
03127	50	1206	2336	□	OBUF0UT'6'AD'1'AQUTN+3
03130	00	3161			
03131	00	3160			
03132	50	2206	2337	□	OSKP0IN'6
03133	34	3132	2340	□	OJP'L0K-1
03134	12	2646	2341	□	CENTAL'EAIRIN
03135	24	3154	2342	□	OMULAL'AK2N
03136	50	4303	2343	□	ORSHA'3
03137	76	3166	2344	□	ORJP'ATSTN

TABLE 3-5. (Continued)

03140	44	3161	2345	□	OSTRAL'ACUTN+4
03141	50	1306	2346	□	CEXFCT'6'AD'I'EAREFN
03142	00	3166			
03143	00	3165			
03144	50	2706	2347	□	CEXFCT'6
03145	50	1206	2350	□	CEXFCT'6'AD'I'ACUTN+4
03146	00	3162			
03147	00	3161			
03150	50	2206	2351	□	OSKP0IN'6
03151	34	3150	2352	□	OJP'L0K-1
03152	55	3061	2353	□	OJJP'DATRDN
03153	00	0045	2354	□	OAKIN O45'
03154	00	0062	2355	□	OAK2N O62'
03155	00	0000	2356	□	OACUTN O0'
03156	00	0000	2357	□	O0'
03157	00	0000	2360	□	O0'
03160	00	0000	2361	□	O0'
03161	00	0000	2362	□	O0'
03162	00	0001	2363	□	OAREFN O1'ODA NO. 1
03163	00	0010	2364	□	OAREFN O10'ODA NO. 4
03164	00	0020	2365	□	OAREFN O20'ODA NO. 5
03165	00	0040	2366	□	OAREFN O40'ODA NO. 6
03166	00	0000	2367	□	OATSTN O0'OVERFLOW SUBROUTINE
03167	65	3173	2370	□	OJPALP'L0K+4
03170	50	6100	2371	□	OCPAL'
03171	44	3206	2372	□	OSTRAL'AFLGN
03172	34	3174	2373	□	OJP'L0K+2
03173	40	3206	2374	□	OCL'AFLGN
03174	02	3205	2375	□	OCMAL'AKON
03175	65	3203	2376	□	OJPMLEQ'L0K+6
03176	10	3206	2377	□	OENTAU'AFLGN
03177	62	3201	2400	□	OJPAUNZ'L0K+2
03200	55	3166	2401	□	OJJP'ATSTN
03201	50	6100	2402	□	OCPAL'
03202	55	3166	2403	□	OJJP'ATSTN
03203	12	3205	2404	□	OENTAL'AKON
03204	34	3176	2405	□	OJP'L0K-6
03205	01	4400	2406	□	OAKON O14400'
03206	00	0000	2407	□	OAFGLN O0'
00321	00	0000	2410	□	OTETABN O0'OTRAIN ERROR CURVE TABLE
04175	00	0000	2411	□	OELTBN O0'CELEV ERROR CURVE TABLE
05162	00	0000	2412	□	ONTABN O0'ONNOISE TABLE

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PART 4
COMPUTER PROGRAM OPERATOR'S MANUAL

REVERSE SIDE BLANK

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1.0 SCOPE

Part 4 contains complete instructions for the operation of the computer program described in Part 2, Computer Program Performance Specification, and Part 3, Computer Program Design Specification. The procedures given presume a basic knowledge of the UNIVAC Type 1218 (CP 789) Digital Computer and familiarity with its operating controls. The program was designed for feasibility demonstration of both train and elevation. Operating procedures are identical for both since the program is run as a continuous entity.

2.0 OPERATIONAL ENVIRONMENT

The following paragraphs describe the requirements for computer program operation in terms of equipment, program materials, and personnel.

2.1 Equipment Requirements

Computer and Peripheral

- a. 1 Digital Computer, Model CP 789 (UNIVAC Type 1218).
- b. 1 Paper Tape Unit, Model 1232 I/O Console.

Supporting

- c. 1 Digital Data Converter, Model CV1123/USQ-20 (V).
- d. 6 Digital-to-Analog Converters, Packard-Bell Model DA6.
- e. 2 Operational Amplifiers, Zeltex Model 142C.
- f. 1 4-Channel Strip Recorder, Brush Model Mk 20G.
- g. 1 Command Selector Control Panel, NELC Prototype.
- h. 1 Logic Chassis, NELC Prototype.
- i. 2 Special Switch Boxes, NELC Prototype.

- j. 2 Shaft-to-Digital Encoders, Datex Model 12-300-27.
- k. 1 Special Mode Selector Control Panel, NELC Prototype.
- l. 4 Power Supplies, Sorensen Model Q Nobatron QRC 20-8A.

The complete feasibility of demonstration equipment setup is shown in block-diagram form for train in figure 4-1. A similar configuration is used for elevation

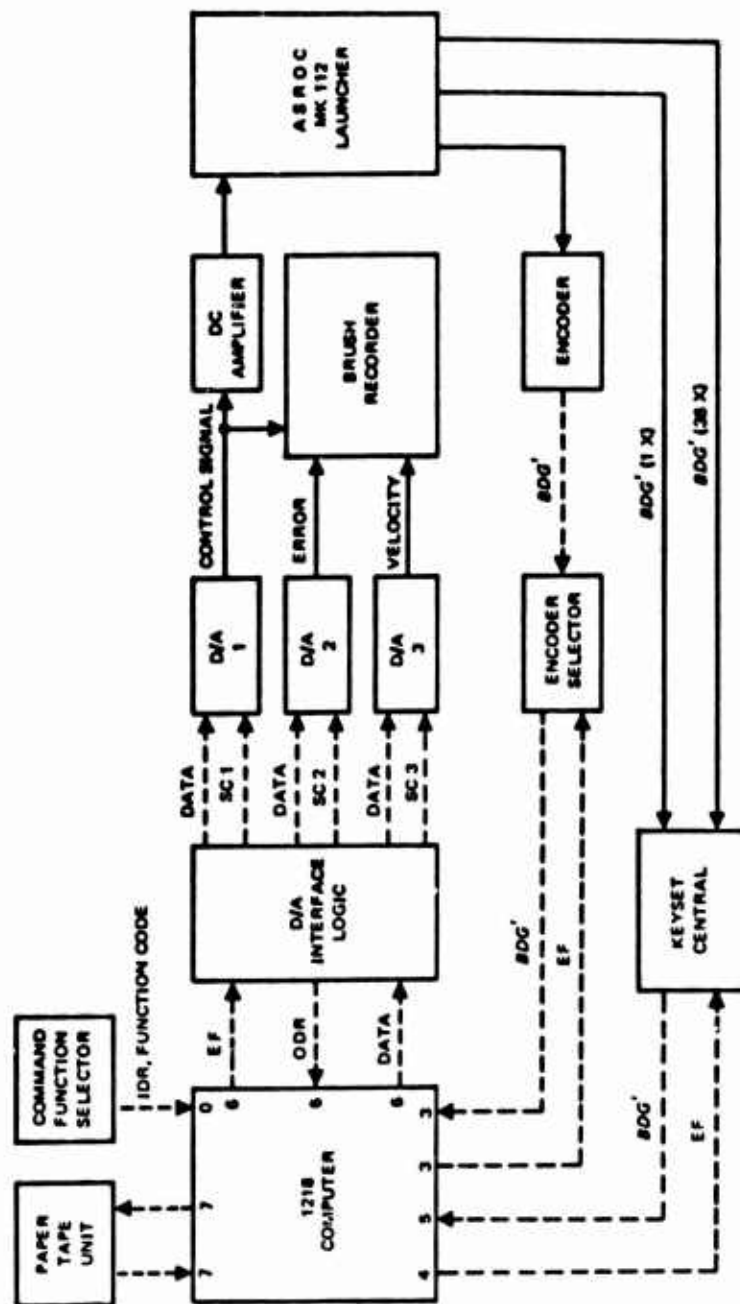


Figure 4-1. Configuration, block diagram.

2.2 Computer Program Materials

The following program paper tapes are required for operation of the launcher test program:

- a. ASROC Test Program (Paper Tape, Biocotal)
- b. "UPAK 1B" Utility Program (Paper Tape, Biocotal)

2.3 Supporting Documentation

Assuming a familiarity with the Type 1218 digital computer, the only supporting documentation necessary for program operation is Part 3, Computer Program Design Specification. The design specification contains a printed output listing and detailed information concerning all functions of the computer program.

2.4 Personnel Requirements

Program operation requires a minimum of two people: (1) the system operator, who is responsible for the operation of the computer, the Command Selector Control Panel, and the Mode Selector Control Panel; and (2) the launcher operator, who is stationed at the launcher controls and performs, as required, the switchover between the continuous analog control and the digital computer control system.

3.0 PRE-STANDBY PROCEDURES

Assuming power ON, and that all launcher and supporting equipment is properly connected and aligned, the computer operator will follow the procedures described in the next paragraphs.

3.1 Equipment Setup

The computer operator has no responsibilities with regard to equipment setup. The equipment setup and the power requirements for computer operation are the responsibilities of assigned electronic technicians.

3.2 Computer Program Setup

The following procedures are necessary prior to program initialization:

- a. Using the computer bootstrap and the automatic-load routine on the UPAK 1B tape, load UPAK 1B into the computer via the 1232 tape reader.
- b. Manually clear the computer via the MASTER CLEAR switch on the computer panel and enter 26006 octal into the P register.
- c. Place the ASROC test program tape in the 1232 tape reader and depress the computer RESTART switch, thus loading the ASROC test program.
- d. Using the inspect and change feature of UPAK 1B, insert into the memory the sampling-rate controller coefficients and the sine-wave parameters appropriate to the given test run.

4.0 STANDBY/OPERATE PROCEDURES

With all program setup steps completed the program initialization and execution are performed as follows:

- a. Depress the MASTER CLEAR switch on the computer panel and enter the 500 octal, the program initial address, in the P register.
- b. Depress the RESTART switch on the computer panel.
- c. Set the SYNCII (synchronizing interrupt) switch on the computer panel to ON.
- d. If encoder input is desired, set Skip Key 2 on the computer panel. If synchro input through KSC is desired, do not set Skip Key 2.

- e. Set all switches on the Command Selector Control Panel (fig. 4-2) to the OFF position and depress the input data request pushbutton.
- f. Set the mode select switches on the Mode Selector Control Panel (fig. 4-3) to DIGITAL.
- g. Depress the RESTART switch on the computer panel to begin program operation.
- h. Request the launcher operator to switch to digital control.
- i. Exercise the launcher in various control functions by entering appropriate switch settings at Command Selector Control Panel, in accordance with the schedule shown in tables 4-1 and 4-2.

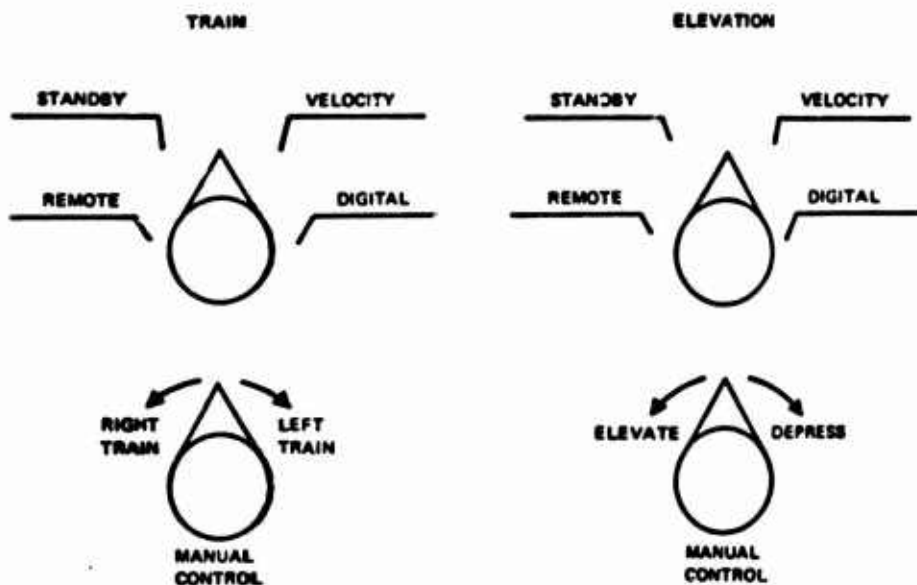


Figure 4-2. Mode Selector Control Panel

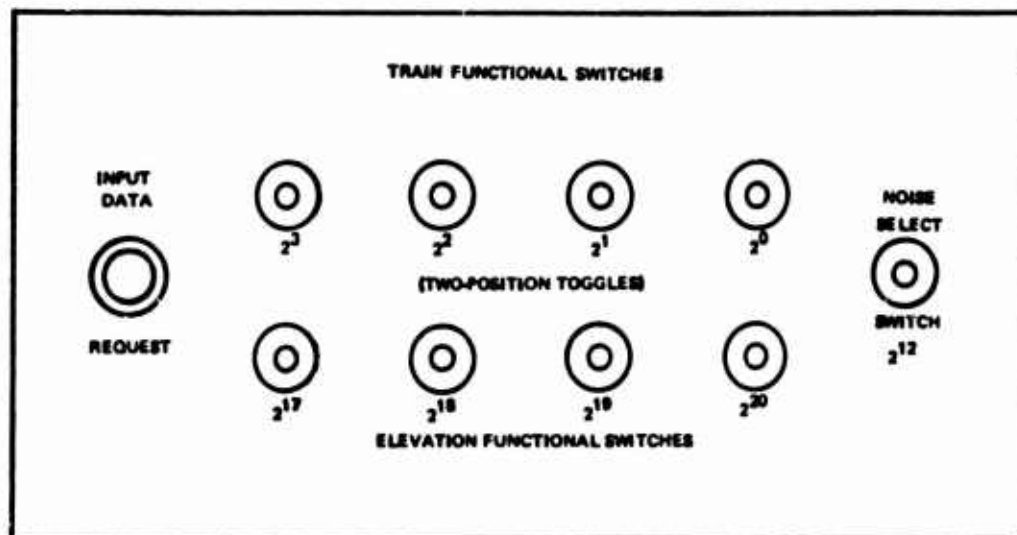


Figure 4-3. Command Selector Control Panel

TABLE 4-1. TRAIN POSITION COMMAND SWITCH SETTINGS

Function	Binary code	Control panel switch setting (function)
Generate zero position command	0000	None
1-degree step	0001	1
10-degree step	0010	2
45-degree step	0011	1, 2
90-degree step	0100	3
75-degree square wave	0101	1, 3
5-deg/sec ramp	0110	2, 3
20-deg/sec ramp	0111	1, 2, 3
30-deg/sec ramp	1000	4
30-deg step, plus 15-deg/sec ramp to 90 degrees	1001	1, 4
60-deg step, minus 20 deg/sec to -60 degrees	1010	2, 4
30-deg amplitude, 9-second period sine wave	1011	1, 2, 4
17.5-deg amplitude, 4.5-second period sine wave	1100	3, 4

TABLE 4-2. ELEVATION POSITION COMMAND SWITCH SETTINGS

Function	Binary code	Control Panel switch setting (function)
Generate zero position command	0000	None
1-degree step	0001	1
10-degree step	0010	2
45-degree step	0011	1, 2
60-degree step	0100	3
45-degree square wave	0101	1, 3
5-deg/sec ramp	0110	2, 3
15-deg/sec ramp	0111	1, 2, 3
20-degree step, plus 15-deg/sec ramp to 65 degrees	1000	4
60-degree step, minus 15-deg/sec ramp to zero	1001	1, 4
*20-degree amplitude, 9-second period sine wave	1010	2, 4
**5-degree amplitude, 4.5-second period sine wave	1011	1, 2, 4

*Offset from zero 30 degrees upward

**Offset from zero 20 degrees upward

NOTE: Noise may be added to any of the functions in tables 4-1 and 4-2 by additionally setting the noise function switch on the control panel.

5.0 MONITORING PROCEDURES

Program monitoring in the feasibility demonstration is accomplished both visually and electronically: visually by observing launcher response to Command Selector Control Panel inputs, and electronically by a Brush Strip Recorder, which produces paper recordings of test responses. In view of the extremely short program cycle time, no provisions are made for interrupt or abort, in the event of system malfunction during a program run, other than to switch control of the launcher from digital control to velocity control or analog control by use of the Mode Selector Control Panel switches or the two special switch boxes.

6.0 RECOVERY PROCEDURES

In the event of system malfunction and consequent stopping of the computer program, recovery is accomplished using the program restart procedure given in Section 4.0.

7.0 MAINTENANCE PROCEDURES

The information normally contained in a maintenance section is not applicable to this program since it is not designed for operational use.

PART 5
COMPUTER PROGRAM TEST PLAN

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1.0 SCOPE

Part 5 defines the scope of test activities conducted by NELC personnel at NWTCP in connection with the digital computer program and specialized hardware configurations required for the feasibility demonstration of digital computer control of the ASROC Mk 112 launcher. The test plan describes in general terms the nature and organization of the required tests. The tests served the dual function of (1) program test and validation, and (2) verification of engineering analysis techniques employed in simulation of the launcher during program design and the design of the digital system. The program exercises the launcher in both train and elevation. The computer program employs two distinct methods of inputting the Launcher Position into the computer, as described in Part 3, Computer Program Design Specification.

1.1 Test Objectives

The tests were planned to meet the following major objectives:

- a. Test the digital computer program for accuracy and completeness.
- b. Validate the results of the hybrid simulation conducted at NELC by observation and analysis of launcher response to varying input functions.
- c. Accumulate and evaluate test data for application to the overall digital fire-control problem.

1.2 Test Description

Tests were planned to (1) exercise the computer program using either KSC or shaft position encoders, and (2) validate all routines. Preparation for the test included outfitting a 40-foot trailer, which transported the computer and all required peripheral equipment to the test site at NWTCP. The trailer also provided a work area for test personnel. The first part of testing included setup of all equipment, interconnection between the launcher and digital computer, installation and checkout of recording instrumentation, and checkout of the launcher to verify that it met its performance specifications.

The second part of testing included running the computer program using the KSC or shaft position encoder feedback, exercising the launcher in all programmed functions, observing launcher responses, and recording data for postmortem evaluation.

1.2.1 INPUTS

In the absence of operational launcher environment (director, continuous control) certain functions were selected as representative of those that would be necessary in the operational configuration. To arrive at a set of parameters that satisfy feasibility demonstration requirements, control functions of the same magnitude as those used in the launcher acceptance tests were used as guidelines. Reference functions used by the digital computer program consist of step functions, ramp functions, sine waves, and combinations of these wave forms. Table 5-1 lists the control functions available to the computer program.

TABLE 5-1. COMPUTER PROGRAM REFERENCE FUNCTIONS

Train	Elevation
STEPS (DEGREES)	
1	1
10	10
45	45
90	60
RAMPS (DEG/SEC)	
5	5
20	15
30	

SINE WAVE

30-degree amplitude, 9-second period	20-degree amplitude, 9-second period
17.5-degree amplitude, 4.5-second period	5-degree amplitude, 4.5-second period

Program inputs take into consideration the following launcher response limitations: For train — maximum position, 0 degree to ± 170 degrees; maximum velocity, 38.5 deg/sec; maximum acceleration, 120 deg/sec per second. For elevation — maximum position, 0 degree to 116 degrees; maximum velocity, 25 deg/sec; maximum acceleration, 94 deg/sec per second. Program inputs were also designed to prove the capability of the launcher to follow and synchronize to signals in accordance with the accuracies and times of those specified in tables 9, 10, and 12, chapter 9, NAVWEPS OD 10729, of reference K, Part 6, Section 2.4.

1.2.2 ANTICIPATED TEST RESULTS

Since the program was designed as a feasibility demonstration, the actual test of program accuracy and completeness was dependent upon observed and recorded launcher response to programmed control function inputs. If launcher response was within the allowable error parameters shown in tables 9, 10, and 12, chapter 9, NAVWEPS OD 10729, the program was considered valid and complete. This program represents a demonstration of techniques that can be refined and used in the creation of the launcher control portion of an operational fire-control system.

2.0 SCHEDULE

The feasibility demonstration and program test activities were scheduled for the period 10 July 1968 through 28 August 1968. The first two weeks of the scheduled test period were occupied with cabling equipment in the necessary test configuration, resolving various interface problems, debugging computer program routines, and making mechanical adjustments to the launcher power drives. The balance of the test period was devoted to actual test and demonstration activities. All tests were done on a non-interfering, after-hours basis, so that the launcher would be free for scheduled classes during the day.

3.0 TEST SUPPORT REQUIREMENTS

The following paragraphs list the test support requirements in terms of personnel, equipment, and computer programs.

3.1 Personnel Requirements

NELC was responsible for the management and evaluation of the Mk 112 launcher tests. Support in resolving launcher interface problems was made available from Naval Underwater Weapons Research and Engineering Station (NUWRES). The following personnel were required to carry out the test activities.

- a. Four electronic engineers, including a project manager, test director and two engineers responsible for test documentation and program execution.
- b. Two electronic technicians, one of whom was stationed at the launcher control panel.

3.2 Equipment/Facility Requirements

Facilities for the test were provided at NWTCP adjacent to an ASROC Mk 112 launcher that was made available, along with a dummy director, by NWTCP. All other necessary equipment, including interconnecting cabling, was housed in a 40-foot semi-trailer obtained on loan from the U.S. Naval Schools Command, Mare Island, California, and transported to the test site. A listing of the equipment requirements is contained in Part 6, Computer Program Test Specification.

3.3 Software Requirements

In addition to the computer program, the following supporting programs were required in the conduct of the tests:

- a. "UPAK 1B" - 1218 Utility package.
- b. "TRIM II FIELD-DATA" Trim II Field Data Code Assembler.
- c. "EDITOR" Raytheon Conversational Software Package for the UNIVAC 1218/1232 Computer.
- d. Launcher Test Program (Source).
- e. "ICE" 1232 Input/Output Console Test Program.
- f. "DAADCK" D/A Converter Test program.

PART 6

COMPUTER PROGRAM TEST SPECIFICATION

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1.0 SCOPE

Part 6 contains a detailed description of the program tests and feasibility demonstration conducted by NELC at NWTCP. The tests required a specialized configuration of hardware, including replacement of portions of the launcher system. All equipment necessary to conduct the tests, except the two encoders and two special switch boxes, was housed in a trailer transported to NWTCP and placed adjacent to the launcher. Section 3.0, Part 6, describes the hardware configuration installed in the trailer, discusses the system environment, and gives a detailed account of test methods, procedures, and requirements. All program functions in both train and elevation were exercised during the tests.

The test objectives were as follows:

- a. Ascertain the feasibility of utilizing digital control techniques in the operation of the Mk 112 ASROC Launcher.
- b. Establish the validity of the engineering analysis and techniques employed in simulating a conventional launcher environment.
- c. Validate the results, in terms of hardware response, of hybrid simulation conducted at NELC.
- d. Accumulate test data for determination of a transfer function model of the launcher system.
- e. Test the digital computer program for accuracy and completeness.
- f. Determine optimum sampling rate for overall system performance, considering both the launcher response and conservation of computer time.
- g. Gather test data for evaluation and application to future digital fire-control problems.

All test objectives were achieved. The results indicated that digital control of the Mk 112 ASROC launcher is entirely feasible. The basic program design, although in no sense an operational configuration, proved to be sound and completely adequate for the mission performed.

2.0 APPLICABLE DOCUMENTS

The documents listed in paragraphs 2.1 through 2.4 are applicable to Part 6.

2.1 Computer Program Test Plan, Mk 112 ASROC Launcher Digital Control System

Part 5 outlines the scope of testing to be performed and the support requirements for testing in terms of personnel, facilities, and equipment

2.2 Computer Program Performance Specification, Mk 112 ASROC Launcher Digital Control System

Part 2 provides a logical, detailed description of the performance requirements of the computer program. It also describes the hardware interfaces in terms of applicability to the feasibility demonstration task.

2.3 Computer Program Design Specification, Mk 112 ASROC Launcher Digital Control System

Part 3 provides an overall description of the functions of the computer program and detailed information concerning each routine.

2.4 Other Publications

The following publications contain reference material applicable to the content of this specification.

- a. NAVWEPS OD 14430, "Factory Acceptance Test Power Drive Mk 61 and Mk 62, Power Amplifier Mk 153 "

- b. Naval Underwater Weapons Research and Engineering Station TM 379, *Operational Tests of the ASROC Launcher MK 112 With Simulated ASROC and ERA Missile Loads*, by W. B. Cullison, CONFIDENTIAL, November 1966
- c. Naval Electronics Laboratory Center Drawing RAAC 340.1-2230, *Encoder-Synchro Assembly*, March 1968
- d. Univac PX 2526, 4 vols., *Technical Manual For Type 1218 Digital Data Computer*, May 1964
- e. Bureau of Ordnance Drawing LD 541510, *ASROC Weapon System FCG Mk 111 Functional Schematics For DD 710 Class Ships*, 28 June 1961
- f. Univac PX 2910, Revision A, *Programmers Reference Manual For UNIVAC 1218 Computer*, December 1963
- g. Bureau of Ships NavShips 94093(A), v.2, *Technical Manual For Digital Data Converter CV-1123/USQ-20(V), Section 8*, v.2, 14 June 1963
- h. Naval Electronics Laboratory Center, *Computer Program Performance Specifications For the MK 112 ASROC Launcher*, by D. L. Buck, 28 June 1968
- i. Bureau of Weapons NavWeps OP 2385, v.2 (Revision 1, Change 2), *Launching Group MK 16 Mods 1, 2, 3 and 4, Train Power Drive MK 61, Mods 0 and 1, Elevation Power Drive MK 62 Mods 0 and 1, and Power Drive Amplifier MK 153 Mod 0 Amplifier Chassis; Description and Maintenance*, 14 May 1965
- j. Navy Electronics Laboratory Technical Memorandum 977, *Digital Multiplexer For the 1218 Computer*, by R. W. Nowlin, 11 August 1966
- k. Bureau of Weapons NavWeps OD 10729, Revision 5, *Launching Group MK 16 Mod 4 Shipboard Installation and Checkout, Instructions For*, CONFIDENTIAL, 14 February 1962

3.0 REQUIREMENTS

Paragraphs 3.1 through 3.7 define the detailed test requirements for the feasibility demonstration, including test management, personnel, hardware, functions tested, and procedures. Test results are documented in Section 6.0, Part 6.

3.1 Test Management

All test activities conducted at NWTCP, during the period 10 July to 28 August 1968 were the responsibility of NELC. This responsibility included not only the actual conduct of the feasibility demonstration and program tests, but implementation of the test setup. Cabling equipment in the necessary test configuration, resolving interface problems, and verifying equipment operational status constituted major portions of the hardware setup requirements. Technical and mechanical assistance in areas concerned with the Mk 112 ASROC Launcher was made available by NWTCP.

3.2 Personnel Requirements

Table 6-1 lists the NELC personnel involved in the test activities. The services of NWTCP were used on an as-needed basis. NWTCP personnel assisted with all mechanical and technical problems concerned with the ASROC Launcher on a part-time, as-required basis. The following personnel were present as observers during the feasibility demonstration:

P. McCann (NUWC, Pasadena)

H. Mori (NUWC, Pasadena)

N. Wilbur (NUWRES)

T. Calto (NUWRES)

C. Manning (NELC)

J. Slaughter (NELC)

TABLE 6-1. PERSONNEL REQUIREMENTS

PERSONNEL	CLASSIFICATION	DUTIES
D. W. Doherty (NELC)	Electronic Engr. (Project Manager)	Overall administrative and technical supervision of project. Coordination and direction of test activities and system design.
D. L. Buck (NELC)	Electronic Engr.	Program execution, test monitoring, resolution of design problems, and test documentation.
R. L. Bruck (NELC)	Electronic Engr.	Test monitoring, test documentation, and administrative details.
R. W. Nowlin (NELC)	Electronic Engr.	Computer programming, hardware interface resolution, test preparation, and hardware and software consultation.
P. G. Sibert (NELC)	Electronic Tech.	Initial equipment installation and interconnection, trouble shooting, equipment checkout, and test monitoring.
G. F. Grable	Electronic Tech.	Initial equipment installation and interconnection, trouble shooting, equipment checkout, and test monitoring.

3.3 Hardware Requirements

The testing equipment was housed in the trailer except for the two special switch boxes located in the ASROC Control Room and the two encoders located in the train and elevation receiver regulators Mk 46 and 47, Mod 2. The cable listing and description are covered in paragraph 3.3.3. The location of hardware in the trailer is shown in figure 6-1.

The computer and peripheral equipment are as follows:

- a. 1 Digital Computer, Model CP 789 (UNIVAC Type 1218).
- b. 1 Paper Tape Unit, Type 1232 Input/Output Console.

The supporting equipments, which include some of the special testing assemblies designed and built by NELC, are as follows (miscellaneous types are not listed):

- a. 1 Digital Data Converter, Model CV 1123/USQ-20(V).
- b. 6 Digital-to-Analog Converters, Packard Bell Model DA6.
- c. 2 Operational Amplifiers, Zeltex Model 142C.
- d. 1 4-Channel Strip Recorder, Brush Model Mark 200.
- e. 2 Shaft-to-Digital Encoders, Datex Model 12-300-27.
- f. 1 +6-Volt Power Supply, Sorensen Model Q Nobatron QRC 20-8A.
- g. 1 -12-Volt Power Supply, Sorensen Model Q Nobatron QRC 20-8A.
- h. 1 +15-Volt Power Supply, Sorensen Model Q Nobatron QRC 20-8A.
- i. 1 -15-Volt Power Supply, Sorensen Model Q Nobatron ARC 20-8A.

3.3.1 HARDWARE DESCRIPTIONS

The hardware described in the following paragraphs is that which was designed and built by NELC and is not treated elsewhere. Each description is headed by the title of the equipment being described.

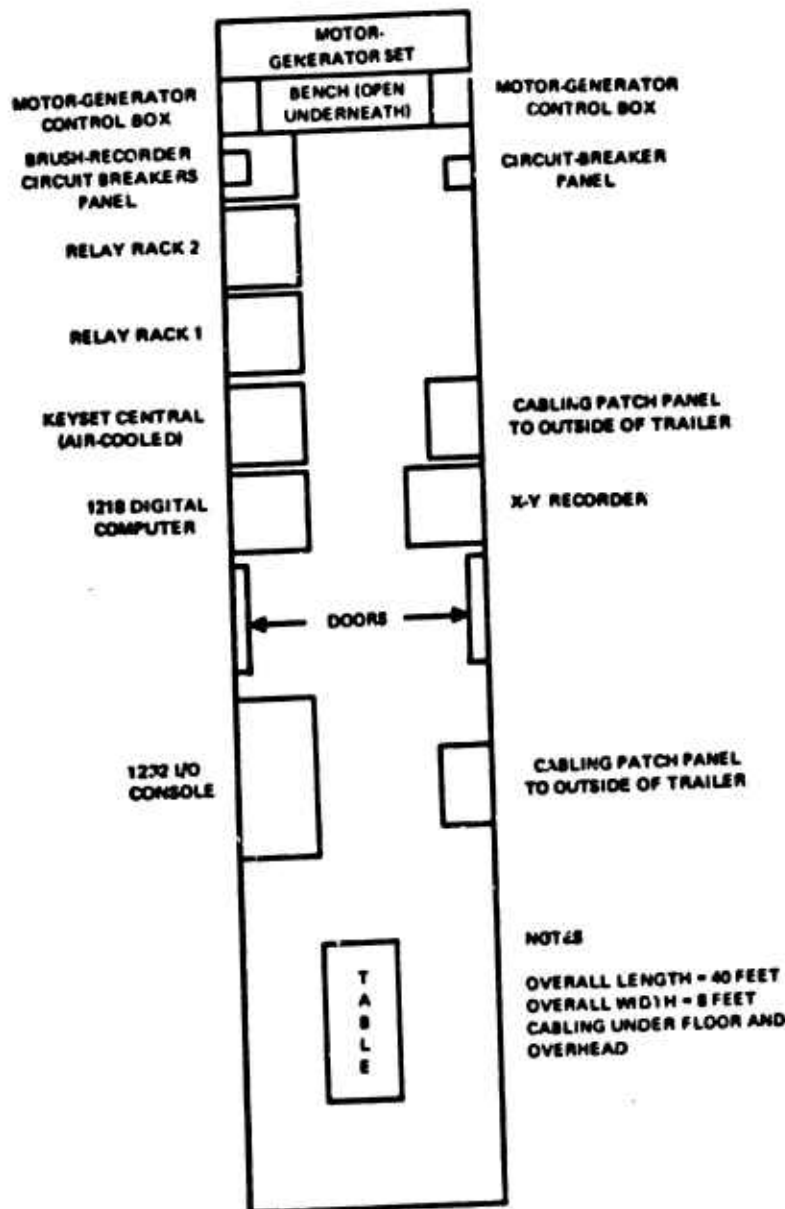


Figure 6-1. Trailer hardware configuration.

3.3.1.1 Command Selector Control Panel Logic

The Command Selector Control Panel is described sufficiently in other sections of this document, but associated with the panel is the logic shown in figure 6-2. All the switches associated with the data bits ($2^0 - 2^{17}$) are two-position toggle switches. The switch associated with the flip-flop is a spring-loaded, pushbutton type. The data word, to be generated by this panel and logic, is selected by setting the desired toggle switches to give zero volts. After the appropriate switch selection has been performed, the pushbutton switch is pushed. This puts 0 volt on the set side of the flip-flop, causing it to switch to the set state. The output of the flip-flop changes states and causes the line driver to send an Input Data Request (IDR) to the computer. After the computer recognizes the IDR, it reads the data of the switch settings and sends an Input Data Acknowledge (IDA) to the Command Selector Control Panel that resets the flip-flop and drops the IDR. A new command is generated by resetting the desired switches and again actuating the pushbutton switch.

3.3.1.2 Command Selector Control Panel Logic

The Command Selector Control Panel is described sufficiently in other sections of this document, but associated with the panel is the logic shown in figure 6-2. All switches, except the one on the left of figure 4-3, are of the two-position toggle variety. The left-most switch is a spring-loaded pushbutton type. The data word generated by this panel is selected by setting the desired switches to give zero volts. After switch selection has been performed, the pushbutton switch is pushed, setting the flip-flop, activating the line driver, and generating an Input Data Request at the computer. When the computer reads the data, it sends an Input Acknowledge, resetting the flip-flop, and dropping the IDR.

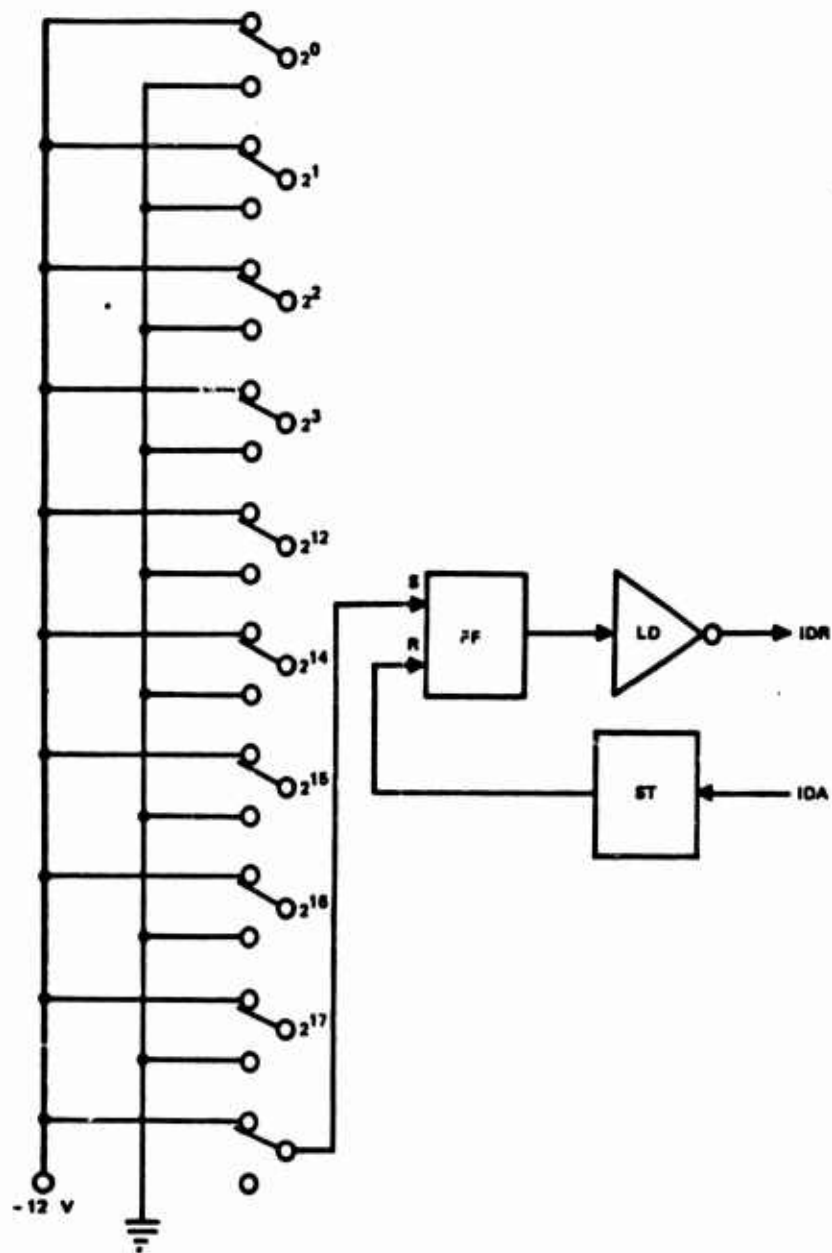


Figure 6-2. Command Selector Control Panel logic.

3.3.1.3 Special Logic Chassis

Included in this special logic chassis are the necessary components to interface the D/A converters and the encoders with the computer. The philosophy and operation of the computer-to-D/A-converter interface are adequately presented in reference j, Section 2.4, Part 6. There are some differences between the interface described and the interface used in the tests at NWCTP. Instead of feeding the external-function code bits directly into the D/A selection circuitry, they are inverted before being applied. The external-function code for selecting D/A 1 through 6 then becomes 000001₈, 000002₈, 000004₈, 000010₈, 000020₈, and 000040₈ instead of as given in reference j.

The encoder-to-computer interface is shown in figure 6-3. The Datex encoders require the following control signal characteristics:

- a. Before Interrogation,
 - Inhibit = -12 V
 - Store/follow = 0 V
- b. Start of Interrogation,
 - Inhibit = 0 V
 - Store/follow = 0 V
- c. 100 μ sec after start of Interrogation,
 - Inhibit = 0 V
 - Store/follow = -12 V

(Computer reads data at this time.)

The interface was designed to ensure that the encoder receives these signals as needed and that the computer does not read the data until the encoder is ready. The Schmitt triggers are used for shaping computer pulses and activating subsequent circuits. An external function and external-function code are sent by the computer to initiate action and to select the desired encoder. External-function signal "A" is applied to OR Gate 1, resetting Flip-flops 1, 2, and 3, deactivating Line Drivers 1, 2, and 3, and activating Line Driver 4. This ensures the inhibits to be -12V, the store/follow to be 0 V, and the input data request deactivated. Several μ sec after these events, external-function signal "B" is applied to the AND gates, gating the external-function code and selecting the desired encoder. This sets

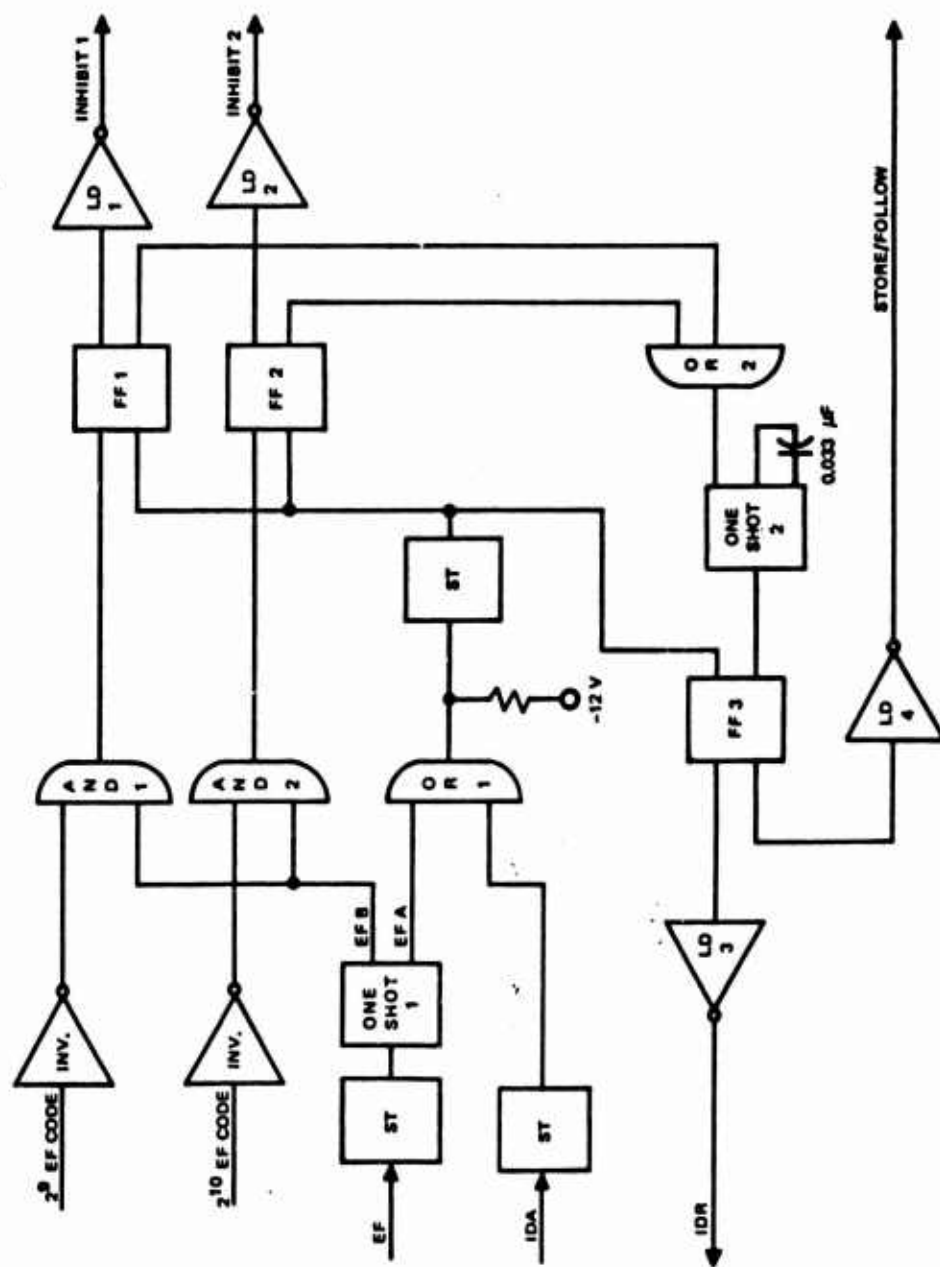


Figure 6-3. Encoder-computer interface logic.

the proper flip-flop and activates the correct line driver, forcing the inhibit of the selected encoder to 0 V. OR Gate 2 applies the output of the flip-flop selected to One Shot 2. The output of this circuit is delayed 100 μ sec, after which Flip-flop 3 is set, activating Line Driver 3 and deactivating Line Driver 4.

These actions drive the input data request to 0 V (activated) and the store/follow to -12 V. The computer reads the data at this time and then sends an Input Data Acknowledge. The IDA generates the same sequence of actions as does external function signal "A." The sequence of events can now be reinitiated. The logic chassis also contains (but is not shown in fig. 6-3) the necessary circuitry to convert the encoder data bits to the level acceptable by the computer and for converting computer data to the level acceptable by the D/A converters.

3.3.1.4 MoJa Selector Control Panel

The Mode Selector Control Panel, designed and built by NELC, controls the configuration of the launcher system in both train and elevation. Only the train part of the panel will be discussed since the elevation functions are identical to that of the train. The remote position (fig. 6-4) allows the launcher to be operated, in its normal mode, from the Launcher Captain's Control Panel Mk 199. The STANDBY position freezes all launcher operation by disconnecting control of the power drives from the Mk 199. Manual control of the launcher at the Mode Selector Control Panel is obtained with the Mode Selector switch in the VELOCITY position. In the velocity mode, the operator can position the launcher to the left or right by turning the MANUAL CONTROL potentiometer, which adjusts a control voltage applied to the power amplifier driving the torque motor. When the switch is in the DIGITAL position, the launcher power drives are controlled by the computer program.

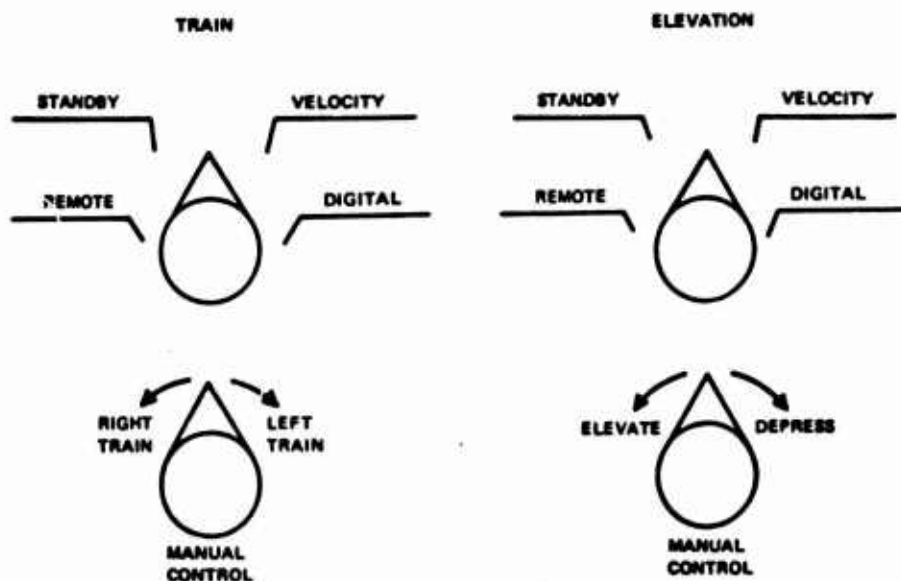


Figure 6-4. Mode Selector Control Panel.

3.3.3 CABLES REQUIRED

3.3.3.1 Cable List

The cables are numbered sequentially from beginning to end, although they are divided into two groups, "digital data" and "analog data, miscellaneous":

DIGITAL DATA

<u>No.</u>	<u>Cable</u>
1	1218 Computer Input Channel 0 to Relay Rack 1
2	1218 Computer Input Channel 5 to KSC output
3	1218 Computer Input Channel 6 to logic chassis
4	1218 Computer Input Channel 7 to 1232 I/O Console output

<u>No.</u>	<u>Cable</u>
5	1218 Computer Output Channel 5 to KSC input
6	1218 Computer Output Channel 6 to logic chassis
7	1218 Computer Output Channel 7 to 1232 I/O Console input
8	Train shaft encoder to logic chassis
9	Elevation shaft encoder to logic chassis
10	Logic chassis to DA6 Rack 1
11	Logic chassis to DA6 Rack 1
12	Logic chassis to DA6 Rack 2
13	Logic chassis to DA6 Rack 2

ANALOG DATA, MISCELLANEOUS

14	DA6 1 output to Relay Rack 2 (patch panel)
15	DA6 2 output to Relay Rack 2 (patch panel)
16	DA6 3 output to Relay Rack 2 (patch panel)
17	DA6 4 output to Relay Rack 2 (patch panel)
18	DA6 5 output to Relay Rack 2 (patch panel)
19	DA6 6 output to Relay Rack 2 (patch panel)
20	Brush Recorder to Relay Rack 2 (patch panel)
21	Mode Selector Control chassis to Captain's Control Panel (Mk 199), Train
22	Mode Selector Control chassis to Captain's Control Panel (Mk 199), Elevation
23	Relay Rack 2 (patch panel) to variplotter (X-Y recorder)
24	Train synchro to KSC
25	Elevation synchro to KSC

3.3.3.2 Cable Descriptions

Each of the following descriptions is headed by a cable number(s); these numbers correspond to those in the cable list (par. 3.3.3.1).

CABLE 1

Title: 1218 Computer Input Channel 0 to Relay Rack 1

Length: 15 feet

Connectors: Cannon DPD 4500-5002 (both ends)

<u>Number, pins</u>	<u>Function</u>	<u>Number, pins</u>
---------------------	-----------------	---------------------

Note: Transmits Command Selector Control Panel word data bits via standard computer cable.

CABLE 2

Title: 1218 Computer Input Channel 5 to KSC output

Length: 15 feet

Connectors: Cannon DPD 4500-5002 (both ends)

<u>Number, pins</u>	<u>Function</u>	<u>Number, pins</u>
---------------------	-----------------	---------------------

Note: Transmits Bdg' and Edg' from KSC to 1218 via standard computer cable.

CABLE 3

Title: 1218 Computer Input Channel 6 to logic chassis

Length: 15 feet

Connectors: Cannon DPD 4500-5002 (both ends)

<u>Number, pins</u>	<u>Function</u>	<u>Number, pins</u>
---------------------	-----------------	---------------------

Note: Transmits Bdg' and Edg' from encoder logic to 1218 via standard computer cable.

CABLE 4

Title: 1218 Computer Input Channel 7 to 1232 I/O console output

Length: 20 feet

Connectors: Cannon DPD 4500-5002 (both ends)

<u>Number, pins</u>	<u>Function</u>	<u>Number, pins</u>
---------------------	-----------------	---------------------

Note: Standard computer cable.

CABLE 5

Title: 1218 Computer Output Channel 5 to KSC input

Length: 15 feet

Connectors: Cannon DPD 4500-5002 (both ends)

<u>Number, pins</u>	<u>Function</u>	<u>Number, pins</u>
---------------------	-----------------	---------------------

Note: Standard computer cable.

CABLE 6

Title: 1218 Computer Output Channel 6 to logic chassis

Length: 15 feet

Connectors: Cannon DPD 4500-5002 (both ends)

<u>Number, pins</u>	<u>Function</u>	<u>Number, pins</u>
---------------------	-----------------	---------------------

Note: Transmits *Bdg1'*, *Edg1'*, *c(Bdg')*, *c(Edg')*, *DBdg1'* and *DEdg1'* to the D/A converters via standard computer cable.

CABLE 7

Title: 1218 Output Channel 7 to 1232 I/O Console input

Length: 20 feet

Connectors: Cannon DPD 4500-5002 (both ends)

<u>Number, pins</u>	<u>Function</u>	<u>Number, pins</u>
---------------------	-----------------	---------------------

Note: Standard computer cable.

CABLE 8

Title: Train shaft encoder to logic chassis

Length: 100 feet

Connectors: Encoder: KOA6-21S20-38-SN

Chassis: Bendix 20-41S SR

<u>Number, pins</u> (Encoder)	<u>Function</u>	<u>Number, pins</u>
1	-15 V dc	V
1	Common (0 V dc)	D
2	+15 V dc	X
2	Store-follow	A
3	Inhibit	Z
5	2^0	E
6	2^1	F
6	2^2	G
7	2^3	H
7	Parity 1 (not used)	
8	2^4	J
8	2^5	K
9	2^6	L
9	2^7	M
10	Parity 2 (not used)	
10	2^8	N
11	2^9	P
11	2^{10}	R
12	2^{11}	S
13	2^{12}	T
13	2^{13}	U
14	2^{14}	W
18	Test 1 (not used)	
18	Test 2 (not used)	

CABLE 9

Title: Elevation shaft encoder to logic chassis

Length: 100 feet

Connectors: Encoder: KOA6-21S20-38 SN

Chassis: Bendix 20-41S SR

<u>Number, pins</u> (Encoder)	<u>Function</u>	<u>Number, pins</u>
1	-15 V dc	V
1	Common (0 V dc)	D
2	+15 V dc	X
2	Store-follow	A
3	Inhibit	Z
5	2^0	E
6	2^1	F
6	2^2	G
7	2^3	H
7	Parity 1 (not used)	
8	2^4	J
8	2^5	K
9	2^6	L
9	2^7	M
10	Parity 2 (not used)	
10	2^8	N
11	2^9	P
11	2^{10}	R
12	2^{11}	S
13	2^{12}	T
13	2^{13}	U
14	2^{14}	W

CABLE 9 (Continued)

<u>Number, pins</u> (Encoder)	<u>Function</u>	<u>Number, pins</u>
18	Test 1 (not used)	
18	Test 2 (not used)	

CABLE 10 AND 12

Title: Logic chassis to DA6 Rack 1 and Rack 2

Length: 5 feet

Connectors: Winchester MRE 26H XMRE 26-0300 (both ends)

<u>Number, pins</u> (Chassis - P5)	<u>Function</u>	<u>Number, pins</u> (DA6 - J23)
A	2^0	A
B	2^1	B
C	2^2	C
D	2^3	D
E	2^4	E
F	2^5	F
H	2^6	H
J	2^7	J
K	2^8	K
L	2^9	L
M	2^{10}	M
N	2^{11}	N
P	2^{12}	P
R	2^{13}	R
V	Convert trigger	V (DA6 1 and 4)
W	Convert trigger	V (DA6 2 and 5)
X	Convert trigger	V (DA6 3 and 6)
AA	Common (0 V dc)	AA

CABLE 11 AND 13

Title: Logic chassis to DA6 rack 1 and rack 2

Length: 5 feet

Connectors: Winchester MRE 26H XMRE 26-0300 (both ends)

<u>Number, pins</u> (Chassis - P6)	<u>Function</u>	<u>Number, pins</u> (DA6 - J24)
A	2 ⁰	A
B	2 ¹	B
C	2 ²	C
D	2 ³	D
E	2 ⁴	E
F	2 ⁵	F
H	2 ⁶	H
J	2 ⁷	J
K	2 ⁸	K
L	2 ⁹	L
M	2 ¹⁰	M
N	2 ¹¹	N
P	2 ¹²	P
R	2 ¹³	R

CABLES 14, 15, 16, 17, 18, AND 19

Title: DA6 1, 2, 3, 4, 5, and 6 outputs to Relay Rack 2 (patch panel)

Length: 5 feet

Connectors: DA6: Microdot
Patch Panel: Phone jack ADC PJ 318

<u>Number, pins</u>	<u>Function</u>	<u>Number, pins</u>
Note: Converter analog output to patch panel via microdot cable.		

CABLE 20

Title: Brush Recorder to Relay Rack 2 (patch panel)

Length: 15 feet

Connectors: Brush Recorder: J3 - Amphenol - 24-28S

Patch Panel: Phone Jack ADC PJ 318

<u>Number, pins</u> (Recorder - J3)	<u>Function</u>	<u>Number, pins</u>
A	Sig. Hi	ADC
B	Sig. Lo	J23A and B
F	Shield	
K	Sig. Hi	
L	Sig. Lo	J24A and B
E	Shield	
P	Sig. Hi	
Q	Sig. Lo	J25A and B
J	Shield	
X	Sig. Hi	
Y	Sig. Lo	J26A and B
T	Shield	

CABLE 21 (TRAIN) AND 22 (ELEVATION)

Title: Mode selector Control chassis to Captain's Control Panel (Mk 199)

Length: 100 feet

Connectors: Mode Selector Control chassis: Bendix MS3102R

Captain's Control Stand (Mk 199): TB 1

<u>Number, pins</u> (MSCC)	<u>Function</u>	<u>Number, pins</u> (Chassis, TB)
A	GND	GND
B	Torque motor center tap	7

CABLE 21 AND 22 (Continued)

<u>Number, pins</u> (MSCC)	<u>Function</u>	<u>Number, pins</u> (Chassis, TB)
C	Torque Motor center tap	End of wire removed from 7
D	Torque motor B+	6
E	Torque motor B+	End of wire removed from 6
F	Stroke potentiometer	3
G	Stroke potentiometer	End of wire removed from 3
H	Tachometer	1
I	Tachometer	End of wire removed from 1
J	Torque motor ground	8
K	Torque motor ground	End of wire removed from 8
L	Stroke potentiometer and tachometer ground	2
M	Stroke potentiometer and tachometer ground	End of wire removed from 2

CABLE 23

Title: Relay Rack 2 (patch panel) to variplotter (X-Y recorder)

Length: 20 feet

Connector: Variplotter: P1 - Amphenol - 201356-3
Patch Panel: Phone jack ADC PJ 318

<u>Number, pins</u> (Variplotter - P1)	<u>Function</u>	<u>Number, pins</u> (Patch Panel)
A	Arm (high)	J27 (A and B) Hi
C	Pen (high)	J28 (A and B) Hi
D	+10 V ref.	Zener from +15 V
E	GND (chassis)	Chassis
L	Arm (low)	J27 (A and B) Lo
N	Pen (low)	J28 (A and B) Lo

CABLE 24**Title:** Train synchro to KSC**Length:** 100 feet**Connectors:** Train synchro (Mk 199): TB-2

Keyset Central: A1J13-MS-1057-10B (Cannon)

<u>Number, pins</u> (TB-2)	<u>Function</u>	<u>Number, pins</u> (A1J13)
1	R1	J
2	R2	I
4	S1 (1X)	A
5	S2 (1X)	B
6	S3 (1X)	C
7	S1 (36X)	D
8	S2 (36X)	E
9	S3 (36X)	F

CABLE 25**Title:** Elevation synchro to KSC**Length:** 100 feet**Connectors:** Elevation synchro (Mk 199): TB-3

Keyset Central: A1J12-MS1057-10B (Cannon)

<u>Number, pins</u> (TB-3)	<u>Function</u>	<u>Number, pins</u> (A1J12)
1	R1	J
2	R2	I
4	S3 (1X)	C
5	S2 (1X)	B
6	S1 (1X)	A
7	S3 (36X)	F
8	S2 (36X)	E
9	S1 (36X)	D

3.4 Supporting Software Requirements

The following programs were utilized in support of the tests. Each program listed is followed by a brief statement of its purpose.

3.4.1 "UPAK 1B" - 1218 UTILITY PACKAGE

This program is used to load the launcher test program and to make any "on-the-spot" changes to the launcher test program.

3.4.2 "TRIM II" - TRIM II FIELD-DATA CODE ASSEMBLER

This program is used to compile and recompile the test program when necessary.

3.4.3 LAUNCHER TEST PROGRAM (SOURCE)

This program is used with Trim II in recompiling the test program.

3.4.4 "EDITOR"

This program is used in making changes to the launcher test program (source).

3.4.5 "TELFA" - COMPUTER DIAGNOSTIC TEST

This program is used to check the computer for any malfunctions.

3.4.6 "ICE" - I/O CONSOLE TEST

This program is used to check the 1232 I/O console for malfunctions.

3.4.7 "MEDIC" - COMPUTER DIAGNOSTIC TEST

This program is used to diagnose troubles in the memory section of the computer.

3.4.8 D/A CONVERTER - ENCODER TEST

This program is used to test the D/A converters and the encoders.

3.5 Test Procedure

Hardware configuration test inputs and operator actions for the feasibility demonstration are discussed in paragraphs 3.5.1 through 3.5.4. The test program was written to contain all routines for both Keyset Central and encoder input configurations. Program execution for either type of input was controlled by skip-key action at the computer.

3.5.1 ENCODER INPUT CONFIGURATION

Figure 6-5 shows a block diagram of the hardware configuration. Encoders were mounted in the train and elevation receiver regulators. The digital outputs of the encoders correspond to launcher train and elevation positions which are sent through NELC-designed interface equipment to the 1218 computer. The computer program uses these position signals to determine errors and the appropriate compensated control signals, which are then outputted to the launcher.

3.5.2 KEYSSET CENTRAL INPUT CONFIGURATION

Figure 6-5 shows the configuration when launcher train and elevation coarse and fine synchros are used for position feedback through KSC. By setting the proper computer skip key the test program obtains these position data instead of those provided by the encoders. Keyset Central converts the launcher coarse and fine synchro signals to digital quantities for use by the digital computer in error determination and compensation.

3.5.3 INPUTS

Inputs for system operation comprise those functions that will most closely simulate the normal command inputs to the ASROC launcher, with additional reference functions added to assist in determining optimum performance parameters. Reference functions used by the program (via appropriate switch setting at the Command Selector Control Panel) consist of step functions, ramp functions, and sine waves of the same magnitude as those used in conducting launcher acceptance tests (table 6-2).

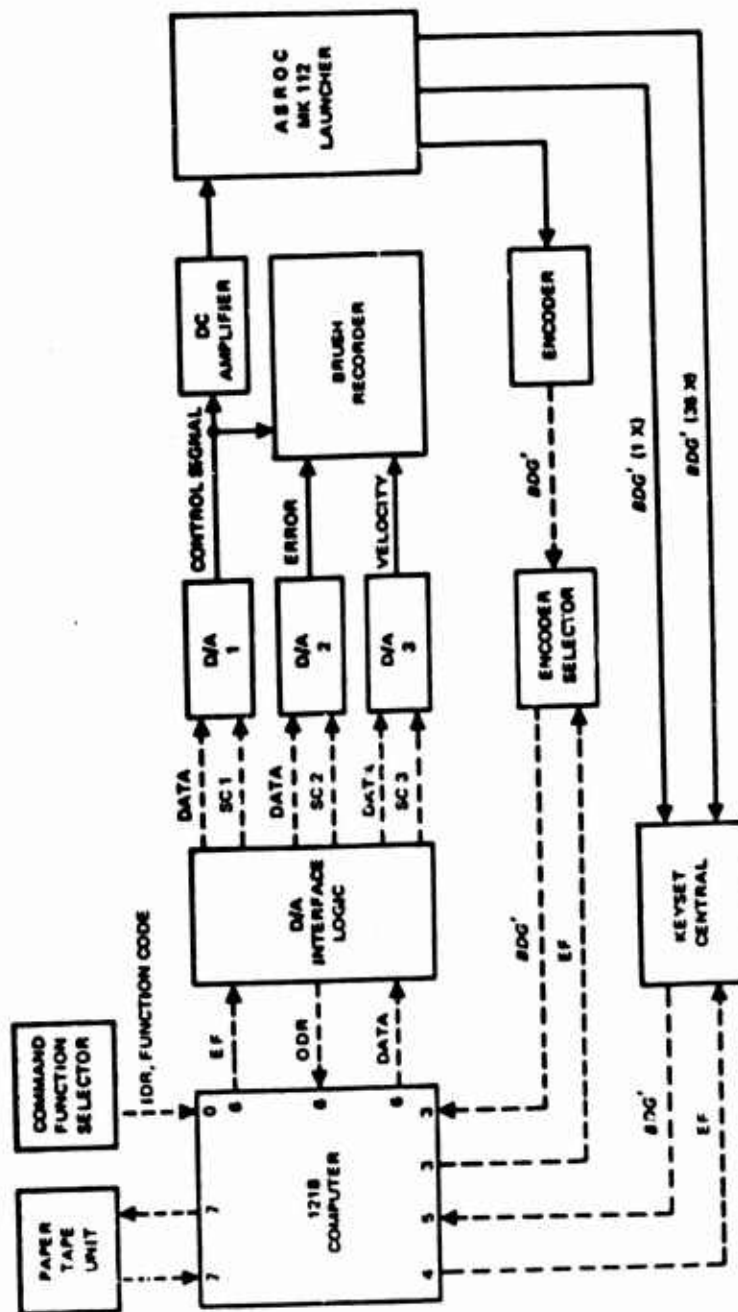


Figure 6-5. Configuration block diagram.

TABLE 6-2. COMPUTER PROGRAM REFERENCE FUNCTIONS

Steps (deg)	Ramps (deg/sec)	Sine wave
1	5	30-degree, 9-second period
10	15	17.5-degree, 4.5-second period
45	20	20-degree, 9-second period
50	30	5-degree, 4.5-second period
75		
160		

3.5.4 OPERATOR ACTIONS

System operation subsequent to initialization and encoder or KSC selection requires only switch and pushbutton action at the Command Selector Control Panel. Figure 6-6 shows the panel and identifies the switches. The four-switch array on top of the panel controls all train function inputs to the computer, with the switch at the extreme left representing the least significant digit. The four-switch array on the bottom of the panel controls all elevation function inputs to the computer, with the least significant digit located at the extreme left. After appropriate switch settings are made, the selection is entered into the computer by depressing the Input Data Request button. Switch settings merely set a binary code that calls up the function required after being entered into the computer. The functions and their binary code are shown in table 6-3. Switches are set by placing them in the UP position.

It should be noted that, regardless of the switch settings, no new launcher commands will be executed until the IDR pushbutton is depressed, thus signaling the program to interrogate the panel.

Step functions are executed by a direct and immediate movement to the new commanded position. Ramp functions impart a rate of change, or velocity component; thus the combinations shown in tables 6-3 and 6-4 (30-degree step plus 15 deg/sec ramp to 90 degrees; 60-degree step, minus 20 deg/sec ramp to -60 degrees; 20-degree step, plus 15/deg/sec ramp to 65 degrees; and 60-degree

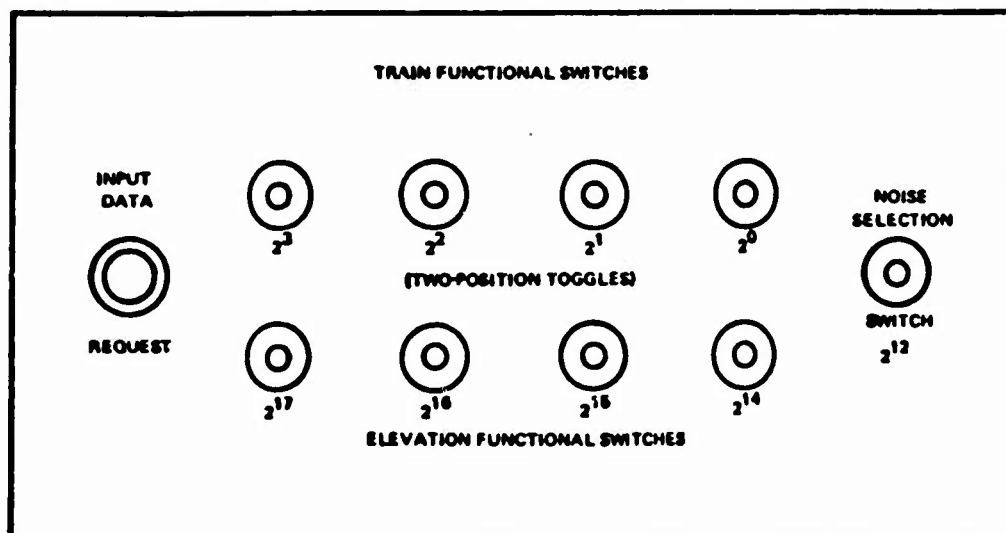


Figure 6-6. Command Selector Control Panel.

TABLE 6-3. TRAIN POSITION COMMAND SWITCH SETTINGS

Function	Binary code	Control panel switch setting (function)
Generate zero position command	0000	None
1-degree step	0001	1
10-degree step	0010	2
45-degree step	0011	1, 2
90-degree step	0100	3
75-degree square wave	0101	1, 3
5-deg/sec ramp	0110	2, 3
20-deg/sec ramp	0111	1, 2, 3
30-deg/sec ramp	1000	4
30-degree step, plus 15-deg/sec ramp to 90 degrees	1001	1, 4
60-degree step, minus 20-deg/sec to -60 degrees	1010	2, 4
30-degree amplitude, 9-second period sine wave	1011	1, 2, 4
17.5-degree amplitude, 4.5-second period sine wave	1100	3, 4

TABLE 6-4. ELEVATION POSITION COMMAND SWITCH SETTINGS

Function	Binary code	Control panel switch settings (function)
Generate zero position command	0000	None
1-degree step	0001	1
10-degree step	0010	2
45-degree step	0011	1, 2
60-degree step	0100	3
45-degree square wave	0101	1, 3
5-deg/sec ramp	0110	2, 3
15-deg/sec ramp	0111	1, 2, 3
20-degree step, plus 15-deg/sec ramp to 65 degrees	1000	4
60-degree step, minus 15-deg/sec ramp to zero	1001	1, 4
*20-degree amplitude, 9-second period sine wave	1010	2, 4
**5-degree amplitude, 4.5-second period sine wave	1011	1, 2, 4

*Offset from zero 30 degrees upward

**Offset from zero 20 degrees upward

step, minus 15 deg/sec ramp to zero) furnish both a position and a velocity command. In similar fashion, the 75 (45)-degree square-wave input furnishes a command that drives the launcher to the 75 (45)-degree position, returns it to 0 degree, drives it back to 75 (45), returns it to 0 degree, etc., until another command is executed. The sine-wave input introduces a sinusoidal movement, about 0 degree in train.

Since elevation will depress below horizontal only a few degrees, the sine-wave command is biased above the horizontal position. A sinusoidal motion is thus produced around this biased position. Typical functions are shown in figure 6-7.

Complete operating instructions are given in Part 4, Computer Program Operator's Manual.

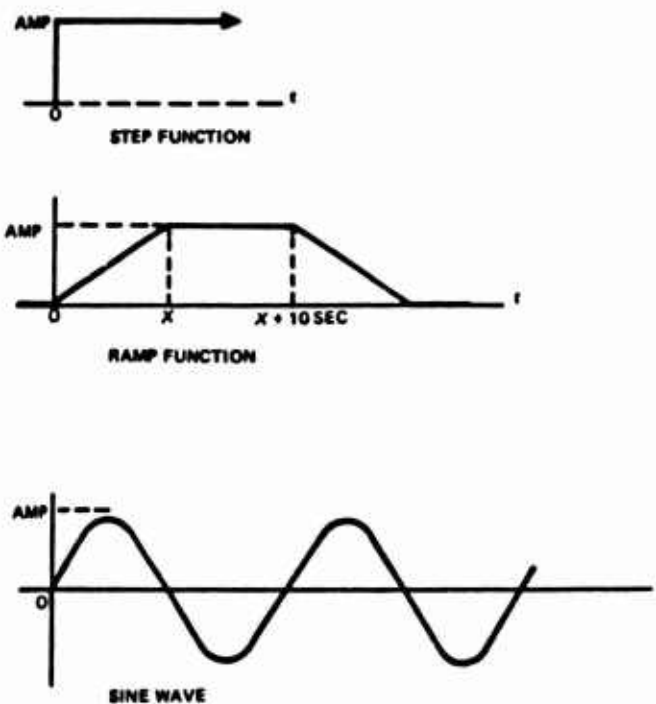


Figure 6-7. Basic launcher position order wave forms.

3.6 Functional Test Design

Paragraphs 3.6.1 through 3.6.8 present the static values, parameters, accuracies required, data collection and analysis methods, and other significant details of the feasibility demonstration tests. Since the demonstration tests were not only of the computer program, but also of the engineering techniques employed to achieve digital control of the ASROC Mk 112 launcher, the following paragraphs contain information concerning the hardware used. Also significant is that the test program exercised the launcher in both axes, multiplexing the functions for both axes as required. Train and elevation portions of the test program are functionally identical.

3.6.1 PRE-STANDBY VALUES

Static data items contained within the computer program are, for the most part, contained in the three tables stored upon program initialization. The noise table (NTABN) and the two error curve tables (TETABN and ELETBN) contain static values that become dynamic program inputs when called by appropriate operator switch action (par. 3.5.4). The noise table is used to modify commands in both train and elevation; TETABN is used to compensate train, and ELETBN is used to compensate elevation. In addition to the static values stored in the tables, certain constants used for internal computation are part of the static data.

3.6.2 RANGE OF PARAMETERS

Inasmuch as the feasibility demonstration program tests are directed toward launcher control within already established error limits, major emphasis is placed upon the generation of digital input signals to create launcher response that meets or exceeds system criteria. The following response parameters were considered: (1) position, -180 degrees to +173 degrees in train and up 116 degrees and down 32 degrees in elevation; (2) velocity, 40 deg/sec in train and 25 deg/sec in elevation; and (3) acceleration, 120 deg/sec per second in train and 94 deg/sec per second in elevation. To demonstrate digital launcher control satisfactorily, the input functions selected paralleled the functions listed in reference k, Part 6, paragraph 2.4. Since these functions are deemed adequate for acceptance testing of the launcher itself, it is believed that they constitute an adequate test of the digital program capabilities.

3.6.3 REQUIRED ACCURACIES

Reference k, Part 6, paragraph 2.4 lists the required accuracies for those functions tested by the feasibility demonstration program.

3.6.4 DATA COLLECTION METHODS

The tests were monitored both visually and electronically. Visual data were gathered by test observers and conductors in the form of test logs and notes. In tests to determine the effects of sampling rates, test personnel rode the launcher to ascertain by feel if any roughness of operation was encountered. Electronic data collection was accomplished by use of a Brush Recorder that produced strip recordings of test responses for later evaluation. In addition to observer and electronic data, a comprehensive photographic record of launcher response during the feasibility demonstration was made.

3.6.5 ANALYSIS TECHNIQUES

The results and data were subjected to immediate post-test analysis, consisting of discussion of visual results and comparison of output recordings against known input values. In addition to the immediate evaluation, all test data accumulated during the series of demonstrations were saved for later analysis and evaluation by NELC. Conclusions and test results are documented in Section 6.0, Part 6.

3.6.6 REPORTING REQUIREMENTS

Since each test was essentially of a "one-shot" nature, reporting of individual test runs and results was conducted on an informal basis, with immediate remedial action undertaken in the event of system malfunction (either hardware or software). Each test, however, was documented for historical purposes. Major reporting requirements are fulfilled by Section 6.0, Part 6.

3.6.7 TEST INPUT VALUES

Test input values are discussed in paragraph 3.5.4 and shown in table 6-3.

3.6.8 EXPECTED OUTPUT VALUES

Test output values are referenced in paragraph 3.6.3 and the required response accuracies are given in reference k, section 2.4.

3.7 Procedure for Test Conduct

For each series of tests, the general procedure remained essentially the same. As discussed in paragraph 3.5, tests were conducted with the option of two distinct methods of inputting launcher position – either via encoders or through KSC. After the hardware was configured to meet test requirements and the appropriate switch settings made, program operation for either input was the same because the computer program contains all routines for both inputs. Specific instructions for program operation are contained in Part 4, Computer Program Operator's Manual.

3.7.1 GENERAL PROCEDURE

The following general procedure was adhered to throughout the tests, with minor variations occurring as circumstances demanded.

- a. Load the program into the computer via the 1232 Input/Output Console.
- b. Using "UPAK 1B," set the sampling rate and insert the controller and sine-wave coefficients, appropriate to the given test run, into memory.
- c. Enter 500 octal in the P register to provide program initial address.

- d. Set computer Skip Key 2 to select the appropriate mode of input.
- e. Start the computer. The computer runs through initialization, then S-stops.
- f. Restart the computer.
- g. Set all switches on the Command Selector Control Panel to the OFF position and depress the Input Data Request pushbutton to zero the system.
- h. Request the test personnel in the ASROC Control Room to set switches on the special switch boxes to allow selection of mode at the Mode Selector Control Panel in the trailer.
- i. Set the mode selector switch on the Mode Selector Control Panel to digital position. The computer program is now controlling the launcher.
- j. Exercise the launcher in various control functions by making appropriate switch settings at the Command Selector Control Panel.

4.0 QUALITY ASSURANCE

No formal quality assurance procedures were undertaken during the test activities since the tests were for feasibility demonstration only. To insure applicability and adequacy of the control functions used as test inputs, these portions of the program were subjected to rigorous in-house testing at NELC through digital simulation of launcher functions. In essence, the tests conducted at NWTCP and the results obtained constituted a valid assurance of the quality of the program and a verification of the concepts involved in its creation. The nature of this program, requiring not only that launcher control be exercised by digital techniques, but that the environmental data necessary to launcher operation be included in the program itself, made it mandatory that all elements of the program be carefully constructed.

5.0 PREPARATION FOR DELIVERY

Not applicable to this document.

6.0 TEST RESULTS

This section of Part 6 contains a compilation of test results achieved during the feasibility demonstration conducted at NWTCP. Tests were run using Keyset Central or encoders to input the Launcher Position to the 1218 Computer.

Several digital controllers were tested. The major development effort was devoted to a discrete compensation controller that could be used at sampling rates of 10, 20, and 32 samples per second. The test results presented in paragraphs 6.1 and 6.2 are a representative sampling of those obtained from numerous program runs and are presented here to show typical responses to program inputs.

6.1 Keyset Central Test

The test results shown in table 6-5 represent a typical program run made using KSC to convert two-speed synchro data into computer words used by the 1218 computer. To obtain these figures, the Brush Recorder tracings for the series of program runs were analyzed for each type of input. Since step functions, regardless of magnitude, represent a direct movement to a preselected position, the overshoot, steady-state error, and time to synchronize to ± 20 minutes are shown for both train and elevation. Similarly, the response for ramps and sine-wave inputs was recorded and the maximum peak-to-peak, steady-state errors for both train and elevation are tabulated in table 6-5. The system met all of the launcher performance specifications using KSC to input the Launcher Position data.

TABLE 6-5. TYPICAL TRAIN RESPONSES USING KSC

A. Maximum Steady State Error		20 samples/second
1. Step input		0.6 minute
2. Ramp input, 20 deg/sec		1.2 minutes
3. Sine wave, 17/4.5		28 minutes
B. Overshoot to 90-degree Step		9 minutes
C. Time to Synch to ± 20 minutes		
1. Step input, 1 degree		0.5 second
2. Sine wave, 17/4.5		1.5 seconds

6.2 Encoder Test

Tables 6-6 and 6-7 show results for the tests using the encoder input of the Launcher Position. All results were arrived at in essentially the same manner as that employed in tabulating KSC input tests, the major difference being in the number of program runs recorded. The encoder gave slightly smoother test results than the KSC. This is partially due to the conversion delay associated with Keyset Central. As in the Keyset Central tests, the sampling rate had no significant effect on launcher steady-state error to a step function. For sample rates of 20 and 32, the launcher performance was equal to, or in most instances better, than the accepted launcher performance.

Although the train error to the 4.5-second-period sine wave for 10 samples per second did not meet the performance specifications, all other errors are well within the allowable limits. No roughness of operation was indicated in the recorded response trace, and personnel who physically "rode" the launcher during sine-wave test runs reported that very little difference in launcher performance could be detected. All considered sampling rates resulted in smooth launcher operation.

TABLE 6-6. TYPICAL TRAIN RESPONSES USING
ENCODER POSITION FEEDBACK

A.	Maximum Steady State Error	10 samples/second			20 samples/second			32 samples/second		
		1. Step inputs	2. Ramp input, 20 deg/sec	3. Sine wave input, 17/4.5	0.9 minute	1.8 minutes	54 minutes	0.6 minute	1.2 minutes	23 minutes
B.	Overshoot to 90-degree Step				27 minutes			6 minutes		4 minutes
C.	Time to Synchron to ± 20 minutes									
	1. Step Input, 1 degree				0.7 second			0.4 second		
	2. Sine Wave, 17/4.5				2.3 seconds			1.5 seconds		
								0.66 second		

TABLE 6-7. TYPICAL ELEVATION RESPONSES USING
ENCODER POSITION FEEDBACK

Maximum Steady State Error		20 samples/second	32 samples/second	32 samples/second
A.	1. Step inputs	0.9 minute	0.6 minute	0.6 minute
	2. Ramp input, 15 degrees/second	24 minutes	1.2 minutes	1.2 minutes
	3. Sine wave input, 5/4.5	30 minutes	10 minutes	10 minutes
B. Overshoot to 60-degree step		11 minutes	10 minutes	4.3 minutes
C.	Time to Synchron to ± 20 minutes			
	1. Step input, 1 degree	0.9 second	0.4 second	0.3 second
	2. Sine wave, 5/4.5	2.0 seconds	1.7 seconds	1.5 seconds

6.3 General Comments

The test results conclusively demonstrated the feasibility of digital launcher control. Runs at other sampling frequencies were made merely to verify the simulation results established during the prior NELC runs; at that time, it was shown that a sampling rate of 20 samples per second or better would give the most desirable response. The actual launcher tests verify the system hybrid simulation at NELC. Therefore the launcher system can be optimized through hybrid simulation techniques, and the results can be applied directly to the launcher with minimum difficulty.

APPENDIX
FORMAT FOR AN OPERATIONAL DIGITAL
LAUNCHER CONTROL PROGRAM

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CONTENTS

- 1.0 GENERAL ... 199
- 1.1 Suggested Operational Program ... 199

TABLE

- A-1 Program listing ... 200 (*Continued through 210*)

1.0 GENERAL

This appendix contains a suggested format that will aid in the development of the launcher control portion of an operational digital fire-control program. The sample program shown has been extracted from the feasibility demonstration program and is presented only for the purpose of illustrating the typical parameters that must be considered.

In addition to the functions specified, an operational program must take into account launcher synchronization. The launcher contains a synchronism firing interlock that prevents the firing of a missile whenever the error signal exceeds 20 minutes. When error is less than 20 minutes, the firing interlock is activated and the missile can be fired. In the digital control system, a sampling rate of 20 samples/second is recommended to allow for optimum smoothness in launcher operation.

1.1 Suggested Operational Program

The following output listing represents a suggested program format for both the train and elevation axes control portion of an operational program.

TABLE A-1. PROGRAM LISTING

MEM. STRG. USED 631

00500 THRU 01326

01350 THRU 01350

02535 THRU 02335

```

0 0 OPR0G'ASR0C'(OPERATIONAL)
R8
00500 00 0000 1 0INITN 00'0INITIALIZATION PRIOR TO OPERATION
00501 10 0551 2 0ERR0RN 00TAU'AZER0N0TRAIN ERROR TABLE GENERATOR
00502 12 0546 3 0 00TAL'K2N
00503 44 1354 4 0 00TRAL'TETABN+4
00504 44 0547 5 0 00TRAL'TEMP0
00505 50 7201 6 0 00NTICR'1
00506 36 0005 7 0 00NTBK'50STARTS STORING AT 1/2 DEGREE
00507 12 0547 10 0AL00PN 00TAL'TEMP0START CALCULATING VALUE

00510 14 0545 11 0 00DDAL'K1N
00511 44 0550 12 0 00TRAL'TEMP0+1
00512 12 0544 13 0 00TAL'KN
00513 26 0550 14 0 00IVA'TEMP0+1
00514 14 0547 15 0 00DDAL'TEMP0
00515 44 0547 16 0 00TRAL'TEMP0
00516 45 1350 17 0 00TRALB'TETABN0STORES VALUE IN TABLE
00517 10 0551 20 0 00TAU'AZER0N

00520 56 0552 21 0 00SK'LCTN05000
00521 34 0507 22 0 00P'AL00PN0NOT FINISHED
00522 10 0551 23 0ERTBGN 00TAU'AZER0N0ELEV ERROR TABLE GENERATION
00523 12 0555 24 0 00TAL'EK2N
00524 44 2341 25 0 00TRAL'ELETBN+4
00525 44 0547 26 0 00TRAL'TEMP0
00526 50 7201 27 0 00NTICR'1
00527 36 0005 30 0 00NTBK'5

00530 12 0547 31 0EL00PN 00TAL'TEMP0
00531 14 0554 32 0 00DDAL'EK1N
00532 44 0550 33 0 00TRAL'TEMP0+1
00533 12 0553 34 0 00TAL'EKN
00534 26 0550 35 0 00IVA'TEMP0+1
00535 14 0547 36 0 00DDAL'TEMP0
00536 44 0547 37 0 00TRAL'TEMP0
00537 45 2335 40 0 00ALB'ELETBN

```

TABLE A-1. (Continued)

00540	10	0551	41	0	0ENTAU'AZER0N
00541	56	0556	42	0	0BSK'ELCTN
00542	34	0530	43	0	0JP'EL00PN
00543	55	0500	44	0	0IJP'INITN
00544	12	1727	45	0KN	0121727'
00545	00	1027	46	0KIN	01027'
00546	00	0700	47	0K2N	0700'
00547	00	0000	50	0TEMPN	00'
00550	00	0000	51	0	00'
00551	00	0000	52	0AZER0N	00'
00552	00	0764	53	0LCTN	05000'
00553	12	1727	54	0EKN	0121727'
00554	00	1027	55	0EKN	01027'
00555	00	0700	56	0EKN	0700'
00556	00	0764	57	0ELCTN	05000'
00557	00	0000	60	0EXECN	00'0PR0GRAM ENTRANCE CELL
00560	12	1226	61	0TRVELN	0ENTAL'VTEMPN0CALCULATE FEEDFORWARD VELOCITY
00561	44	1227	62	0	0STRAL'VTEMPN+1
00562	12	1313	63	0	0ENTAL'R0FTN
00563	16	1314	64	0	0SUBAL'R0FTIN0NEW VELOCITY
00564	24	1171	65	0	0MULAL'VARC0N
00565	16	1227	66	0	0SUBAL'VTEMPN+10VELOCITY FILTER
00566	50	4202	67	0VTIMEN	0RSHAL'20SAMPLE TIME DEPENDENT
00567	14	1227	70	0	0ADDAL'VTEMPN+1
00570	44	1226	71	0	0STRAL'VTEMPN
00571	24	1231	72	0	0MULAL'VSIZEN
00572	50	4316	73	0	0RSHA'140
00573	44	1232	74	0	0STRAL'VELOCN
00574	12	1315	75	0ELVELN	0ENTAL'EVTMPN0CALCULATE ELEV FDFRD VELOCITY
00575	44	1316	76	0	0STRAL'EVTMPN+1
00576	12	1317	77	0	0ENTAL'ER0FTN
00577	16	1320	100	0	0SUBAL'ER0FTN+1
00600	24	1171	101	0	0MULAL'VARC0N
00601	16	1316	102	0	0SUBAL'EVTMPN+1
00602	50	4202	103	0ETIMEN	0RSHAL'2
00603	14	1316	104	0	0ADDAL'EVTMPN+1
00604	44	1315	105	0	0STRAL'EVTMPN
00605	24	1235	106	0	0MULAL'ESIZEN
00606	50	4316	107	0	0RSHA'140
00607	44	1236	110	0	0STRAL'EVELCN

TABLE A-1 (Continued)

00610	12 1237	111	OTKSCIN	CENTAL'INPISNOINPUT TRAIN POSITION
00611	44 0112	112	O	OSTHAL'112
00612	50 1305	113	O	CEXFCT'5'AD'2'RECCON
00613	00 1242			
00614	00 1240			
00615	50 2705	114	O	CEXFV'5
00616	34 0616	115	OWAITIN	OJP'WAITIN
00617	50 3000	116	O	OREENTN ORIL'
00620	12 0113	117	O	CENTAL'113
00621	02 1240	120	O	CCMAL'RECCON
00622	61 0626	121	O	OJPEO'BUERN
00623	02 1246	122	O	CCMAL'TWON
00624	61 0636	123	O	OJPEO'ENDIN
00625	50 5640	124	O	OSTOP'
00626	50 1105	125	O	OBUFERN OBUFIN'5'AD'2'INPDSN
00627	00 1243			
00630	00 1242			
00631	50 1305	126	O	CEXFCT'5'AD'2'INWDCN
00632	00 1246			
00633	00 1244			
00634	50 2705	127	O	CEXFV'5
00635	34 0635	130	O	OJP'LUK-0
00636	12 1242	131	O	ENDIN CENTAL'INPDSN
00637	50 4202	132	O	ORSHAL'2
00640	14 1242	133	O	OADDAL'INPDSN
00641	02 1247	134	O	CCMAL'PIRON
00642	67 0644	135	O	OJPMGR'LUK+2
00643	16 1250	136	O	OSUBAL'P36ON
00644	50 6100	137	O	CCPAL'
00645	44 1321	140	O	OSTHAL'CEFTN
00646	12 1313	141	O	CENTAL'RUFINONNEW POSITION COMMAND
00647	16 1321	142	O	OSUBAL'CEFTNOPRESENT TRAIN POSITION
00650	44 1251	143	O	LEXITN OSTHAL'AIRNOSTORE ERROR
00651	44 1252	144	O	OSTHAL'AIRIN
00652	10 1251	145	O	CENJAU'AIRN
00653	50 4412	146	O	OSF'100
00654	12 0017	147	O	CENTAL'17
00655	61 0713	150	O	OJPAZ'SWJPN
00656	40 1170	151	O	OCL'MUDJPN
00657	50 7201	152	O	DECTABN CENTICK'10TRAIN ERROR CURVE TABLE LOOKUP

TABLE A-1 (Continued)

00660	36	0000	153	0	CENTBK'00ZER0S B BOX1
00661	12	1251	154	0	CENTAL'AIRN
00662	65	0666	155	0	CJPALP'L0K+40JUMP IF ERROR POSITIVE
00663	50	6100	156	0	CCPAL'0MAKE VALUE ABSOLUTE
00664	44	1256	157	0	OSTRAL'TESTN0FLAG, NEGATIVE NUMBER
00665	34	0667	160	0	CJP'L0K+2
00666	40	1256	161	0	OCL'TESTN0FLAG, POSITIVE NUMBER
00667	44	1257	162	0	OSTRAL'TESTN+10SAVE ABSOLUTE ERROR
00670	16	1255	163	0	OSUBAL'LIMITN
00671	65	0674	164	0	CJPALP'L0K+3
00672	12	1257	165	0	CENTAL'TESTN+10ABSOLUTE VALUE
00673	34	0675	166	0	CJP'L0K+2
00674	12	1255	167	0	CENTAL'LIMITN0MAXIMUM ERROR
00675	24	1254	170	0	CMULAL'TEN0TENTHS 0F DEGREES
00676	50	4307	171	0	ORSHA'70REMOVES SF
00677	44	1257	172	0	OSTRAL'TESTN+10STORE ERROR TABLE INDEX
00700	32	1257	173	0	CENTB'TESTN+1
00701	13	1350	174	0	CENTALB'TETABN
00702	10	1256	175	0	CENTAU'TESTN0CHECK SIGN 0F ERROR
00703	60	0705	176	0	CJPAUZ'L0K+20JUMP IF SIGN POSITIVE
00704	50	6100	177	0	CCPAL'0NEGATIVE ERROR
00705	50	4203	200	0	ORSHAL'30REDUCE SF 7
00706	44	1260	201	0	OSTRAL'M0FZN0CONTAINS OUTPUT
00707	36	0005	202	0	CCLEAR'6'TEKISN
00710	41	1272			
00711	73	0710			
00712	34	0733	203	0	CJP'ADDVLN
00713	57	1170	204	0	OSWJPN CISK'M0DJPN
00714	34	0720	205	0	CJP'LESSIN
00715	50	4401	206	0	CSF'1
00716	12	0017	207	0	CENTAL'17
00717	63	0657	210	0	CJPALNZ'ECTABN
00720	70	0001	211	0	CLESSIN CENTALK'1
00721	44	1170	212	0	OSTRAL'M0DJPN
00722	12	1251	213	0	CENTAL'AIRN0COMPLETE TRAIN CONTROLLER
00723	24	1326	214	0	CMULAL'STLIN
00724	50	4314	215	0	ORSHA'120
00725	44	1272	216	0	OSTRAL'TEHISN0SAVE TRAIN ERROR HISTORY
00726	24	1176	217	0	CMULAL'AC0EFN00 TIMES E(N) SF22
00727	50	4310	220	0	ORSHA'80CSF 14

TABLE A-1. (Continued)

00730	14	1277	221	□	QADAL*TWISTN+2QPREVIOUS PARTIAL PRODUCT
00731	44	1275	222	□	QSTRAL*TWISTN
00732	50	4207	223	□	QRSAL*7
00733	14	1232	224	QADVEN	QADAL*VELOCNOADS VELOCITY TO TRAIN M(2)
00734	24	1262	225	□	QDIAL*PKN
00735	50	4307	226	□	CRSHA*7
00736	76	1203	227	□	QRJP*ATSTN
00737	44	1263	230	□	QSTRAL*BWUTN
00740	50	1306	231	□	QEXFCT*6*AD*1*TEFN
00741	00	1262			
00742	00	1261			
00743	50	2706	232	□	QEXFV*6
00744	50	1206	233	□	QSUBUT*6*AD*1*BWUTN
00745	00	1264			
00746	00	1263			
00747	50	2206	234	□	QSKP0IN*6
00750	34	0747	235	□	QJP*LUK-1
00751	12	1264	236	QEXSCIN	QENTAL*ERPISNCINPUT ELEVATION POSITION
00752	44	0112	237	□	QSTRAL*112
00753	50	1105	240	□	QSUBIN*5*AD*2*ELP0SN
00754	00	1323			
00755	00	1322			
00756	50	1305	241	□	QEXFCT*5*AD*2*ENWDCN
00757	00	1267			
00760	00	1265			
00761	50	2705	242	□	QEXFV*5
00762	34	0761	243	□	QJP*LUK-1
00763	50	3000	244	QERENTN	QRIL*
00764	12	0113	245	□	QENTAL*113
00765	02	1246	246	□	QCMAL*TW0N
00766	61	0770	247	□	QJP00*EEDIN
00767	50	5640	250	□	QSTOP*
00770	12	1322	251	QCEEDIN	QENTAL*ELP0SN
00771	50	4202	252	□	QRSAL*2
00772	14	1322	253	□	QADAL*ELP0SN
00773	02	1247	254	□	QCMAL*PIB0N
00774	67	0775	255	□	QJPMGR*LUK+2
00775	16	1250	256	□	QSUBAL*P360N
00776	50	6100	257	□	QCPAL*
00777	44	1324	260	□	QSTRAL*EC0FTN

TABLE A-1. (Continued)

01000	12	1317	261	□	CENTAL'ERCFINOCALCULATE ELEV ERROR
01001	16	1324	262	□	OSUBAL'ECOFIN
01002	44	1267	263	□	OSTRAL'EAIRN
01003	44	1270	264	□	OSTRAL'EAIRN
01004	10	1267	265	□	CENTAU'EAIRN
01005	50	4412	266	□	OSF'100
01006	12	0017	267	□	CENTAL'17
01007	61	1045	270	□	CJPALZ'ESWJPN
01010	40	1224	271	□	CCL'ELCFGN
01011	50	7201	272	□	CCLERLN CENTAL'ICELEV ERROR CURVE TABLE LOOKUP
01012	36	0000	273	□	CENTBK'0
01013	12	1267	274	□	CENTAL'EAIRN
01014	65	1020	275	□	CJPALP'L0K+4
01015	50	6100	276	□	CCPAL'
01016	44	1271	277	□	OSTRAL'ETESTN
01017	34	1021	300	□	CJP'L0K+2
01020	40	1271	301	□	CCL'ETESTN
01021	44	1272	302	□	OSTRAL'ETESTN+1
01022	16	1255	303	□	OSUBAL'LIMITN
01023	65	1026	304	□	CJPALP'L0K+3
01024	12	1272	305	□	CENTAL'ETESTN+1
01025	34	1027	306	□	CJP'L0K+2
01026	12	1255	307	□	CENTAL'LIMITN
01027	24	1254	310	□	CMULAL'TEN
01030	50	4307	311	□	ORSHA'1
01031	44	1272	312	□	OSTRAL'ETESTN+1
01032	32	1272	313	□	CENTB'ETESTN+1
01033	13	2335	314	□	CENTALB'ELETBN
01034	10	1271	315	□	CENTAU'ETESTN
01035	60	1037	316	□	CJPAUZ'L0K+2
01036	50	6100	317	□	CCPAL'
01037	50	4203	320	□	ORSHAL'3
01040	44	1325	321	□	OSTRAL'EMJFN
01041	36	0005	322	□	CCLEAK'6'EENISM
01042	41	1305			
01043	73	1042			
01044	34	1065	323	□	CJP'EADVLN
01045	57	1224	324	□	CESWJPN CISK'ELCFGN
01046	34	1052	325	□	CJP'ELESIN
01047	50	4401	326	□	OSF'1

TABLE A-1. (Continued)

01050	12 0017	327	□	QENTAL'17
01051	63 1011	330	□	QJPALNZ'ELERLN
01052	70 0001	331	□	QELESIN QENTALK'1
01053	44 1224	332	□	QSTRAL'ELCFGN
01054	12 1267	333	□	QCMCON QENTAL'EAIRN QCOMPLETE ELEV CONTROLLER
01055	24 1326	334	□	QMULAL'STLIN
01056	50 4314	335	□	QORSHA'12D
01057	44 1305	336	□	QSTRAL'EEHISN
01060	24 1300	337	□	QMULAL'EACOFN
01061	50 4310	340	□	QORSHA'8D
01062	14 1312	341	□	QADDAL'EHISTN+2
01063	44 1310	342	□	QSTRAL'EHISTN
01064	50 4207	343	□	QORSHAL'7
01065	14 1236	344	□	QADVLN QADDAL'EVELCN QADDS VEL TO ELEV M(2)
01066	24 1262	345	□	QMULAL'PKN
01067	50 4307	346	□	QORSHA'7
01070	76 1203	347	□	QORJP'ATSTN
01071	44 1174	350	□	QSTRAL'EBOUTN
01072	50 1306	351	□	QEXFCT'6'AD'1'ELEFN
01073	00 1176			
01074	00 1175			
01075	50 2706	352	□	QEXFW'6
01076	50 1206	353	□	QBUFOUT'6'AD'1'EBOUTN
01077	00 1175			
01100	00 1174			
01101	50 2206	354	□	QSKPWIN'6
01102	34 1101	355	□	QJP'LC'-1
01103	12 1273	356	□	QTRPDZN QENTAL'EHISN+1 QTRAIN PARTIAL CONT CALC
01104	44 1274	357	□	QSTRAL'EHISN+2
01105	12 1272	360	□	QENTAL'EHISN
01106	44 1273	361	□	QSTRAL'EHISN+1
01107	24 1177	362	□	QMULAL'ACDEFN+1 QAI TIMES E(N-1)
01110	50 4310	363	□	QORSHA'8D
01111	44 1277	364	□	QSTRAL'THISTN+2
01112	12 1274	365	□	QENTAL'THISN+2
01113	24 1200	366	□	QMULAL'ACDEFN+2
01114	50 4310	367	□	QORSHA'8D
01115	14 1277	370	□	QADDAL'THISTN+2
01116	44 1277	371	□	QSTRAL'THISTN+2
01117	12 1275	372	□	QENTAL'THISTN

TABLE A-1. (Continued)

01120	24	1201	373	□	CMULAL'BCDEFNOB1 TIMES M(Z)
01121	50	4317	374	□	ORSHA'150
01122	50	6100	375	□	CCPAL'
01123	14	1277	376	□	QADDAL'EHISTN+2
01124	44	1277	377	□	QSTRAL'EHISTN+2
01125	12	1276	400	□	QENTAL'EHISTN+1
01126	24	1202	401	□	CMULAL'BCDEFN+1
01127	50	4317	402	□	ORSHA'150
01130	50	6100	403	□	CCPAL'
01131	14	1277	404	□	QADDAL'EHISTN+2
01132	44	1277	405	□	QSTRAL'EHISTN+2
01133	12	1275	406	□	QENTAL'EHISTN
01134	44	1276	407	□	QSTRAL'EHISTN+1
01135	12	1306	410	□	QENTAL'EEHISN+1
01136	44	1307	411	□	QSTRAL'EEHISN+2
01137	12	1305	412	□	QENTAL'EEHISN
01140	44	1306	413	□	QSTRAL'EEHISN+1
01141	24	1301	414	□	CMULAL'EACOFN+1
01142	50	4310	415	□	ORSHA'80
01143	44	1312	416	□	QSTRAL'EHISTN+2
01144	12	1307	417	□	QENTAL'EEHISN+2
01145	24	1302	420	□	CMULAL'EACOFN+2
01146	50	4310	421	□	ORSHA'80
01147	14	1312	422	□	QADDAL'EHISTN+2
01150	44	1312	423	□	QSTRAL'EHISTN+2
01151	12	1310	424	□	QENTAL'EHISTN
01152	24	1303	425	□	CMULAL'EBCOFN
01153	50	4317	426	□	ORSHA'150
01154	50	6100	427	□	CCPAL'
01155	14	1312	430	□	QADDAL'EHISTN+2
01156	44	1312	431	□	QSTRAL'EHISTN+2
01157	12	1311	432	□	QENTAL'EHISTN+1
01160	24	1304	433	□	CMULAL'EBCOFN+1
01161	50	4317	434	□	ORSHA'150
01162	50	6100	435	□	CCPAL'
01163	14	1312	436	□	QADDAL'EHISTN+2
01164	44	1312	437	□	QSTRAL'EHISTN+2
01165	12	1310	440	□	QENTAL'EHISTN
01166	44	1311	441	□	QSTRAL'EHISTN+1
01167	55	0557	442	□	QJP'EXECIN

TABLE A-1. (Continued)

01170	00 0000	443	CM0DJPN	00'
01171	00 0000	444	CVARC0N	00'0SAMPLES PER SECOND
01172	00 0000	445	CMZVELN	00'0TRAIN M(Z) PLUS VELOCITY, SF7
01173	00 0000	446	0	00'
01174	00 0000	447	CEB0UTN	00'
01175	00 0004	450	CELEFN	04'00A N0 3
01176	10 0000	451	0AC0EFN	0100000'0A0 SF 15
01177	61 4642	452	0	0614642'0A1 SF 15
01200	06 3636	453	0	0063636'0A2 SF 15
01201	60 3115	454	03C0EFN	0603115'031 SF 15
01202	07 4702	455	0	0074702'082 SF 15
01203	00 0000	456	0ATSTN	00'0OVERFLOW SUBROUTINE
01204	65 1210	457	0	0JPALP'L0K+4
01205	50 6100	460	0	0CPAL'
01206	44 1223	461	0	0STRAL'AFLGN
01207	34 1211	462	0	0JP'L0K+2
01210	40 1223	463	0	0CL'AFLGN
01211	02 1222	464	0	0CNAL'AK0N
01212	65 1220	465	0	0JPMLE0'L0K+6
01213	10 1223	466	0	0ENTAU'AFLGN
01214	62 1216	467	0	0JPAUNZ'L0K+2
01215	55 1203	470	0	0IJP'ATSTN
01216	50 6100	471	0	0CPAL'
01217	55 1203	472	0	0IJP'ATSTN
01220	12 1222	473	0	0ENTAL'AK0N
01221	34 1213	474	0	0JP'L0K-6
01222	01 4400	475	0AK0N	014400'
01223	00 0000	476	0AFLGN	00'
01224	00 0000	477	0ELCFGN	00'
01225	00 0000	500	0EMZVLN	00'0ELEV M(Z) PLUS VEL,SF7
01226	00 0000	501	0VTEMPN	00'
01227	00 0000	502	0	00'
01230	00 0000	503	0VFLAGN	00'
01231	00 3400	504	0VSIZE0	03400'
01232	00 0000	505	0VEL0CN	00'0FILTERED VELOCITY
01233	00 0000	506	0	00'
01234	00 0000	507	0EFLAGN	00'
01235	00 4500	510	0ESIZE0	04500'
01236	00 0000	511	0EVELCN	00'
01237	34 0617	512	0IRPISN	0JP'REENTN

TABLE A-1. (Continued)

01240	00	0001	513	OREQCN	0200001°
01241	00	0000	514	0	00°
01242	00	0000	515	0INPOSN	00°
01243	00	0000	516	0	00°
01244	10	0400	517	0INWDCN	0100400°
01245	00	1000	520	0	0001000°
01246	00	0002	521	0TWON	0000002°
01247	05	5000	522	0P18CN	0250400°
01250	13	2000	523	0P360N	0460800°
01251	00	0000	524	CAIRN	00° LATEST ERROR
01252	00	0000	525	CAIRIN	00°
01253	00	0200	526	0WONEN	01200° 01 SF 7
01254	00	0012	527	0TEN	0100°
01255	01	4363	530	0LIMITN	063870° 049.9 DEGREES
01256	00	0000	531	0TESTN	00° 0510N FLAG STORAGE
01257	00	0000	532	0	00°
01260	00	0000	533	0N0FZN	00° 01(2) SF 7
01261	00	0002	534	0TEFN	02° 00A NO. 2
01262	00	2400	535	0PKN	02400°
01263	00	0000	536	030UTN	00°
01264	54	0763	537	0ERPISN	0JP° ERENTN
01265	11	0400	540	0ENWDCN	0110400°
01266	00	1100	541	0	0001100°
01267	00	0000	542	0CAIRN	00°
01270	00	0000	543	0CAIRIN	00°
01271	00	0000	544	0ETESTN	00°
01272	00	0000	545	0TEHISN	00°
01273	00	0000	546	0	00° 05F 7
01274	00	0000	547	0	00° 05F 7
01275	00	0000	550	0THISTN	00°
01276	00	0200	551	0	00° 05F 14
01277	00	0000	552	0	00° 05F 14 C FLL
01300	10	0000	553	0EACOFN	0100000°
01301	61	4642	554	0	0614642°
01302	26	3636	555	0	0063636°
01303	60	3115	556	0E3COFN	0603115°
01304	07	4702	557	0	0074702°
01305	00	0000	560	0EEHISN	00°
01306	00	0000	561	0	00°
01307	00	0000	562	0	00°

TABLE A-1. (Continued)

01310	00 0000	563	CEHISTN	00'
01311	00 0000	564	□	00'
01312	00 0000	565	□	00'
01313	00 0000	566	ORCFIN	00'
01314	00 0000	567	ORCFIN	00'
01315	00 0000	570	CEVTMPN	00'
01316	00 0000	571	□	00'
01317	00 0000	572	CEPOTIN	00'
01320	00 0000	573	□	00'
01321	00 0000	574	OCOTIN	00'
01322	00 0000	575	CELP0SN	00'
01323	00 0000	576	□	00'
01324	00 0000	577	CECOTIN	00'
01325	00 0000	600	CEMCFZN	00'
01326	00 5443	601	OSTLIN	033630'
01350	00 0000	602	OTETA3N	00' DRAIN ERROR CURVE TABLE
02335	00 0000	603	CELET3N	00' DELEV ERROR CURVE TABLE
00 7743				